INVESTIGATION OF INJURIES, ACCIDENTS AND HAZARDS OCCURRED IN A GARMENT FACTORY AND THEIR EFFECT ON LABOR AVAILABILITY

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ABSTRACT: Injuries and accidents have negative effect on organizations rare values such as human resource and organizational reputation. Therefore safety should be in the forefront of any manager's thinking and a priority in the organization's strategy, not only because of the humanitarian reasons, but also because of the financial benefits. The objectives of this research were to investigate injuries, accidents, hazards of a selected garments factory and show their effects on labor availability and overall efficiency. From the analysis of collected data, it is found that 67.24% injury of the total injury and 67.83% absences of the total absences (due to injury) have occurred mainly in the Sewing, Dyeing and Finishing section. Again 84.48% of Injury and 84.35% of absences occurred mainly among the Operator, Assistant, Supervisor and Quality inspector. Injuries of Finger, Hand and Eye comprise 84.48% of the total injury and 87.4% of the total absences (due to injury). It is also found that 81.04% of Injury and 73.04% of absences are due to the Needle, Toxic chemicals, Knife edge, Cloth iron, Spindle, Dust, Electricity and Heat agents. Availability (ranging from 10%-5%) and Overall efficiency (ranging from 9.5% - 5%) are decreasing due to injury in the injury day compared to before the injury day and after the injury day. Training on safety and accidents, adequate supply of personal protective equipment's and proper supervision are the most important actions that should be carried out to minimize accidents and losses from them.

Keywords: Safety, injury, absenteeism, efficiency and availability.

1. INTRODUCTION

Safety is the condition to which risks are managed to acceptable levels [1]. It is the activity that seeks to minimize or eliminate hazardous conditions that can cause bodily injury. According to Weick [5], safety is defined as a dynamic non-event that tends to be taken for granted, particularly in the face of continuous and compelling productive demands [1]. Safety deals with securing or reducing accidents at work environment, which has a negative impact on the organization operations at many levels. Accidents cost money to any organization and could affect the worker moral through [2]: (i) Damaging the machinery or buildings (ii)Delaying in the production or business (iii)Losing experienced workers partially or totally (iv)Cost of Compensation to the injured worker or public (v) Organizations losing part of their reputation and(vi) Legal expenses

A positive safety culture can be an effective tool for improving safety in an organization and creating good atmosphere in the workplace [6]. This will help organizations to benefit financially through reduced lost work hours and accident related compensation cost, increased employee's motivation, higher quality product, and reduced turnover; all of which lead to improved productivity [7].

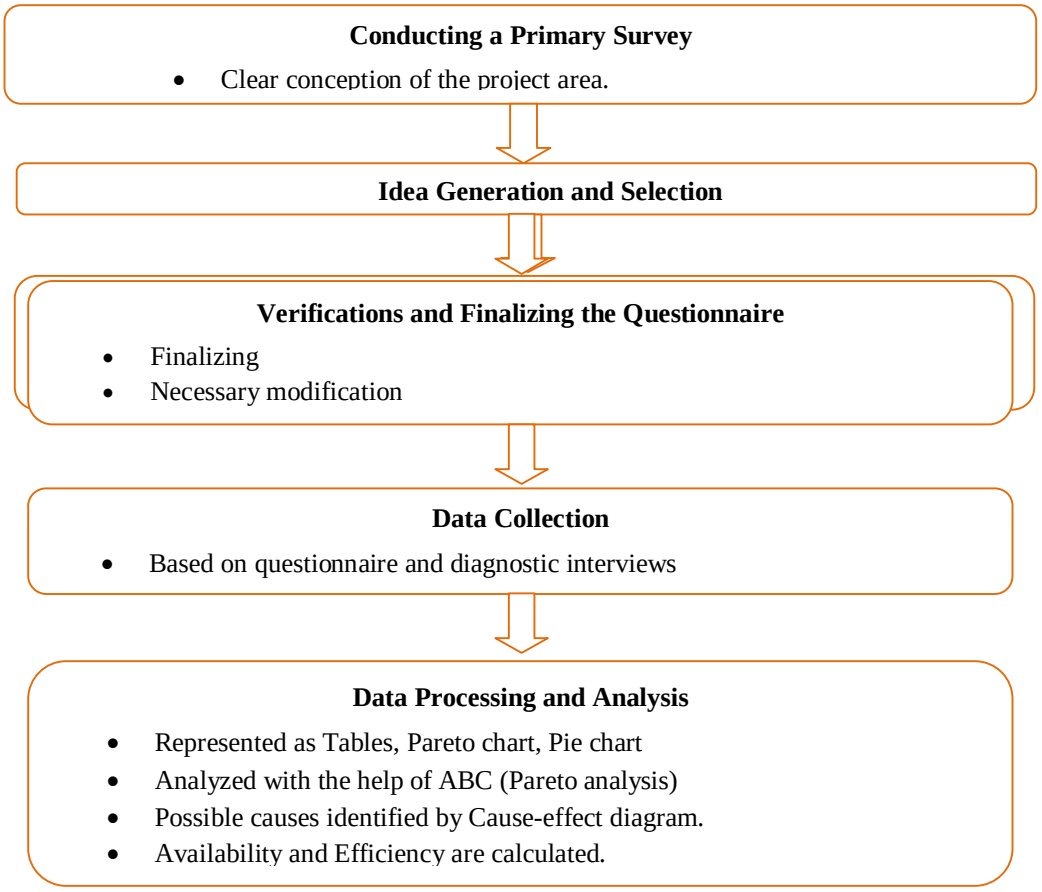
2. PREVIOUS WORK

In 2010, a research was done by P. Katsuro, C. T. Gadzirayi, Taruwona M and Suzanna Mupararanoon **"***Impact of occupational health and safety on worker productivity: A case of Zimbabwe food industry"***.** The research found out that bad occupational health safety (OHS) practices in food factories decrease the workers 'performance, leading to the decline of productivity. A worker who is suffering from an

occupational illness is slower and weaker, thereby, missing set targets [8]. In 2012, a research was done by Thanwadee Chinda, Supatana Techapreechawong, and Suthaporn Teeraprasert on "An *Investigation of Relationships between Employees' Safety and Productivity"*. It is found that People Results has direct effect to Productivity, explaining that productivity tends to be higher when employees, for example, have high job satisfaction, are accounted for proper safety responsibilities, work as a team, and have adequate safety training. The results also showed that productivity can be higher with a good safety implementation, as seen by an indirect effect from People to Productivity through People Results [9]. In 2012, a research was done by Bhattacharya A, Park RM on *"Excess healthcare costs associated with prior workers' compensation activity"*. The results reveal that individuals with prior WC claims had higher probability of filing a group health medical claim and higher average monthly medical costs in all sectors[10].

3. METHODOLOGY

A process flow chart of research methodology can be developed as shown below:



4. ANALYSIS AND DISCUSSION

4.1. Injury frequency by the Location of injury

From figure 2 it is evident that above 79% of the total injury have occurred in the Sewing, Dyeing, Finishing and Cutting section. These are the vital few sections where injuries have been occurring in a frequent rate, so these can be marked as hazardous places to work. Personal protective equipments and other initiatives are necessary to prevent accidents and work more safely. In the Sewing section injuries mainly occurs due to needle, as there is no needle guards in most of the Sewing machines. The other agents which contribute to the injury occurrence are scissors, dust and leakage in the electric wire of the Sewing machine which gives uneven electric shocks. In the Dyeing section toxic chemicals are used to

clean and color fabrics, these toxic chemicals are very hazardous to health. Sharp cutting edges of cutting machine, dust of fiber and Cloth iron are the main agents which enforce the injury rate in the Finishing section and Cutting section.

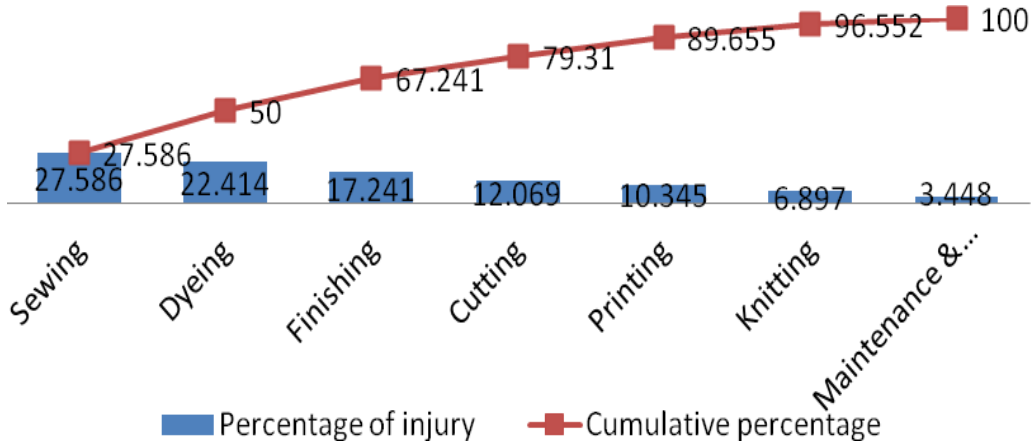


Fig 2: Pareto chart of Injury frequency by the Location of injury.

4.2. Injury frequency by the level of worker

Injury frequency by the level of worker is shown in figure 3 below.

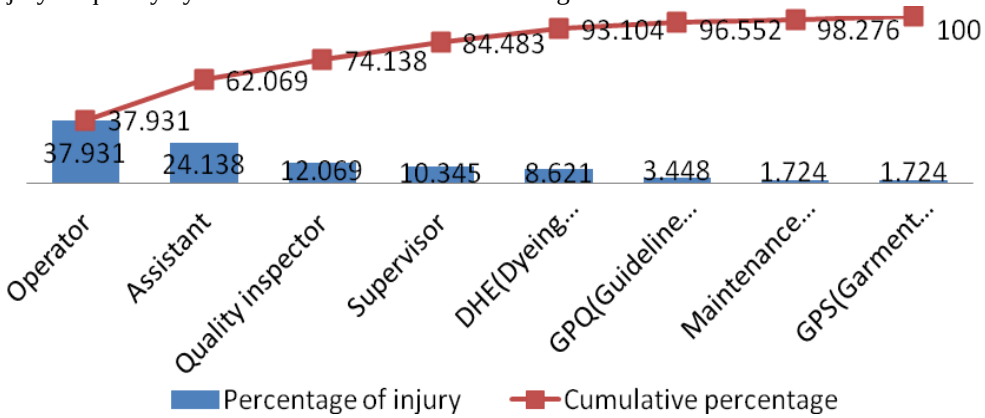


Fig 3: Pareto chart of Injury frequency by the level of worker.

Figure 3 shows that, over 74% of the total injury occur only among the Operators, Assistants and Quality inspectors, because they are directly involved to the work. Operators and Assistants operate different machines and perform different productive tasks in the all production sections, but they do not have proper working procedure and close supervision to do their work safely. As Quality inspector must inspect the quality of different work done by the worker such as coloring of fabrics in Dyeing section, they must inspect closely because the color should not vary from the desired color and thus these inspectors are also directly involved with Toxic chemicals mixture and other agents of injury.

Absences frequency due to injury by the body parts

Absences frequency due to injury by the body parts is shown in figure 4 below.

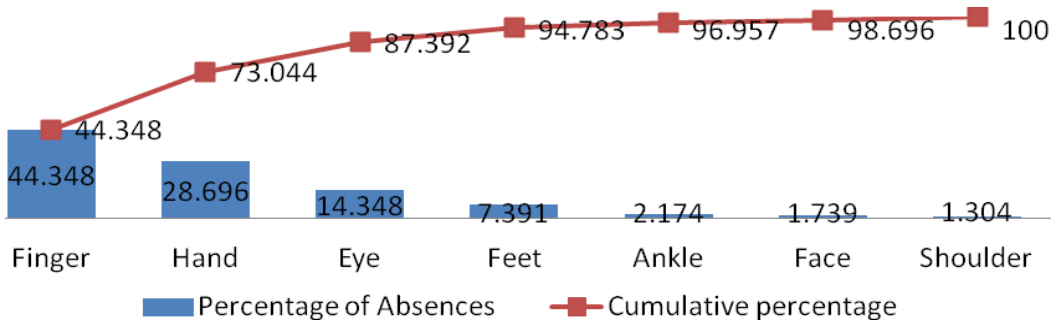


Fig 4: Pareto chart of Absences frequency due to injury by the body parts.

The Figure 4 shows that over 87% absences are due to vital few injuries which are Fingers, Hand and Eye injury. The reasons behind this are that the injury frequency is higher than the other injuries. Finger and Hand injuries were mainly by needle and knife edge agents and these injuries takes a long time to recover. Eye injuries were mainly from working with Toxic chemical and dusty environment and not using eye protective equipments.

4.4. Absences frequency due to injury by the Agent of accident

Figure 5 represents the absences frequency due to injury by the Agent of accident.

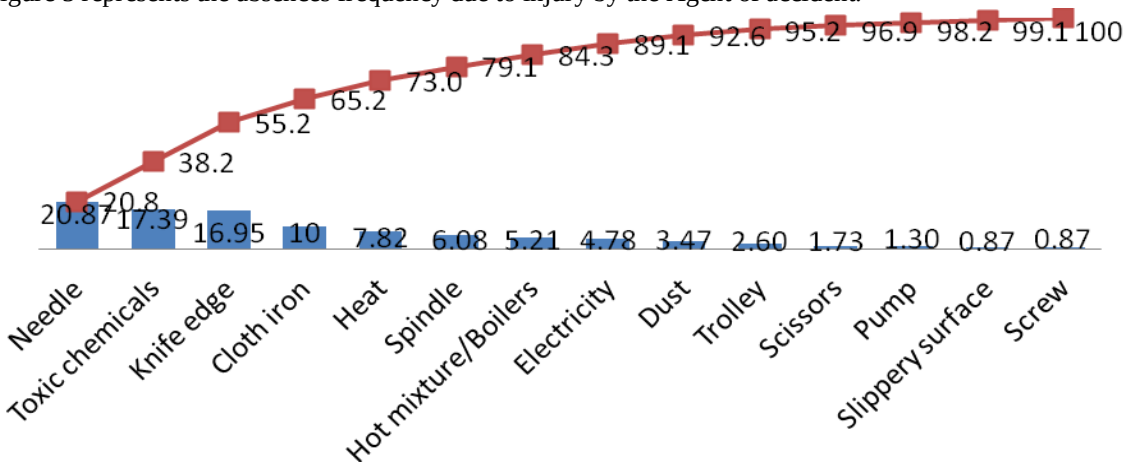


Fig 5: Pareto chart of Absences frequency due to injury by the Agent of accident.

Figure 5 shows that, about 73% Absences of the total Absences are due to Needle, Toxic chemicals, Knife edge, Cloth iron, Heat and Spindle agent's injury. As the injury frequency by these agents are higher so the absence frequency is also higher.

4.5. INJURY EFFECTS ON LABOR AVAILABILITY

One calculation has been shown below, which shows the change in the labor Availability and Overall Efficiency due to injury. Here working hour, SAM and Actual output of the injured worker before the injury day, in the injury day and after the injury day was collected from the factory. Loss time due to injury has been gained by conducting informal interviews with supervisor and injured worker and observation of some injuries. It is to be mentioned that workers working hour is 8 hours per day and 60 minutes of breaks include tea and lunch breaks.

Table 1: Injury Effects on Labor Availability.

Date	worker	Production department and Line No.	Availability (%)	Date	worker	Production department and Line No.	Availability (%)
19.1.13 (Before)	Operator	Sewing (10B)	100	21.1.13 (After)	Operator	Sewing (10B)	100
20.1.13 (Injury Day)	Operator	Sewing (10B)	92	28.1.13 (Before)	Operator	Finishing (3)	100
29.1.13 (Injury Day)	Operator	Finishing (3)	94	9.4.13 (Injury Day)	Operator	Sewing (3B)	95
30.1.13 (After)	Operator	Finishing (3)	100	10.4.13 (After)	Operator	Sewing (3B)	100
10.2.13 (Before)	Assistant	Sewing (7A)	100	16.4.13 (Before)	Operator	Sewing (2A)	100
11.2.13 (Injury Day)	Assistant	Sewing (7A)	95	17.4.13 (Injury Day)	Operator	Sewing (2A)	94
12.2.13 (After)	Assistant	Sewing (7A)	100	18.4.13 (After)	Operator	Sewing (2A)	100
19.2.13 (Before)	Operator	Sewing (6C)	100	18.5.13 (Before)	Assistant	Sewing (8B)	100
20.2.13 (Injury Day)	Operator	Sewing (6C)	90	19.5.13 (Injury Day)	Assistant	Sewing (8B)	93
21.2.13 (After)	Operator	Sewing (6C)	100	20.5.13 (After)	Assistant	Sewing (8B)	100
2.3.13 (Before)	Operator	Finishing (7)	100	27.5.13 (Before)	Operator	Sewing (11A)	100
3.3.13 (Injury Day)	Operator	Finishing (7)	93	28.5.13 (Injury Day)	Operator	Sewing (11A)	93
4.3.13 (After)	Operator	Finishing (7)	100	29.5.13 (After)	Operator	Sewing (11A)	100
5.3.13 (Before)	Assistant	Sewing (10A)	100	4.6.13 (Before)	Operator	Sewing (1B)	100
6.3.13 (Injury Day)	Assistant	Sewing (10A)	91	5.6.13 (Injury Day)	Operator	Sewing (1B)	92
7.3.13 (After)	Assistant	Sewing (10A)	100	6.6.13 (After)	Operator	Sewing (1B)	100
9.3.13 (Before)	Assistant	Sewing (3A)	100	9.6.13 (Before)	Assistant	Finishing (4)	100
10.3.13 (Injury Day)	Assistant	Sewing (3A)	93	10.6.13 (Injury Day)	Assistant	Finishing (4)	94
11.3.13 (After)	Assistant	Sewing (3A)	100	11.6.13 (After)	Assistant	Finishing (4)	100
16.3.13 (Before)	Operator	Sewing (10B)	100	17.6.13 (Before)	Operator	Sewing (7B)	100

17.3.13 (Injury Day)	Operator	Sewing (10B)	93	18.6.13 (Injury Day)	Operator	Sewing (7B)	90
18.3.13 (After)	Operator	Sewing (10B)	100	19.6.13 (After)	Operator	Sewing (7B)	100
24.3.13 (Before)	Operator	Sewing (5A)	100	25.6.13 (Before)	Operator	Sewing (2B)	100
25.3.13 (Injury Day)	Operator	Sewing (5A)	94	26.6.13 (Injury Day)	Operator	Sewing (2B)	90
26.3.13 (After)	Operator	Sewing (5A)	100	27.6.13 (After)	Operator	Sewing (2B)	100
8.4.13 (Before)	Operator	Sewing (3B)	100				

From the table 1 it is evident that, due to injury there are some losses from the scheduled time which results in the availability losses. It is seen that, before the injury day (19.01.13) and after the injury day (21.01.13) the availability is 100% as there has been no time losses due to injury, but in the injury day (20.01.13) there has been 35min loss for that working position so that the availability reduces to 92%. In the Table 4.11, for a production section in a specific production line injured workers previous day, injury day and after the injury day production calculation is shown. Here, Sewing and Finishing production sections are only included but SAM of the Quality inspector, Supervisor and Garment Production & Quality have not been found, so these are excluded from the calculation. Availability is decreasing ranging from 10% - 5% due to injury from the normal total availability.

4.6 POSSIBLE ROOT CAUSE OF INJURY

Root cause analysis (RCA) practice tries to solve problems by attempting to identify and correct the root causes of events, as opposed to simply addressing their symptoms. By focusing correction on root causes, problem recurrence can be prevented. Here injury causes have been categorized as machine, environment, management, man, method etc. For the management causes, this is as follows- inadequate training, lack of motivation, poor supervision, not providing personal protective equipment etc. Unawareness, unwillingness of using personal protective equipments, Overconfidence etc are the causes from man. We have tried to identify the major causes responsible for injury by fishbone diagram. These causes are detected during our floor examination.

5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The objectives of this research are to investigate injuries, accidents, hazards of a selected garments factory and their effects on labor availability and overall efficiency. The analysis is done by the Pareto analysis and different formulas on Availability and Overall efficiency. From this research following conclusions have been drown.

- 67.24% Injury and 67.83% absences have been occurred mainly in Sewing, Dyeing and Finishing section.
- 84.48% Injury and 84.35% absences have been occurred mainly among Operator, Assistant, Supervisor and Quality inspector level of workers.
- 84.48% Injury and 87.4% absences have been occurred mainly from Finger, Hand and Eye injury of the workers.
- 81.04% Injury and 73.04% absences have been occurred mainly by Needle, Toxic chemicals, Knife edge, Cloth iron, Spindle, Dust, Electricity and Heat agents.
- The main reasons behind these are improper or shortage of personal protective equipments (hand and Finger gloves, eye protective equipments, masks etc.), workers unawareness, wrong procedure,

lack of training, improper knowledge about these injuries, poor supervision, over confidence, Dusty environment, poor maintenance etc.

- Availability is decreasing at 10% - 5% due to injury from the normal availability.
- Overall efficiency is decreasing about 9.5% - 5% due to injury of the normal total overall efficiency.

The research found out that, poor safety practices in garment factories decreases the workers Availability and Overall efficiency leading to the decline of productivity. A worker who is suffering from an injury is slower and weaker, thereby, missing set targets.

5.2 RECOMMENDATION

Some recommendations are as follows:
Sufficient training for workers on safe operation of sewing, finishing, cutting, printing, knitting machines as well as proper handling of chemicals. Regular supervision regarding safety. b. Adequate supply, regulation and distribution of personal protective equipments and fire fighting equipments and ensure proper use of those equipments at work place c. Motivating the workers for using personal protective equipments d.Every industry should have a safety department for reducing accident, injury and to get maximum output.

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A PROCEDURE TO JUDGE THE RELIABILITY OF A MANUFACTURING PROCESS BY SPC AND FUZZY LOGIC

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ABSTRACT: Statistical process control is one of the best techniques for monitoring and controlling the process of a production. This verifies, graphically, variation in output quality characteristics against pre-fixed upper and lower limits which give signals whether the process is within control or not; but this cannot give any quantitative value to evaluate the process. Fuzzy logic can handle approximate information in a systematic way & can manage such vagueness of control charts mathematically. Thus fuzzy logic can be used as an improvement tool for control charts which provides a quantitative evaluation on a process in case of decision-making and problem-solving. As well as the concept of reliability test of a process enhances the outcome of that decision-making and problem-solving. Thus, the integration of SPC, fuzzy logic & reliability test provides a perfect synchronization for appraisement of the process & improvement thereby. This innovative idea has been carried out on a pasting process of a lead acid battery manufacturing company to show how it works: result of use of SPC describes that the pasting process is in control, result of use of fuzzy logic on SPC describes that the total score of pasting process is 12.3 out of 15 and the reliability level of that process is 82%.

Keywords: Process control, SPC, Fuzzy logic, Process reliability.

1. INTRODUCTION

Variation seems inevitable in nature. Manufacturing processes are no exception to this. There are several sources of variations, such as machines, operators, materials, etc., which bring in a certain amount of natural variations at every step of operations in the entire production system. Thus it is necessary to bring a production process into a state of "statistical control". And by this, here comes the concept of SPC (Statistical Process Control) which is regarded as one of the most powerful policy of total quality management. Mainly SPC has seven tools (process flowchart, check sheet, cause and effect diagram, pareto chart, scatter diagram, histogram &control chart) for collecting, presenting and analyzing the data of a process; ultimately to monitor the process variations and subsequently control it. However, for this paper work the cheek sheet & control chart, among the tools of SPC, have mainly been used.

Check sheets are used for collecting data from a process in an easy, systematic and organized manner. Data collected using check sheets can be used as input data for other SPC tools. The control chart is a graph used to study how a process changes over time. A control chart always has a mean or CL (Central Line) for the average, an upper line for the UCL (Upper Control Limit) and a lower line for the LCL (Lower Control Limit). By comparing current data to these lines, one can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control). It is expected that the values of quality characteristics remain randomly on both sides of the centre line but within the UCL & LCL for the process to be said 'in control'.

By this traditional concept of control chart, the quality of a process may be expressed by a binary quality function that takes values 1 and 0 for 'in control' and 'out-of-control' quality, respectively. Fuzzy logic can manage such vagueness mathematically; it is efficient for operating linguistic data & enables us to make applications effective. In fuzzy approach, quality is always a value between 0 and 1. For engineering purposes, reliability is defined as the probability that a device will perform its intended function during a specified period of time under stated conditions. It is often measured as the resistance to failure or a measure of availability. Reliability is inversely related to random error. The purpose of reliability testing is to discover potential problems with the design as early as possible and, ultimately, provide confidence that the system meets its requirements.

For this paper work we have used check sheet, P-chart & fuzzy control chart one by one on a process of lead acid battery manufacturing system and showed how we can develop a procedure to judge the reliability level of a manufacturing process.

2. MATHEMATICAL & LOGICAL EQUATIONS

2.1. CHECK SHEET

f= sample fraction nonconforming = d□/n (1)

2.2. P - CHART

UCL = p□ + zσ□$_p$ (2a)

CL = p□ (2b)

LCL = p□ - zσ□$_p$ (2c)

p□ = sample mean fraction nonconforming = $\frac{\sum d}{i \times n}$ (2d)

$\sigma\square_p = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$ (2e)

2.3. FUZZY CONTROL CHART

The union of two fuzzy sets ***A*** and ***B*** is a fuzzy set ***C***, written as ***C***=***A***U***B*** or ***C***= (***A*** OR ***B)***; Fig 1(a). The intersection of two fuzzy sets ***A*** and ***B*** is a fuzzy set ***C***, written as ***C***=***A***∩***B*** or ***C***= ***(A*** AND ***B)***; Fig 1(b). The complement of fuzzy set ***A***, denoted by $\bar{A}$; Fig 1(c).

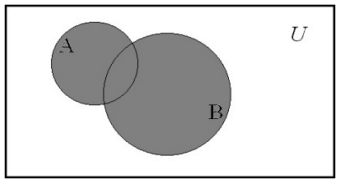

Fig.1(a): Union of Set A and B

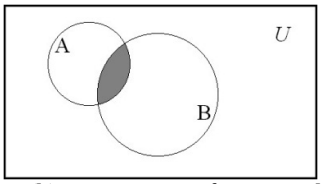

Fig.1(b): Intersection of Set A and B

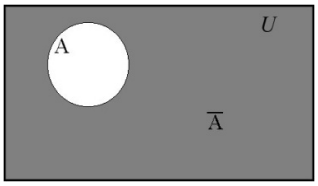

Fig 1(c): Complement of Set A

Total score = (a ×absolutely in control) + (b × only mostly in control) + (c × only quite in control) + (d × only probably in control) + (e × only poorly in control) + (f × only somewhat in control) + (q × only quite out of control) + (h × only mostly out of control) + (i × only absolutely out of control) (3)

Here a, b, c, d, e, f, g, h & i are coefficient factors of observations. The limits with their ranges for the Fuzzy Control Chart are stated through table 1.

Table 1: Limits with their ranges for the Fuzzy Chart

Fuzzy control limits	Range of fraction nonconforming
Absolutely in control	$p\square - \sigma\square_p/3 \leq$ fraction $\leq p\square + \sigma\square_p/3$
Mostly in control	$p\square - \sigma\square_p/2 \leq$ fraction $\leq p\square + \sigma\square_p/2$
Quite in control	$p\square - \sigma\square_p \leq$ fraction $\leq p\square + \sigma\square_p$
Probably in control	$p\square - 3\sigma\square_p/2 \leq$ fraction $\leq p\square + 3\sigma\square_p/2$
Poorly in control	$p\square - 2\sigma\square_p \leq$ fraction $\leq p\square + 2\sigma\square_p$
Somewhat in control	$p\square - 5\sigma\square_p/2 \leq$ fraction $\leq p\square + 5\sigma\square_p/2$
Quite out of control	$p\square - 3\sigma\square_p \leq$ fraction $\leq p\square + 3\sigma\square_p$
Mostly out of control	$p\square - 7\sigma\square_p/2 \leq$ fraction $\leq p\square + 7\sigma\square_p/2$
Absolutely out of control	$p\square - 4\sigma\square_p \leq$ fraction $\leq p\square + 4\sigma\square_p$

2.4. RELIABILITY

The reliability level of a process, $$R = \frac{\text{total score}}{\text{total no. of observations}} \quad (4a)$$

Total production system reliability:

For processes of series line layout, $R = \{r_1 * r_2 * r_3 * \ldots\}$ (4b)

For processes of parallel line layout, $R = \{1-(1- r_1)*(1- r_2)\ldots\}$ (4c)

For mixed system: combination of above two equations (4b) & (4c).

3. EXPERIMENTAL PROCEDURE

This procedure (illustrated by fig. 2) provides a step by step pathway to judge the reliability level of a manufacturing process and to improve that reliability, if it is necessary. In this figure, DOE stands for "Design of Experiment", EVOP stand for "Evolutionary Operation" and DFR stands for Design for Reliability. In this paper we have gone up to reliability test, to show how this procedure works for finding reliability.

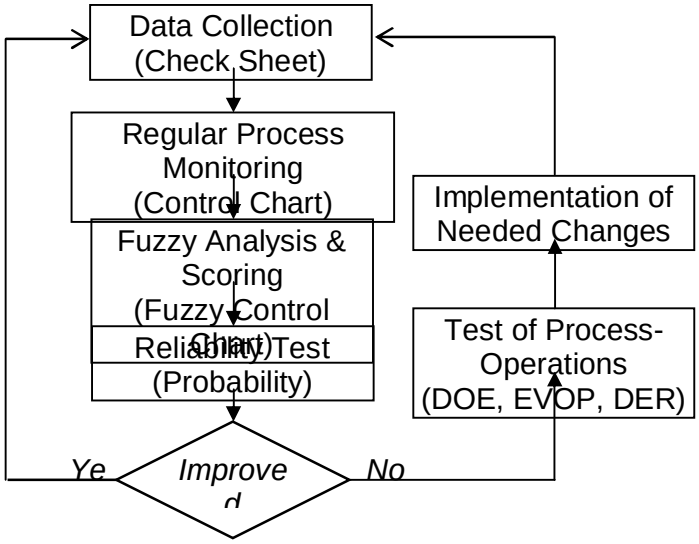

Fig 2: A schematic view of overall procedure

4. DISCUSSION & RESULTS

4.1. CHECK SHEET

A typical automotive battery production has several processes (casting, mixing, pasting, curing, conditioning, formation, drying, assembling and charging). As Pasting is the most defective occurring & control needing process in a lead acid battery production system, data have been collected on nonconforming plates of that process using a 'Single Sampling Plan' & represented

through the 'Checkup Confirmation Check Sheet', table 2. Here, sample fraction nonconforming 'f' has been found by using eq. (1).

Table 2: A Check Sheet for the pasting process

Sample no. (i)	No. of plates	d□	n	f
1	14530	35	500	0.070
2	15230	40	500	0.080
3	15000	37	500	0.074
4	14480	30	500	0.060
5	14430	29	500	0.058
6	15300	26	500	0.052
7	15700	45	500	0.090
8	14860	41	500	0.082
9	14930	32	500	0.064
10	15120	38	500	0.076
11	15200	42	500	0.084
12	15150	35	500	0.070
13	14940	30	500	0.060
14	14680	32	500	0.064
15	14730	36	500	0.072
Sum	224280	528		

4.2. CONTROL CHART

By using equations (2a), (2b), (2c), (2d) & (2e):

$$p\square = \frac{528}{15 * 500} = 0.0704$$

$$\sigma\square_p = \sqrt{\left(\frac{0.0704 * (1 - 0.0704}{500}\right)} = 0.011441$$

So, for $3\sigma\square_p$ control (z = 3):

$UCL_p = 0.0704 + 3\times0.011441 = 0.105$

$CL_p = 0.0704$

$LCL_p = 0.0704 - 3\times0.011441 = 0.036$

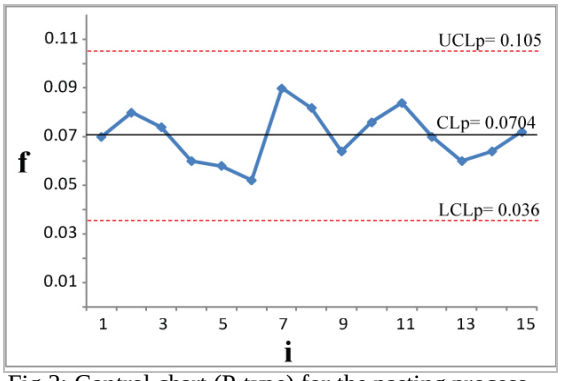

Fig 3: Control chart (P-type) for the pasting process

This p-type control chart (Fig 3) has been derived from the data of Table 2. It states that the pasting process is in control; it needs just regular monitoring through using the control chart.

4.3. COST OF WASTAGE

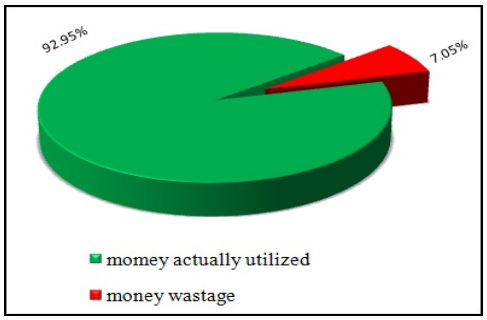

Fig. 4: pie chart; percentage of wastage of money

Though the control chart (fig. 3) describes that the pasting process is in $6\sigma_p$ control; it is seen from the pie chart generated from the data of table 2 that the pasting process suffers for a huge amount of wastage of nonconforming battery plates. Here comes a thinking of improvement of control chart through fuzzy logic to decide on the process more precisely.

4.4. FUZZY CONTROL CHART

Table 3 is derived from the equations stated in table 1 and Figure 5 is derived with the help of table 3. In the fig 5, it is found that 4 sample fraction nonconforming values fall within the 'absolutely in control limits'; 1 value falls outside the 'absolutely in control limits' but within the 'Mostly in control limits'; 6 values fall outside the 'Mostly in control limits' but within the 'Quite in control limits'; and so on.

Table 3: Ranges of control lines

Fuzzy control limits	Upper limit	Lower limit	Control lines
Absolutely in control	0.074	0.067	
Mostly in control	0.076	0.065	
Quite in control	0.082	0.059	
Probably in control	0.088	0.053	
Poorly in control	0.093	0.048	
Somewhat in control	0.099	0.042	
Quite out of control	0.105	0.036	
Mostly out of control	0.110	0.030	
Absolutely out of control	0.116	0.025	

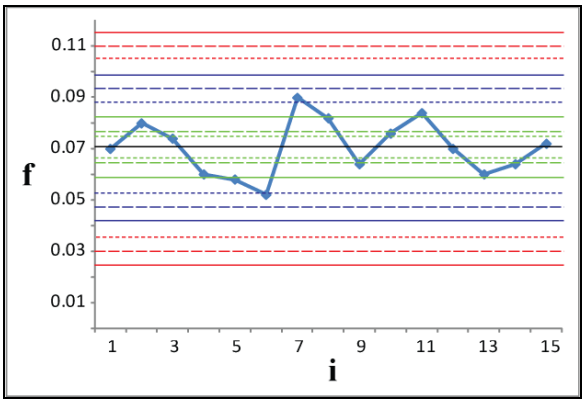

Fig 5: Fuzzy control chart for the pasting process

Table 4: Coefficients & Weightages of control limits

Parameters	Coefficient	Weightage	Observation
Absolutely in control	a	1	4
Only mostly in control	b	0.9	1
Only quite in control	c	0.8	6
Only probably in control	d	0.7	2
Only poorly in control	e	0.6	2
Only somewhat in control	f	0.5	0
Only quite out of control	g	0.3	0
Only mostly out of control	h	0.1	0
Only absolutely out of control	i	0	0
Total			**15**

By using the eq (3),

Total score= 4+0.9+4.8+1.4+1.2+0+0+0+0 = 12.3

That means total score of health of the pasting process is 12.3 out of 15.

4.5. RELIABILITY

By using the equation (4a),

$$R = \frac{12.3}{15} = 0.82 = 82\%$$

This shows that the pasting section has only 82% probability to perform its intended function; in other words it has only 82% time of well performing availability of the total processing time.

5. CONCLUSION

By using the check sheet & p-type control chart, it is found that the experimented pasting process is quite in $6\sigma_p$ control; yet the pie-chart shows 7.05% money wastage on that process. Use of fuzzy control chart & reliability test reveal that the quality score of the pasting process is 12.3 out of 15 & reliability level of that process is 82%.

One of the most successful ways to gain in business is to increase the ratio of Quality/Cost. Saving the cost of wastage of manufacturing processes, as a result of reliability judgment & improvement, will lower the cost of manufacturing; resulting in increase of profit subsequently gaining in business. However, proper judgment of reliability level of a process is the key pre-condition of improvement. This paper has provided a step by step guideline to judge the reliability level of a manufacturing process, here the pasting process of lead acid battery manufacture, as well as reliability level of the total manufacturing system. This paper also suggests to use DOE, EVOP and DFR tools if there needs any improvement on the reliability level of a process.

6. NOMENCLATURE

Symbol	Meaning
n	Sample size
d	no. of nonconforming in a sample
f	fraction of nonconforming in a sample
p	mean of nonconforming of samples
σ_p	standard deviation
z	number of standard deviation
a, b, c,..	coefficient of fuzzy control limits
r	reliability

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WASTE MINIMIZATION OF JUTE INDUSTRIES THROUGH VALUE STREAM MAPPING

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ABSTRACT: Value stream mapping is a step by step set of direction from current state map to future state map. It is a tool that analyzes and identifies the waste in material flow and information flow. The purpose of this paper is to identify and address various wastes in the supply chain of the jute industry (specifically the processing side) using a value stream mapping (VSM) approach to improve productivity and capacity utilization in a Bangladesh context. This paper considers the implementation of value stream mapping on jute products that are made by a jute mill and focuses on product family, current map and the future map as well as the improvements made. The aim is to identify waste and then translate the waste opportunities to improve company performance. It is concluded that value stream mapping is the first tool that any company should use to implement lean systems. Also, the implementation of one piece flow in the shop floor could reduce the lead time, cycle time and level of inventories. Also, companies that start the lean journey can use this as a guideline to draw the current state map and find the future state. In this paper waste is minimized in the Ajax Jute Mill. Here seven types of waste has been identified. These are bottleneck, no line balancing and there is no use of other lean tools. This paper also proposed an appropriate line balancing, plan for work cell and to implement other lean tools to improve productivity and working condition of the jute mill.

Keywords: Value stream mapping, Total Productive Maintenance, Visual Management, Continuous Replenishment Program

1. INTRODUCTION

During the last two decades, the companies have been looking for reaching the world class manufacturing. To achieve this it is necessary to fulfill the competitive dimensions such as cheap product, good quality products, high delivery speed, and delivery on time, quick respond to increase and decrease in the demand, flexibility to innovation of products and meet product specification [1]. Value stream management is an organization technique for planning, managing, implementing, sustaining and linking lean initiatives to activities of the company by taking and analyzing data. [2].

These dimensions were observed at the Ajax jute mill and a lack of them was found in its activities and processes. Ajaxs Jute Mill is a Private Limited Company and established in 1988.It is a professionally managed company engaged in the manufacture of Jute & Jute allied products. The factory is situated at Fulbarigate in Khulna. The present Management has not enough experience in running jute manufacturing units in the world efficiently, maintaining good rapport with the skilled workforce of the Company. The unit has not been modernized to produce value added diversified jute products like geo-textiles, food grade quality jute cloth and bags. They only manufacture traditional jute - products including yarn/twine, bleached yarn & cloth, Hessian Cloth & Bags.

The purpose of this study is to utilize VSM as a tool to identify the value and eliminate the waste with the intention of minimizing cost, rework and lead time to reach the competitive dimensions. This starts with the identification of the family product and the current state of the product relate to information flow and material flow. Then, the analysis and future state will be presented and will give the suggestions to reduce the lead times, change over time, and inventories, as well as, improve the communication of the information flow issues. Finally, the improvements are shown.

2. LITERATURE REVIEW

TÖzkan, Birgün, Kılıçoğulları, and Akman, [3] define value stream management as a tool that helps the workers to recognize the waste and build up a future state to reduce it. Value stream management consists of eight steps [2]: committing to lean, choosing the value stream, learning about lean,

mapping the current state, determining lean metrics, mapping the future state, creating Kaizen plans, and implementing Kaizen. There are 8 steps to reach the VSM which are: 1. commit to lean; 2. choose the vale; 3. Learn about lean; 4. map the current state; 5. determine lean metrics; 6. map the future state; 7. create kaizen state; and 8. implement kaizen plans [2]. Tapping [2] highlights that value stream management seeks to "treat employees as human fixed assets".

Lovelle [4] and Seth and Gupta [5] defines VSM as a tool to understand the material and information flow that links the lean initiatives. The value stream are part of the value added activities and non-value added activities. Also, the VSM looks to increase the flow from the information and material flow. The aim of VSM is to switch from batches and push systems to pull system and continuous flow [10]. Also, Tappin [2] calls attention to identifying the production process, the communication between departments, the bottlenecks and the all types of waste. The VSM is divided into 4 stages [6]:

1. Identify product family
2. Draw the current state
3. Develop future state
4. Make the work plan

3. METHODOLOGY

Initially, the methodology was developed to achieve the objectives of the project. The first stage was to gather and research VSM and the lean manufacturing system in books, articles and from center of investigation. The aim of this gather was to find case studies in companies that have applied VSM in a make to order environment. Also, it was required to identify the key concepts and recent frameworks in research. The main difficulties to implement VSM were identified.

The second stag to identify product family that the company chose and the products that should be mapped. In order to reach this objective, it was requested to identify features and the quantity of product or products that will be made and the starting date of the production to avoid missing any stage of the process. In this project one family product were observed in order to draw VSM. The third stage was to identify the current state to achieve it. It was required to collect 4 types of information as Information flow, Material Flow, Layout and process floor mapping and 7 types of waste

The key people were introduced to the researcher such as managers, operators and sales people. A meeting was organized with the operations manager, engineering managers purchasing people and sales people to understand the current situation of the information flow for a specific product. Having the information flow and a general view of the process, the next stage is the collection of data related to the material flow that was taken in the shop floor, the material flow and information flow were done in parallel. And the final stage was to identify the waste and find improvement strategies and suggestions to the current state map. Then, the future state map was drawn.

4. CURRENT STATE MAP

All the information and material flow information for the current state map were collected according to given suggestions in the literature review. The first step was to identify and understand the information flow and all the processes that are involved to make the jute product in the production floor. Here productions are followed by pull system and raw jute is collected in different market according to the annual demand. Jute is a seasonal crop, so it is collected in the season and stored in the store house. That means jute is collected by pull system. So the main focus was on the production floor.

4.1 LAYOUT OF THE PRODUCTION FLOOR

It was analyzed one family product, which are made in the production shop. To understand the process and the machines was required to draw and identified the lay out of the productions shop (see Figure 1.). Furthermore, all the machines and equipment are identified with different names that do not have mean and are sometime chosen random by the operator and managers. Having the layout and the general view of the production floor, the next state is to identify the current state of each product.

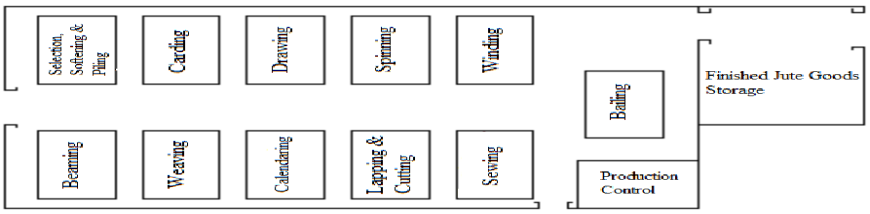

Fig.1: Layout of the production floor

4.2 PROCESS ATTRIBUTES

The attributes of each operation was gathered by taking manual time and observations. The measures, that were taken cycle time, are value added time, Non value added time, necessary non value added time; change over time, uptime, number of operators, case size, work in process (WIP), and number of the days that the inventory was sitting on the production floor. The identification of the attributes was required to analyze these specific orders which are.

4.2.1 AVAILABILITY

The total available production time is 8 hours per shift. There is a 40 minute lunch break. Total available = total time per shift in seconds – total time of breaks, meeting, etc. Total available = (8 hours x (60 min/1hour) x (60 sec/1min)) – (40 min x (60 sec/1min))
Total available = 26, 400 seconds per shift. Therefore, the available production time is 440 minutes (26,400 seconds) per shift. This available time is the same in each step of the production.

4.2.2 UPTIME

It is calculated by dividing actual operating time by available time. The operation time is the total available time minus the time that the changeover takes.
Uptime = [Total available (sec) – change over time (sec)] / Total available (sec)

Uptime first operation = 26, 400 seconds per shift – 60 min x (60 sec/1min)/ 26, 400 seconds per shift) Uptime first operation = 86.36 %.

All the attributes of each process are summarized in the Table 1. The selection, softening &piling, carding, drawing, spinning, winding, beaming, weaving, calendaring, lapping and cutting, hemming & swing and bailing are operations which are performed in the production floor. Raw jute is processed in the form of bales (180kg).All attributes are considered according to one bales.

All process is required average two people, so that are not shown in the current state map. The current state map is shown in Figure 2 bellow. It was analyzed a path of process which starts in the selection, softening &piling and ends in the bailing. The current state map also shows the inventories points which are represented by a triangle which is critical in the operations in the production floor, by this is considered the high work in process. All the information and the material flow are connected by arrows which represent the way of upstream and downstream operations.

Looking at the current map, the lean metrics which are below the current state map (see Table 2) has four metrics. The first metrics is the total value stream lead time, which is the total time the work in process to receive the final product by the buyer, is 15 days. This data was collected in each state by observation and included the time the raw material were on the material floor. The second metric is the value adding time, which indicates the actual value adding time. The third lean metric is necessary non value adding time, which is required to add value. The fourth lean metric is waste, which is produced during the production period.

Table 1. Summary of the data for current state map

Process stage / Attributes	Selection softening & pilling	Carding	Drawing	Spinning	Winding	Beaming	Weaving	Calendaring	Lapping &cutting	Hemming & Herackle Sewing	Bailing
Cycle time(sec)	108000 (30hr)	43200 (12h)	54000 (15h)	21600 (6h)	21600 (6h)	21600 (6h)	28800 (8h)	14400 (4h)	14400 (4h)	14400 (4h)	18000 (5h)
Value added time(sec)	86400 (24h)	36000 (10h)	43200 (12h)	14400 (4h)	14400 (4h)	14400 (4h)	21600 (6h)	7200 (2h)	7200 (2h)	7200 (2h)	10800 (3h)
Non value added time(sec)	1800 (1/2h)	1800 (1/2h)	1800 (1/2)	1800 (1/2h)	3600 (1h)	1800 (1/2h)	5400 (3/2h)	1800 (1/2h)	1800 (1/2h)	3600 (1h)	
Availability	26400	26400	26400	26400	26400	26400	26400	26400	26400	26400	26400
Uptime (%)	86.36	86.36	86.36	86.36	86.36	86.36	86.36	86.36	86.36	86.36	86.36
Waste (%)	0	0	0.4	1	0.4	0.6	1	0	0.3	0.3	0

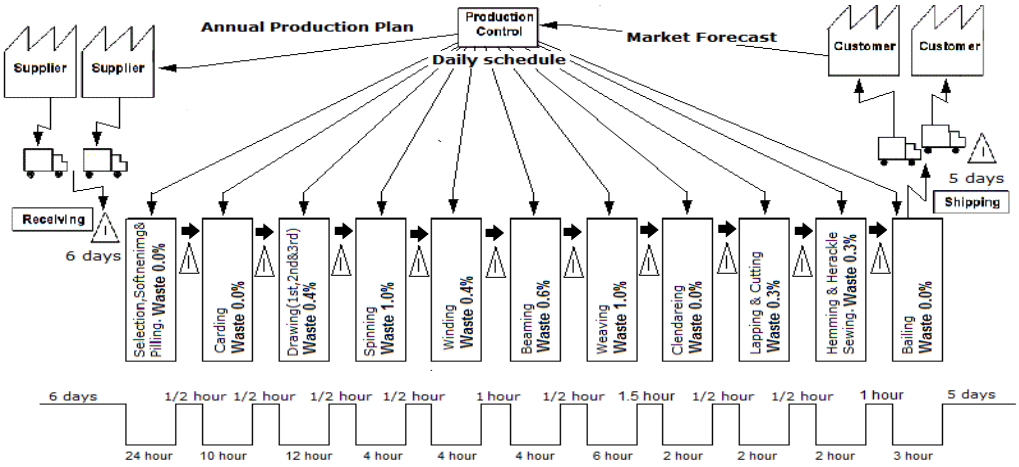

Fig.2: Current State Map of the Jute Mill

Table 2. Lean metrics of the current state map

Lead time	Value added time	Necessary non value added	Total waste
15 days	73 hours	7 hours	4 %

5. RESULT

Defining the product family and drawing the current state are the guidelines to describe the future state map due to the main problems were identified. Looking at the current state maps for the production floor of the jute mill is clear that there are high levels of inventory, the lead times, and the value added time are different, problems of communication between departments, and each stage of production has its own schedule to make the product.

Additional to these difficulties, different operator runs the machines in different ways and there is not standard procedures in the operations were evidenced during the research. The aim of the future state is to minimize waste and satisfy the customer requirements reducing the lean metrics such as cycle time, lead time, number of workers and work in process (WIP). According to Rother [7], the cycle time can be reduced: "the smaller the FIFO lane, the less work on the floor and the shorter the lead time". Also, there were identified in the current state the 7 types of waste in product family. To achieve the ideal future state is necessary to find the takt time, the pinch time [8] and asking the sequence of questions that were found doing the literature review. Furthermore, the information flow will be analyzed in one section and its contents the main issues of products.

5.1 TAKT TIME FOR THE PRODUCTION FLOOR

The overall production process can be divided with three sections with three different production rate. Selection, softening &piling, carding, drawing, spinning and winding constitute the first section, whose production rate is 30ton per day. Beaming and weaving constitute the second section, whose production rate is 26ton per day. And calendaring, lapping and cutting and hemming & swing constitute the third section, whose production rate is 24ton per day. So the bottleneck is occurred in the third section. The non-value added time can be eliminated if the suggestions given in the section5.1.4.1 are followed. However, there is another operation with higher which is selection, softening & piling, but this operation is catalogued unnecessary according to the manager and operators.

If the cycle time of the selection, softening &piling is subtracted by the non-valued added time. The future cycle time will be nearly 24 hours per bales. This takt time does not represent that a bales has to be processed in 24 hours, but rather that one bales will be processed every 24 hours on average. However, the total cycle time will depend on the sum of the lead time of each activity or operation. It means that in the selection, softening &piling of the product should be done in 24 hours. It is suggested that the make to order companies are "dynamic systems" that the takt time and bath size have to be updated to understand the changes in the system.

5.2 CONTINUOUS FLOW

The goal is to work on flow without interrupting regular, timely deliveries to your customer. To design continuous flow is necessary to: perform line balancing, plan for work cells, determinate how to control production upstream and determinate which improvement methods to use.

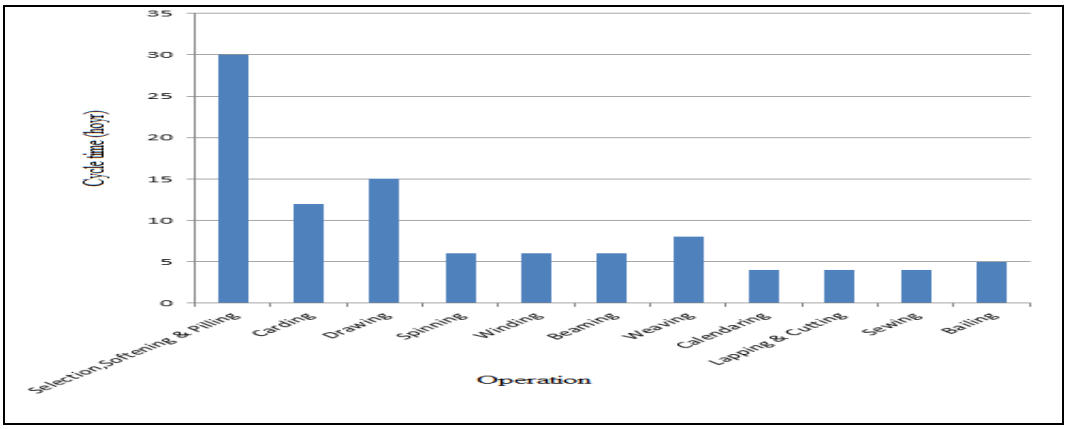

Fig.3: Operator balance chart-current state

5.2.1 LINE BALANCING

It is used to balance the workers and to move smooth into the process. It is graphed the balance chart of the current state in the Figure 3. Looking at it, there is one critical operation which takes long lead time to be done which is the Selection, softening &piling.

Also, it is calculated, the theoretical number of workers needed to make this product which is:
Total cycle time = 100 hours
Number of operators = total cycle time / takt time
Number of operators = 100 hours / 24 hours = 4.2 ± 5 operators

It seems that the production of the jute product uses 11 workers and the production should be needed 5 workers instead of 11.To balance the line is required to reduce the cycle time by 20 % from 100 hours to 80 hours. This reduction is based on the observations and the managers and operators' comments the new cycle time can be achieved by making the following kaizen targets:

- Selection, softening &piling: the company should set up two processes to meet the demand. Also, the operator spends on putting the product can be done during the machine is running. By this suggestion, the non-value added time can be reduced. Finally, this operation can be done by 1 operator and a program of improve efficiency of the process.
- Drawing. If the changeover is improved from 60 minutes to 15 minutes. The operation can be improved if the operator does not need to reach to get the intermediate product by 20% less of the cycle time.
- Form a cell with drawing and selection, softening &piling. Alternatively, it is possible to arrange full cell with all operations on it.
- Carding: Improving programming and tooling maintenance to eliminate long cycle time in the production shop.
- Improving programming and tools maintenance.
- Spinning, winding and beaming operation can be done with the same operator.
- Also calendaring, lapping and cutting operation can be done with the same operator.

According to the literature, it requests to find the theoretical number of workers require to reach the new cycle time.
Number of operator with the new cycle time = total cycle time / takt time
Number of operators = 80 hours / 24 hours = 3.33 ± 4 operators

It shows that the production shop needs 11 operators. While, the theoretical number of workers are 4 operators. To reach the number of workers is necessary to organize 3 cells. Subsequently, it is necessary to balance the new process and arrange the operations to meet the takt time. The Figure 4 shows the new arrangement of the operations that should work at the same level of the takt time. Looking at the figure No. 15, the number of worker needed is the same as the calculated theoretical requirement.

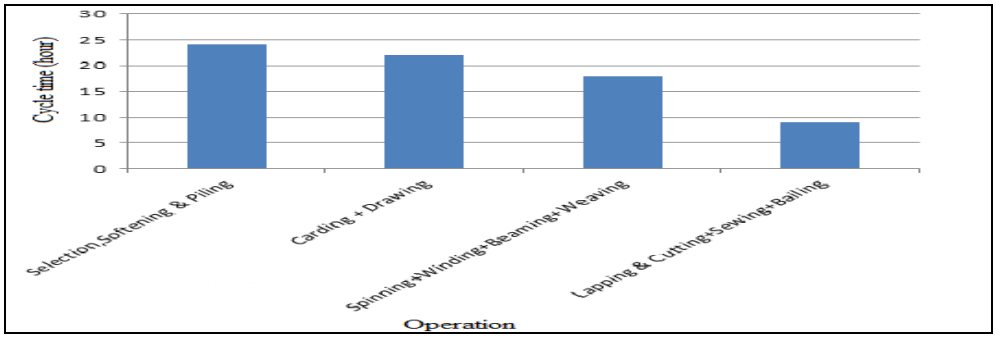

Fig.4: Operator balance chart (proposed)

5.2.2 PLAN FOR WORK CELLS

It is required to design a cell is required to balance the operations. Also, the cell has to be designed with rigid adherence to ergonomic principles to minimize reach distances and times and to eliminate worker fatigue [9]. To realize this, three cells should be designed. The first cell should include the selection, softening &piling operations. The second cell will be consisted of the, carding, drawing and calendaring operations. The last cell should include spinning, winding, beaming, weaving, lapping and cutting, hemming & swing and bailing operations. To achieve the cycle time is required to implement: 5S, Total productive maintenance (TPM), quick change over (QCO) and standardized work, cell design.

Alternatively, to reduce the distance between the different operations in production shop it should be needed to design the production floor. To reach this, it should be needed to design the cell and have a high confidence with the operations and operators. This project is a long term because of the difficult of moving machines and stopping production. The attributes of the three cell will be shown on Table 3 and the information is taken by following the suggestions. The proposed lean shows that lead time will be reduced and the cycle time will be a decrease. Also, numbers of workers are less.

Table 3. Lean metrics - the future state (proposed)

Process stage / Attributes	Selection, softening &piling	Carding + Drawing + Calendaring	Spinning+ Winding+ Beaming+ Weaving+ Lapping and Cutting + Sewing + Bailing.	Total
Cycle time (hour)	24	24	25	73
Availability (sec)	26400	26400	26400	
Uptime (%)	86.36	86.36	86.36	
No. Operators	1	1	2	4

5.3 IMPROVEMENT METHODS

According to the identified seven types of waste, it is indispensable to suggest improvement strategies to reduce the waste and improve the production which are shown in table 4.

Table 4. Improvement strategy to reduce the waste

Types of waste	**Wastes Identified**	**Improvement Strategy**
Over production	Bach production Bottlenecks Many Operations	• Continuous flow • Improve Cell design and layout • Implement 6 sigma and quality control programs and additional to this, 5S can be used to setup rules for storing, define space and places. The rules have to be updated and stick to the newest state. • Standard the procedures to visit the customer and take the information form behalf of the customer to be interpreted by the engineering department. It could be necessary to identify the main specification that the engineering department wants to have to make a product right at the first time. • Make procedures to check the quality of the raw materials.
Waiting time	Long lead time Long change over Breaks	• Quick change over • Total productive maintenance • Implement 5s to reduce the time to find a specific tool or bold. • Change the layout of press shops such machines and the tool stores. The tool could be close to the small press. • Redefine the main specification that engineering department would like to have

	downs	from the customer to make the product right at the first time. • Train the workers to allocate the product into the machine and identify damage product. • Include on the production plan, the materials requirement and the tools requirements to avoid the late on the production.
Transportation and Handling	Poor plant Layout	• 5S, Visual controls • Implement cell layout • 5S can be used to setup rules for storing, define space and places. • Identify the short routes and the possibility of implement cell work or continuous process. Also, incorporate the assembly area in the press shop. • Decentralize process. Store the raw materials for the press shop in the same shop.
Inventories	Bach production Long change over time	• One piece flow, Kanban pull • Material planning control • 5S can be used to setup rules for storing, define space and places. • Try to identify the minimum amount extra of blank sheet that are required to make an order. • Make a quality control to the blanks. • Check in the material floor how many materials are on the floor and set that information on the computer. • Use a common system to do the production plan and the materials plan.
Over processing	Redundancy of Operations	• Standardized work. • Standardize the procedures of operating machines and cleaning products. • Meet the engineering department and the sales department to clarify the information that the engineering department needs to produce a specific product. Standardize the procedures and the order form to by clear for both divisions.
Motion time	Poor layout Multiple Handling	• Standardized work. • Graphic work instructions • Identify the short routes and the possibility of implement cell work or continuous process. Also, incorporate the assembly area in the press shop.
Defects	Processes not in Control	• Six sigma, Poka yoke • Reduce the number of defect in the machine by applying quality tools to identify the causes of the machines and processes. • Standardize the processes in each machine. Also, add the information in special cases such as defects, or break downs.

Looking at the table 5, we remove all possible waste and gather related data to draw the future state map. The related data is given in the following table.

Table 5. Summary of the data in the future state map for jute mill

Process stage / Attributes	**Selection softening & pilling**	**Carding**	**Drawing**	**Spinning**	**Winding**	**Beaming**	**Weaving**	**Calendaring**	**Lapping &cutting**	**Hemming & Herackle Sewing**	**Bailing**
Cycle time(sec)	86400 (24hour)	28800 (8h)	36000 (10h)	14400 (4h)	14400 (4h)	14400 (4h)	21600 (6h)	3600 (1h)	3600 (1h)	3600 (1h)	7200 (2h)
Value added time(sec)	86400 (24hr)	28800 (8h)	36000 (10h)	14400 (4h)	14400 (4h)	14400 (4h)	21600 (6h)	3600 (1h)	3600 (1h)	3600 (1h)	7200 (2h)

Non value added time(sec)	1500 (25min)	1500 (25min)	1500 25(min)	1500 (25min)	1800 (30min)	1500 (25min	3000 (50min)	1500 (25min)	1500 (25min)	3000 (50min)	
Availability	26400	26400	26400	26400	26400	26400	26400	26400	26400	26400	26400
Uptime(%)	86.36	86.36	86.36	86.36	86.36	86.36	86.36	86.36	86.36	86.36	86.36
Waste (%)	0	0	0.3	.8	0.3	0.4	0.8	0	0.2	0.2	0

All process is required average two people, so that are not shown in the future state map. The future state map is shown in figure 5 bellow. The main focus on waste that is created during the operation and time is required to receive raw jute, to process the raw jute and to ship jute product. The future state map also shows the inventories points which are represented by a triangle which is critical in the operations in the production floor, by this is considered the high work in process. All the information and the material flow are connected by arrows which represent the way of upstream and downstream operations.

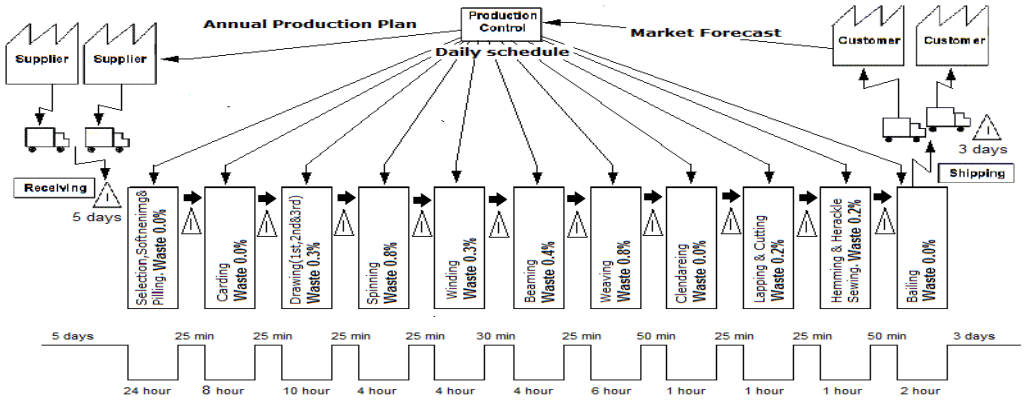

Fig.5: Future State Map for the Jute Mill

Table 6. Lean metrics of the future state map

Lead time	Value added time	Necessary non value added	Total waste
11 days	70 hours	5 hours	3 %

Looking at the future map, the lean metrics which are below the future state map (see table 6) has four metrics. The first metrics is the total value stream lead time, which is 11 days less than the current state map. This data was collected in each state by observation and included the time the raw material were on the material floor. The second metric is the value adding time, which is decreased. The third lean metric is necessary non value adding time, which is also decreased. The fourth lean metric is waste, which is less than the before.

6. CONCLUSIONS

The purpose of this thesis was to apply a methodology of VSM for one families of product at Ajax Jute Mill. This methodology allows the organization to identify the current state of a product and gather the data of the process such as cycle time, value added time, inventories points, work in process and change over. Also, VSM links manpower, equipment, tools and metrics to achieve the lean system by connecting the information flow and the material flow.

Also, VSM tool can be applied for any type of product that wants to be analyzed. However, it is necessary to identify the location of the customer order decoupling point type of environment that the company works such as engineering to order, make to order, assemble to order or make to store. According to the manufacturing environment the future state will be analyzed differently [10].

The current state map does not show all the types of waste easily and also what the main issues are in each during the production. By this, extra tools were incorporated to generate a better identification of the waste such as the seven types of waste, floor mapping and analysis of motion. The identified wastes are not 'problems' but they are golden opportunities to gain market support and reduce costs. These frameworks were analyzed to find opportunities to improve the process and the production floor and draw the future map. VSM seems as the first tool to be implemented to any company than would like to switch its production process to lean process.

Having the future map is not the last step. After that the suggestions have to be come real. By this, 5s and one piece flow were implemented that can be accommodated in any environment without having any difficult. It is showed that the organizational changes are not welcome for the operators who like to have the ways they usually have their activities. The top manager was pleased to implement the changes. However, when the changes were implemented, there was little participation from the operators to achieve the goals. The operators' participation, during the implementation was quite low; it demonstrates that the implementation of 5s is not be likely to be performed correctly.There were not actions or investment for the companies, if the company wanted to implement lean manufacturing to reduce costs and waste. Also, the company looks for reduction of manpower. However, it is argued that the lean manufacturing works in favor of the workers [11].

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IMPROVEMENT OF INGREDIENTS OF LEAD ACID BATTERY BY INVESTIGATION WITH TOOLS OF TQM: AN EMPIRICAL STUDY

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ABSTRACT: Battery is an energy shortage device which converts chemical energy directly to useable electric energy. The quality of a battery (energy density, durability, allowable discharge rate, cycle numbers etc.) is dependent on hundreds of criteria of battery quality technology; also the quality of battery production (productivity, wastage rate, battery nonconformity rate, battery-plate nonconformity rate etc.) is dependent on hundreds of criteria of battery manufacturing technology. In a concern of achieving both product & production quality, here several tools & techniques of TQM such as fish bone diagram, pareto chart, histogram, normal distribution etc. have been used. With use of TQM, it is perspicuous that productivity and battery quality mainly depend on conformity of battery plates' processing. 73.67% reason of nonconformities of battery plates is the chemical ingredients of paste of plates. At last it has been found from this empirical study that FLC of the grey oxide should be kept 30% as a quality standard of grey oxide.

Keywords: Lead acid battery, FLC, Grey oxide, Paste quality, TQM.

1. INTRODUCTION

The quality of lead acid battery is mainly defined by its plate's quality. Again, the quality of plate is mainly depended on the recipe of paste & the quality of ingredients of paste. The vindication of this paper is to investigate the quality standards of ingredients of that paste trough using the tools of TQM (Total Quality Management).

TQM provides the pathway to control the quality, to ensure the quality, to obtain the required level of performance of both product & process. The primary TQM tools are process flowchart, check sheet, cause & effect diagram, pareto chart, scatter diagram, histogram, normal distribution etc. In brainstorming, QCC (Quality Control Circle), a team, is formed who takes the responsibility of implementing TQM. In engineering, a process flow diagram is used to indicate the general flow of material as well as to display the relationships between major processes. The cause and effect diagram shows all possible contributing factors or causes of an effect. The check sheets are used for collecting data from a process in an easy, systematic and organized manner also used as an input for other TQM tools. Pareto analysis (the 80/20 rule) is a powerful 'narrowing down' tool as well as fundamental for identifying the really important problems and establishing priorities for action. The scatter diagrams are used to examine the relationship between two factors to see if they are related & to find the controlling factors of a dependent variable. A histogram is a graphic summary of variation in a set of data which is analyzed to draw conclusions about the data set. When the size of the statistical data increases, the histogram creates a bell-shaped curve known as normal curve or normal distribution which provides a visual interpretation for probability of happening of an event.

Here, a perfect combination of tools of TQM introduces a perfect procedure-loop to diagnose the problems, to identify the key causes of a problem, to invent the best solution options for a cause. By continuing the procedure-loop for once on a lead acid battery manufacturing process (plate pasting), a few vital quality specifications of paste (paste density, grain property, blending temperature) & its ingredients (FLC of grey oxide) have been found. For optimum production quality, this paper also suggests allowable tolerance of FLC (Free Lead Content) in grey oxide. Thereby, more quality specifications & improvements may be observed by further going through the procedure-loop of experimental procedure.

2. EXPERIMENTAL PROCEDURE

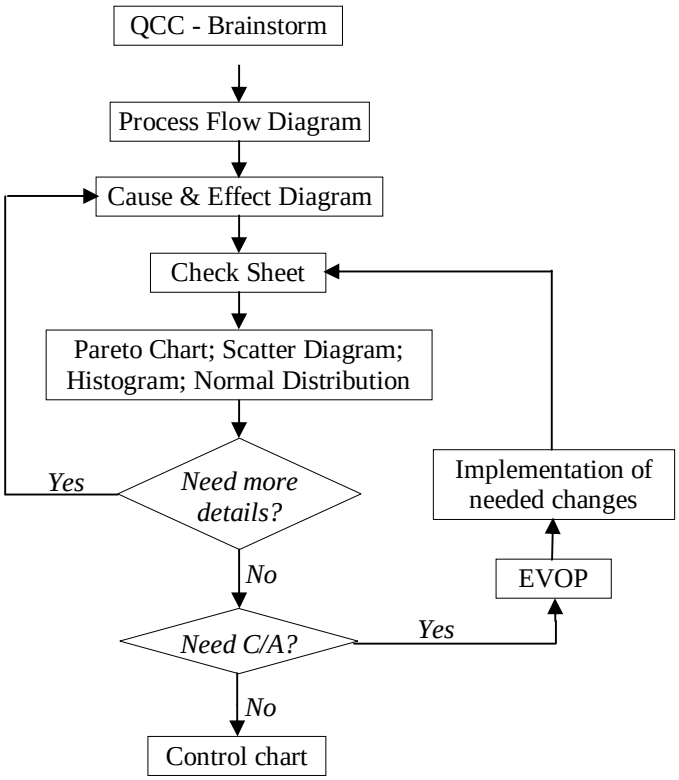

Fig.1: A schematic view of overall procedure

This procedure (illustrated by fig. 1) provides a step by step pathway to set up the quality standards for both product & production; thus improvement comes thereby**.** In this figure, C/A stands for "Corrective Action" and EVOP stand for "Evolutionary Operation". In this paper we have gone up to normal distribution, of the work procedure, to get our desired results.

3. DISCUSSION & RESULTS

3.1. PROCESS FLOW DIAGRAM

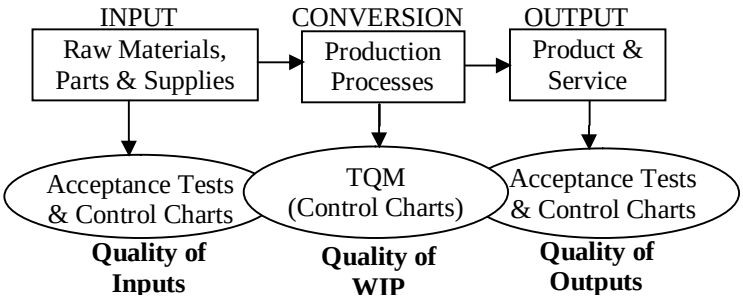

Fig.2: Quality control throughout the production system

Quality needs to be ensured at each of the steps of a production system throughout the input raw material to the end of finished product & service. By the fig 2, it provides a concept of managing quality using various techniques of acceptance test, control chart & tools of TQM.

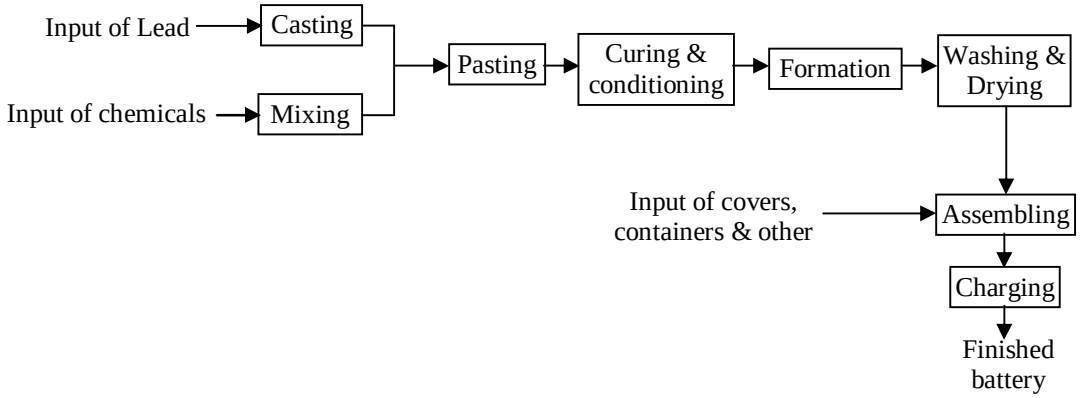

Fig.3: Process flow chart for a typical lead-acid battery production

An automotive lead acid battery production system consists of several processes, illustrated by process flow chart (Fig 3). There may be a lot of reasons for which a process may lose its performance. The effects & the reasons of each effect of the processes of automotive lead acid battery production system have been analyzed though a Cause & Effect diagram (Fig 4).

3.2. CAUSE & EFFECT DIAGRAM

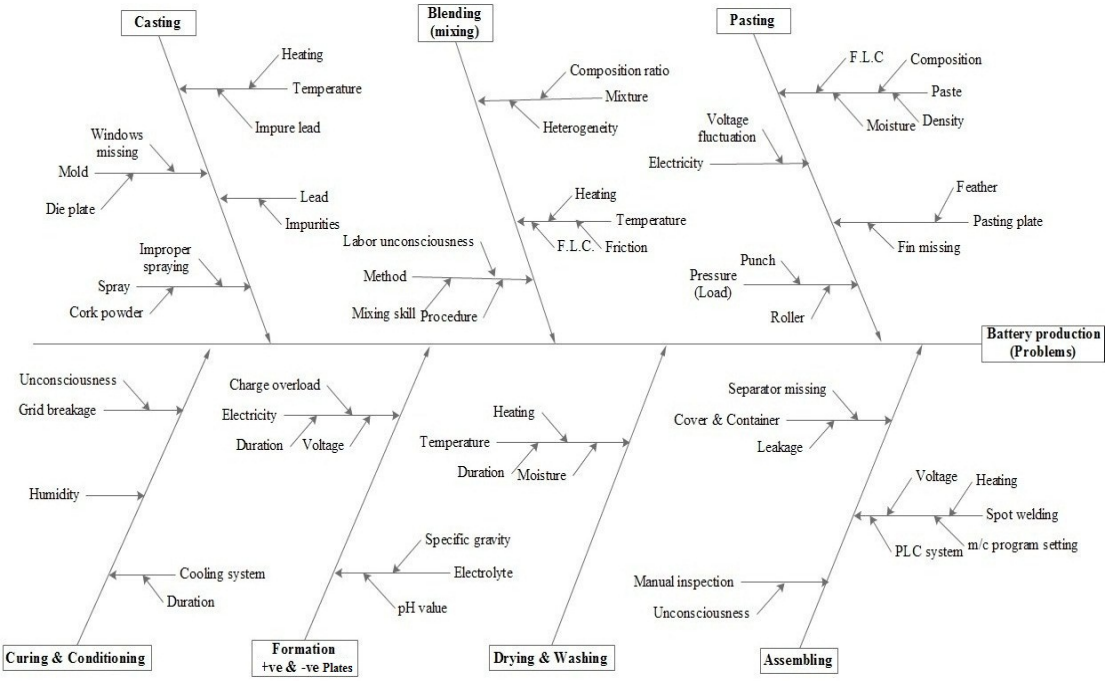

Fig.4: Cause & effect diagram for the battery production

3.3 CHECK SHEET, PARETO CHART & SCATTER DIAGRAM

In concern of battery plates' nonconformities, from the general statistics, it is known that the most defective occurring & control needing processing is the pasting. Thus here data have been collected for that process. Table 1 provides causes of nonconforming of 300 nonconforming plates of successive days' production.

Table 1: Areas of complaints in pasting process

Causes	Frequency	Percentage (%)
Paste problem	221	73.67
Imperfect grid	52	17.33
Load variation	20	6.67
Electricity problem	5	1.67
Others	2	0.67

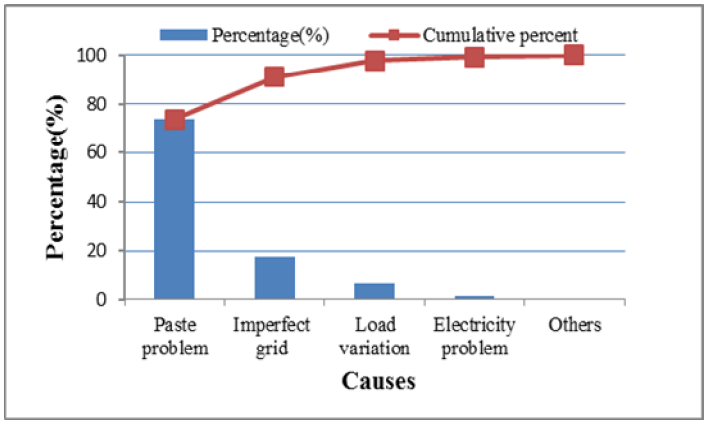

Fig.5: Pareto chart on complaints of pasting process

Fig 5 shows 'paste problem' is the vital reason responsible for maximum number of failure. Paste is prepared by mixing several chemical ingredients: grey lead oxide, red lead oxide, carbon black, fiber flock, barium sulphate, lignin, demineralized water, sulphuric acid, paraffin oil etc.; of which grey lead oxide is around 86% of total mass of the paste. As FLC percentage of grey lead oxide (PbO + Pb) is the most critical issue for the paste, it has been focused on next.

Table 2: FLC% with its various variables

sample	FLC%	Mix. °C	Grain	f	sample	FLC%	Mix. °C	Grain	f
1	30.9	53.20	Fine	0.070	14	30.3	51.10	Fine	0.064
2	31.5	56.50	Coarse	0.080	15	27.7	39.00	No	0.072
3	31.1	53.00	Coarse	0.074	16	29.4	49.20	Very Fine	0.050
4	29.8	50.30	Very Fine	0.060	17	30.0	49.40	Fine	0.050
5	29.6	49.10	Very Fine	0.058	18	30.2	50.00	Fine	0.053
6	29.0	47.60	Very Fine	0.052	19	28.7	47.60	No	0.062
7	32.5	61.60	Very Coarse	0.090	20	30.4	51.40	Fine	0.055
8	31.7	57.80	Coarse	0.082	21	29.3	48.60	Very Fine	0.053
9	28.6	45.60	No	0.064	22	28.9	48.10	No	0.059
10	31.3	55.00	Coarse	0.076	23	30.3	50.10	Fine	0.059
11	32.3	59.20	Very Coarse	0.084	24	30.5	51.00	Fine	0.062
12	30.7	52.00	Fine	0.070	25	32.8	63.40	Very Coarse	0.094
13	29.5	49.40	Very Fine	0.060					

There is a simple assumption that if FLC% of grey lead oxide is more, the temperature of the mixture (paste) rises frequently while blending the chemicals, the grain size becomes coarser & that enhances the no. of failure of pasting process (enhancing no. of nonconforming plates) as well as the fraction nonconforming. On the other hand, poor FLC% in grey lead oxide decelerates the rate of chemical

reactions, which occurs poor bonding property of paste with grid; thus it increases nonconformity of battery plates. These have been analyzed through scatter diagrams.

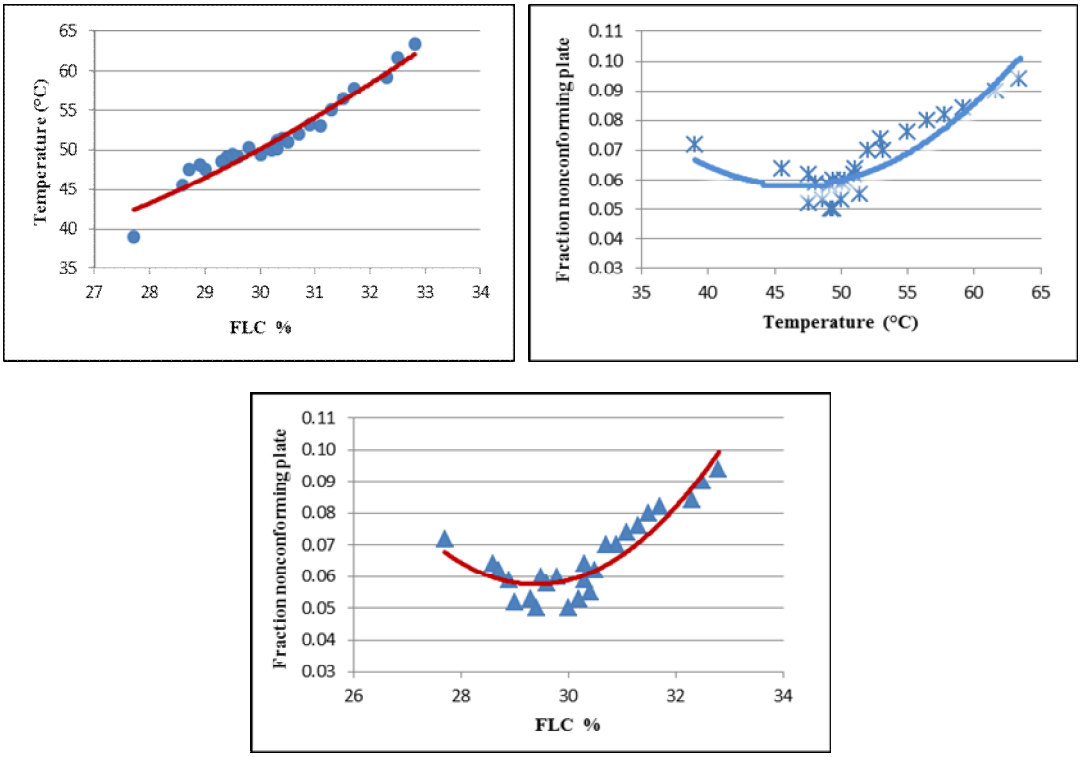

Fig.6(a): Correlation between FLC% & paste Temp. (°C); Fig 6(b): Correlation between paste Temp. (°C) & fraction nonconforming plate (f); Fig 6(c): Correlation between FLC% & f

From the graphs of fig 6, it is concluded that the temperature of mixture is dependent on FLC% of the grey oxide; the temperature of the mixture should be around 48°C to reduce the number of nonconforming plates and FLC% of grey oxide is better to be in the range of "29 □ 31%" for more conforming plates. Another finding is, through the table 3, fine grains & very fine grains (i.e. paste density between 4.18 □ 4.23 gm./cc.) are the expected sizes for the paste to ensure more conforming plates as well as more conforming pasting process.

Table 3: frequency of occurrence within range of FLC% & grain size

FLC %	Grain	Density (gm/cc)	Freq.	Perc.
<28	No	< 4.15	1	4%
28 □ 28.9	No	4.15 □ 4.17	3	12%
29 □ 29.9	Very Fine	4.18 □ 4.20	6	24%
30 □ 30.9	Fine	4.21 □ 4.23	8	32%
31 □ 32	Coarse	4.24 □ 4.26	4	16%
>32	Very Coarse	> 4.26	3	12%

3.4. HISTOGRAM & NORMAL DISTRIBUTION

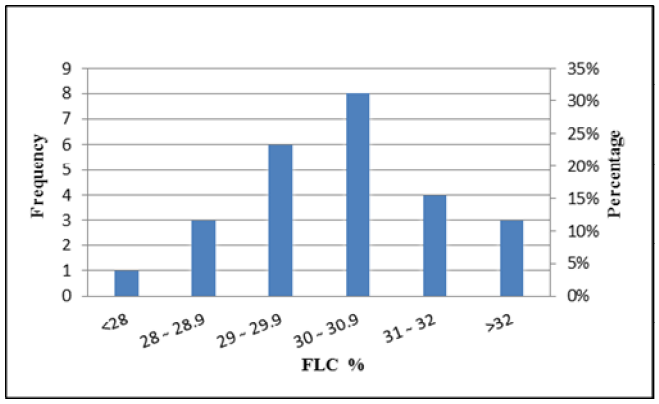

Fig.7: Histogram for grey oxide produced by current process

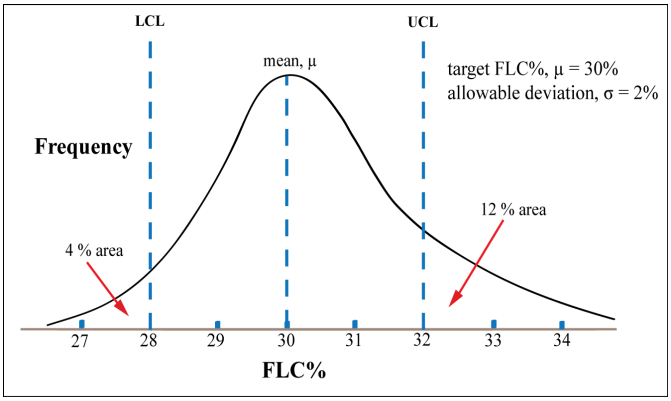

Fig.8: Normal distribution for the FLC% of the grey oxide

This histogram, fig 7, shows the condition of paste produced in the current mixing process. For the best performing of pasting process, control specifications for the FLC% of grey oxide of mixture might be set as: target FLC%= 30% & allowable deviation from the target =2%. The normal distribution, Fig 8, finds that in total 16% paste produced in mixing process is regarded to be in out of specification.

4. CONCLUSION

For the manufacturing of lead acid battery, the temperature of the mixture (paste), while blending, should be around 48°C. Paste of fine and very fine grains, which results in paste density 4.18 □ 4.23gm/cc, are good for bonding of active materials in plate which ensures more number of conforming plates. The key finding is that FLC% of grey oxide is to be in the range of 29 □ 31% for the best quality of plates. For the optimal production quality of that grey oxide production system, the FLC% of grey oxide may be standardized at 30%, allowing 2% tolerance, primarily, from that

5. NOMENCLATURE

Symbol	Meaning
TQM	Total Quality Management
QCC	Quality Control Circle
EVOP	Evolutionary Operation

C/A	Corrective Action
UCL	Upper Control Limit
LCL	Lower Control Limit
FLC	Free Lead Content
f	Fraction of nonconforming
μ	Target mean
σ	Allowable standard deviation

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SCHEDULING JOBS IN A FLOW-SHOP CONSIDERING THE SLOWEST MACHINE

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ABSTRACT: This paper proposes a new production scheduling model which is developed to ease the loading and sequencing problem. Loading and sequencing provide us potential scope to make the scheduling operation or processing efficient. Proper scheduling can eliminate the wastage of time and money. There may be several jobs in the production floor where several machines are used for processing those jobs. The method proposed in this research will help in taking proper decision regarding loading and sequencing of multiple jobs in single machine in a way that will minimize average waiting time and mean flow time. Classic assignment theory suggests assigning only one job in each machine where the capacity of the machine is ignored. Proposed model can assign the jobs in different machines through proper optimization of time that helps to reduce idle time. This scheduling method also considers the capacity of the machines which helps to harness the capacity of resources efficiently to increase productivity.

Keywords: Scheduling, Assignment, Sequencing, Mean Waiting Time, Mean Flow Time.

1. INTRODUCTION

Scheduling is directly related with the proper utilization of the time with allocation of resources. It deals with the way of how to use the equipment capacity, facilities and employees in an organization to bring the optimum throughput. Scheduling helps us to select which part of a product or which productswill be produced in which machine in a manufacturing company. Scheduling normally determines which part of a machine will operate initially, which operator will operate a machine to produce a part, and the order in which the parts are going to be processed. There may be a great number of different orders in a shop at a time. So it becomes important to scheduling the limited resources and monitoring the progress of the system.

Several methods, formulas, models have been developed to mitigate the difficulties related to scheduling. Akpan [1] introduced the network scheduling technique to solve job shop scheduling problem. This technique is developed through the resource allocation procedure considering the limited resources. Caffrey and Hitchings [2] proposed three priority rules to minimize the makespan. In this research authors evaluated the priority rules for scheduling five jobs through a flow shop with five machines.A heuristic model known as the Simulated Annealing algorithm was developed by Parthasarathy and Rajendran [3] which includes two perturbation schemes, *Random Insertion Perturbation Scheme* and *Curtailed Random Insertion Perturbation Scheme.* This Simulated Annealing algorithm minimizes the tardiness and weighted mean tardiness of jobs in flow-shop and flow line based manufacturing cell. An improvement of the heuristic approach was introduced by Agarwalet el. [4] based on the adaptive learning which provides good starting solution in the search space. Chan et el. [5] solved a flexible job-shop-scheduling problem through optimization of the system objectives to assign the operations in the machines and determine the processing order of the jobs in the machines. Another approach of optimization of job sequence in two machine flow shop problem with uncertain processing time was implanted by Petrovic and Song [6]. The uncertain processing times of the jobs in the machines are represented with triangular fuzzy sets. This method uses an optimization algorithm based on the Johnson's algorithm for deterministic processing time. Chan et el. [7] also used a generic algorithmto develop an assignment and scheduling model to study the impact of machining flexibility of production concerns such as job lateness and machine utilization and suggested an overall production performance if the equilibrium condition can be quantified between scheduling performance and capital investment.Konstantinet el. [8] proposed a dynamic generalization of the assignment problem where each task consists of a number of units to

be performed by an agent or a limited number of agents at a time. Torres and Centeno [9] solved a permutation flow shop problem by allocating secondary resources to the various machines with the objective of minimizing the number of tardy jobs.

Flexible flow shop assigning technique offers Scheduling different jobs on a machine or different machines. One of the machines could be the slowest among all which might slow down the entire process. So, for efficient scheduling, this has to be taken into special consideration. We have developed a method to assign some jobs into several machines where one of the machines is the slowest one. After completing the assignment of the jobs in different machines, we established the order of the jobs at each machine. Here, the jobs are assigned considering the efficiency of the machines and the capacity of the machines. Most importantly, more jobs are allowed to load in a machine.

2.1. SCHEDULING

Scheduling helps to determine the destination of the jobs for processing into specific machines and the order of the products or parts of the product to be manufactured or processed which are also known as the loading or assignment and sequencing respectively. Scheduling is the advance stage to put something into production. It is normally applied before the transformation process or activation of a system which provides us output. Depending on the function and volume of the product to be produced, there are three types of scheduling. We generally do scheduling for high volume, intermediate volume and low-volume or job shop system.

2.2. ASSIGNMENT/LOADING

Assignment or loading is a process for assigning some jobs into specific machines. Especially, this methodology is used to assign jobs at optimum place or machine using the inadequate resources. Loading involves assigning specific job to specific machine or work team. The general assignment model for n workers and m machines in mathematical derivation:

$$Minimize\ Z = \sum_{i=1}^{n}\sum_{j=1}^{m} C_{ij} X_{ij}$$

$$Subject\ to \sum_{i=1}^{n} X_{ij} = 1 \text{ for i} = 1, 2 \ldots \ldots \ldots \text{ n}$$

$$\sum_{j=1}^{m} X_{ij} = 1 \text{ for j} = 1, 2 \ldots \ldots \ldots \text{ m}$$

Where X_{ij} = 1 or 0 for all i and j.

C_{ij} = the time of assigning job i to machine j.

X_{ij} = 0, if job i is not assigned to machine j

X_{ij} = 1, if job i is assigned to machine j

According to classical assignment method, it does not allow allocating more jobs to one machine. In our proposed model, there is solution for this problem where more jobs can be assigned to a single machine optimizing resources.

2.3. SEQUENCING

Loading only assigns the jobs to specific machines, but does not establish an order or sequence to follow. Through the sequencing, we can establish an order for processing the jobs in the specific machines. Sequencing process prioritizes jobs. If no particular order is established jobs are processed according to arrival following the FCFS rule. Through proper sequencing, we can reduce the waiting and idle time cost. There are various types of sequencing depending on various factors such as First Come First Serve (FCFS), Shortest Processing Time (SPT), Earliest Due date (EDD), Critical Ratio (CR), Slack per Operation (S/O) etc.

2.4. MAKESPAN AND MEAN FLOW TIME

The total time needed to complete a group of jobs is known as makespan. Makespan includes the total length of time between the start of first job and the end of the last job in the group. Mean flow time is the average amount of time needed to complete each job in a group. It is the average of the total processing time of all jobs in a group. The makespan and the mean flow time are the two parameters that determine the efficiency of a production sequence. The flow time of a job means the amount of time a job spends in the system. Mean flow time is the arithmetic average of the total flow time for all jobs. The *Shortest Processing Time* (SPT) minimizes the mean flow time in the scheduling rule.

3.1. METHOD FORMULATION

To describe the model, some notations are necessary to be mentioned:
PT_{ij} = Processing time of job i on machine j
N = Number of jobs to be completed
M = Number of machines
W = Mean waiting time
W_i= Waiting time for job i
F = Mean flow time
F_i = Flow time for job i
CP_j= Capacity time for machine j
SMI = Slowest Machine Index
The total processing time for job I on machine j must be smaller than the capacity time of machine j which can be showed as:

$$\sum PT_{ij} \leq CP_j \qquad \text{For i = 1, 2 … … n; J = 1, 2 … … m}$$

3.2. SLOWEST MACHINE INDEX (SMI):

To find out the slowest machine index (SMI), it is assumed that one machine is slowest for all the jobs among the machines in the shop. The ratio of the time needed to complete a particular job in a machine with respect to the time needed to complete the job in the slowest machine is known as the slowest machine index (SMI). The slowest machine index is founded for every job in each machine. The equation for SMI can be derived as:

$$\text{SMI of } M_{ij} = \frac{\textit{Processing time of } M_{ij}}{\textit{Processing time of SM}}$$

The average of the slowest machine index (SMI) for a particular job is called the *Average Slowest Machine Index* (ASMI).

3.3. MODEL

To implement the scheduling model, a real case study has been taken from a job shop. We have to allocate 19 jobs or tasks on three machines. Any task can be assigned to any machine. We provide a random serial number for all jobs. The jobs have different completion times in different machines. There is a special consideration that is held in the scheduling method which is one of the machine is the slowest in processing for all the tasks or jobs. The respective processing time for each job are given in Table 1.

From table 1, it is observed that machine 3 is the slowest and the maximum capacity for each machine per week is 25 hours. There are five working days and five working hours per day. There are two targets in the scheduling. At first, we have to assign the jobs in the machines and after that sequencing the jobs for processing at that specific machine. The assignment in each machine must be such that it does not cross the maximum capacity.

Table 1: Processing time for each job in different machines.

Job Number	Processing time (hrs.) for Machine 1	Processing time (hrs.) for Machine 2	Processing time (hrs.) for Machine 3	Average Percentage of time of machine 1 and machine 2 (%)
1	5	5.2	5.8	87.93
2	3.1	3	3.2	95.31
3	3.9	4	5	79.00
4	4.8	4.5	4.9	94.89
5	4.3	4.2	5	85.00
6	4.1	4	4.2	96.42
7	4	4.5	4.9	86.73
8	4	4.3	4.5	92.22
9	4	3.9	4.1	96.34
10	1.9	1.9	2.1	90.47
11	1.9	2	2.1	92.85
12	2	2.1	2.8	73.21
13	3	3.1	3.2	95.31
14	3.1	3	3.2	95.31
15	3.8	4	4.8	81.25
16	3.2	3.1	3.3	95.45
17	3.3	3	3.5	90.00
18	3.7	3.5	3.9	92.30
19	3.5	3.1	3.7	89.18
Total time	66.6	66.4	74.2	-
Capacity of the machine	25 hrs.	25 hrs.	25 hrs.	-

3.4. DATA ANALYSIS

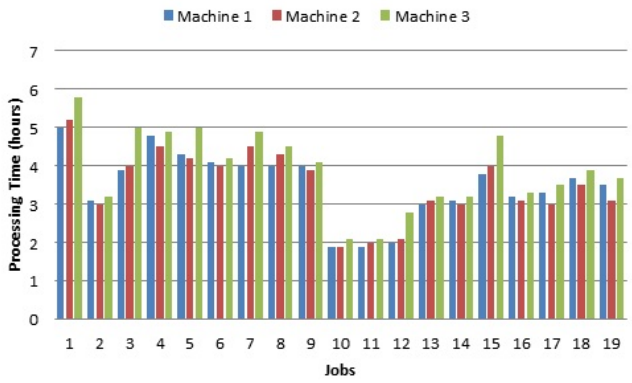

Fig.1: Different processing time in 3 machines for 19 jobs

The third machine is the slowest machine among the others and for processing all the jobs, it will take the highest time which is 74.2 hours. However, the maximum capacity of all machines including machine 3 is 25 hours. That is why it is not possible to process all the jobs even in a single fastest machine due to capacity constraint. The proposed assignment method is designed providing special attention to machine 3 to evaluate its effect on scheduling.

3.5. ASSIGNMENT PROCEDURE

The following procedures for assigning jobs to different machines can be used:

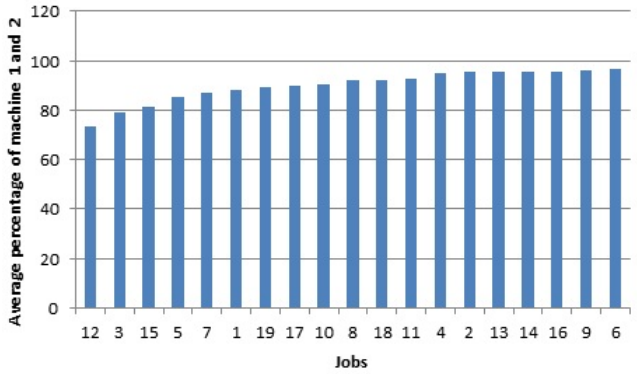

Fig.2: Arranging the ASMI of machine 1 and 2 from smallest to largest.

Step 1: Determine the percentage of time required to complete a job with respect to machine 3 which is described as *Slowest Machine Index* (SMI). The completion time of Machine 3 for each job is marked as 100% as it requires the highest time for processing any job. The SMI for the two machines will be less than 100%.
Step 2: After getting the SMI completing a specific job for the other two machines, we take the average of the SMI for each specific task for machine 1and machine 2 which is mentioned as the *Average Slowest Machine Index* (ASMI) (Table 1).
Step 3: Now, arrange the ASMI according to increasing order and find out the lowest percentage.
Step 4: The task which possesses the lowest ASMI has two completion times for machine 1 and machine 2. The machine which requires less time to process the job or task is selected for that job. The lowest ASMI is 73.214% for job 12. So, we should choose job 12 for first assignment. Machine 1 requires 2 hours and machine 2 requires 2.1 hours to process the job. We assign the job in machine 1 as it requires less time.
Step 5: Following step 4, we will assign the jobs in machine 1 and machine 2 considering the capacity of the machines. After filling the capacities of the two machines, there might be some jobs left for processing which will be assigned to machine 3. The sequence of processing in machine 3 will be got from the increasing order of the *Average Slowest Machine Index* (ASMI) of machine 1 and machine 2.

3.5.1. Assigning parts considering minimum time depending on *Average Slowest Machine Index* (ASMI):

For Machine 1:

Table 2: Calculation of mean flow time (F) and the avg. waiting time (W) for machine 1

Job	Time (M1)	Machine 1		Waiting time (hrs.)
		Ti	To	
12	2	0	2	0
3	3.9	2	5.9	2
15	3.8	5.9	9.7	5.9
7	4	9.7	13.7	9.7
1	5	13.7	18.7	13.7
8	4	18.7	22.7	18.7
11	1.9	22.7	24.6	22.7
Total	24.6		97.3	72.7
Average waiting time (w)			10.385 hrs.	

Mean flow time (F)	13.90 hrs.

For Machine 2:

Table 3: Calculation of mean flow time (F) and the avg. waiting time (W) for machine 2

Job	Time (M2)	Machine 2		Waiting time (hrs.)
		Ti	To	
5	4.2	0	4.2	0
19	3.1	4.2	7.3	4.2
17	3	7.3	10.3	7.3
10	1.9	10.3	12.2	10.3
18	3.5	12.2	15.7	12.2
4	4.5	15.7	20.2	15.7
2	3	20.2	23.2	20.2
Total	23.2		93.1	69.9
Average waiting time (w)			9.985 hrs.	
Mean flow time (F)			13.30 hrs.	

For Machine 3:

Table 4: Calculation of mean flow time (F) and the avg. waiting time (W) for machine 3

Job	Time (M3)	Machine 3		Waiting time (hrs.)
		Ti	To	
13	3.2	0	3.2	0
14	3.2	3.2	6.4	3.2
16	3.3	6.4	9.7	6.4
9	4.1	9.7	13.8	9.7
6	4.2	13.8	18	13.8
Total	18		51.1	37.7
Average waiting time (w)			7.54 hrs.	
Mean flow time (F)			10.22 hrs.	

The jobs are at first loading in the machines according to the *Average Slowest Machine Index* (ASMI). Then, following the order of ASMI, sequencing order for each machine is achieved. The total jobs or tasks assigned to each machine are within the capacity of each machine. However, we can still apply various established methods to find out good sequencing which will provide less waiting time and mean flow time.

3.6. SHORTEST PROCESSING TIME (SPT):

Shortest processing time (SPT) is the most prominent scheduling rule which helps to minimize the average waiting time (W) and the mean flow time (F). Now, the jobs are sequenced according to the shortest processing time (SPT). Here, the assignment of jobs in a machine through the ASMI method keeps constant. Through the shortest processing time analysis, we have calculated the total completion time to perform the jobs as wells the mean flow time (F) and the average waiting time (W). The results are enlisted in the table [5-7] respectively for machine 1, machine 2 and machine 3.

For Machine 1:

Table 5: Calculation of mean flow time (F) and the avg. waiting time (W) for machine 1

Job	Time (M1)	Machine 1		Waiting time (hrs.)
		Ti	To	
11	1.9	0	1.9	0
12	2	1.9	3.9	1.9
15	3.8	3.9	7.7	3.9
3	3.9	7.7	11.6	7.7
7	4	11.6	15.6	11.6
8	4	15.6	19.6	15.6
1	5	19.6	24.6	19.6

Total	24.6		84.9	60.3
Average waiting time (w)			8.614 hrs.	
Mean flow time (F)			12.13 hrs.	

For Machine 2:

Table 6: Calculation of mean flow time (F) and the avg. waiting time (W) for machine 2

Job	Time (M2)	Machine 2		Waiting time (hrs.)
		Ti	To	
10	1.9	0	1.9	0
2	3	1.9	4.9	1.9
17	3	4.9	7.9	4.9
19	3.1	7.9	11	7.9
18	3.5	11	14.5	11
5	4.2	14.5	18.7	14.5
4	4.5	18.7	23.2	18.7
Total	23.2		82.1	58.9
Average waiting time (w)			8.414 hrs.	
Mean flow time (F)			11.728 hrs.	

For Machine 3:

Table 7: Calculation of mean flow time (F) and the avg. waiting time (W) for machine 3

Job	Time (M3)	Machine 3		Waiting time (hrs.)
		Ti	To	
13	3.2	0	3.2	0
14	3.2	3.2	6.4	3.2
16	3.3	6.4	9.7	6.4
9	4.1	9.7	13.8	9.7
6	4.2	13.8	18	13.8
Total	18		51.1	37.7
Average waiting time (w)			7.54 hrs.	
Mean flow time (F)			10.22 hrs.	

4. RESULT

It is observed that all nineteen jobs are distributed optimally in the three machines according to the assignment method. The assignment method has not violated the capacity constraint. Due to choose the minimum time in the assignment, we can expect to have better mean flow time and average waiting time.

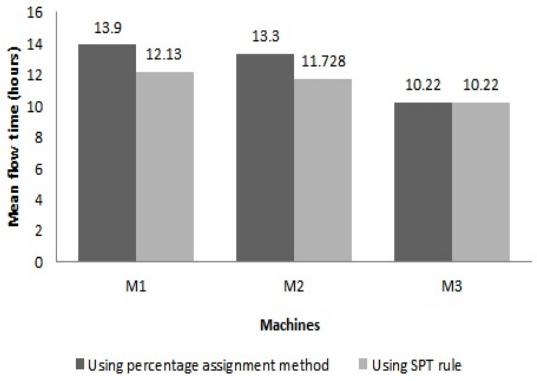

Fig.3: Mean flow time

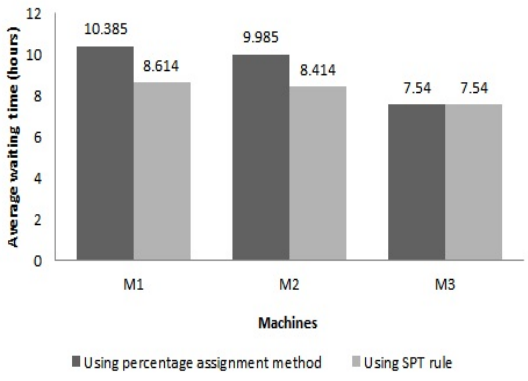

Fig.4: Average waiting time

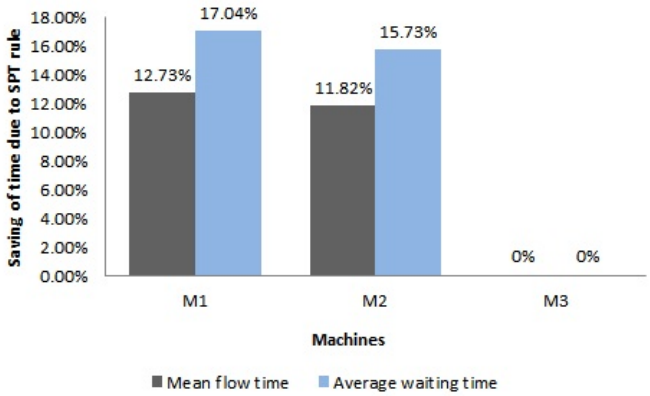

Figure 5: Saving of time in Mean flow time and Average waiting time due to SPT rule

Shortest processing time (SPT) rule helps to find out the optimum order or sequencing. Through following the SPT rule, we have got the minimum mean flow time (F) and average waiting time (W) for all the machines. The mean flow time has decreased (figure 3) from 13.90 hours to 12.13 hours in machine 1, 13.30 hours to 11.728 hours in machine 2 and no change in machine 3. The mean flow time reduced to 12.73%, 11.82% and 0% for machine 1, 2 and 3 respectively (figure 5). The average waiting time has decreased (figure 4) from 10.385 hours to 8.614 hours in machine 1, 9.985 hours to 8.414 hours in machine 2 and no change in machine 3. The average waiting time reduced to 17.04%, 15.73% and 0% for machine 1, 2 and 3 respectively (figure 5).

Table 8: Results for both assignment methods

	Ordering obtained by Assignment method			Sequencing using SPT rules		
Machine	M1	M2	M3	M1	M2	M3
Sequence	12,3,15, 7,1,8,11	5,19,17, 10,18,4,2	13,14,16, 9,6	11,12,15,3, 7,8,1	10,2,17, 19,18,5,4	13,14, 16,9,6
Time Used	24.6	23.2	18	24.6	23.2	18
Efficiency Percentage	98.4	92.8	72	98.4	92.8	72
Total Waiting Time	72.7	69.9	37.7	60.3	58.9	37.7
Avg. Waiting Time (W)	10.385	9.985	7.54	8.614	8.414	7.54
Mean Flow Time (F)	13.90	13.30	10.22	12.13	11.728	10.22
Saving in Average Waiting Time (W)	-	-	-	1.77	1.571	0
Saving in Mean Flow Time (F)	-	-	-	1.77	1.572	0
Percentage of saving in avg. waiting time (W)	-	-	-	17.04%	15.73%	0%
Percentage of Saving in Mean Flow Time (F)	-	-	-	12.73%	11.82%	0%

5. CONCLUSION

A scheduling method or model for a floor shop production is developed in this paper where the slowest machine is taken into special consideration. A special priority rule known as the Shortest Processing Time is applied to check out the difference with previous sequence according to the method we developed. Form the numerical examples it is evident that the SPT rule is better than ASMI rule for sequencing. This method based on *Average Slowest Machine Index (ASMI)* could be applied for properly assigning and sequencing large number of jobs. The set up time of the machines for different products or jobs can be taken into consideration for the development of this method.

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EFFECT OF ALTERNATING SURFACE POTENTIAL ON ION TRANSPORT IN A CIRCULAR CYLINDRICAL MICROCHANNEL

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ABSTRACT: A finite element based electrokinetic transport model has been presented in this paper. Coupled Nernst-Plank and Poisson equations are used to evaluate the charge and potential distributions,while Navier-Stokes equation is employed to determine the flow field. A pressure driven flow of an ionic solution inside a circular cylindrical channel was considered. The effect of charge heterogeneity of the channel wall on the ion rejection was investigated. It was observed that the alternating surface potential causes has significant effect on ionic distributions inside the microchannel. Simulation results were obtained for different inverse Debye length and different charged segment width to channel radius ratio.To verify the numerical study results of the model are then compared with experimental results Such effect of charge heterogeneity has on considerable influence on the nanofiltration membrane, nanofluidics and many other chemical and biological processes

Keywords: Heterogeneous surface charge, ion transport, Nernst-Planck equation, microchannel.

1. INTRODUCTION

Ion transport through nanopores of artificial or biological nature is significantly important in many engineering and biological applications, for example, nano-filtration membrane, nanofluidic diodes, biological transport [1-9]. An understanding of the ion transport mechanism is crucial to gaining fundamental insight into the functioning of biological systems and for improving the design of engineering systems.

The study of salt rejection phenomena in hyperfiltration assumes porous medium as an array of uniformly distributed, straight, infinitely long cylindrical capillaries[14-16]. A single capillary is modeled, solved, and later translated with appropriate physical correlations to apply to porous medium. Fluid and ionic fluxes in a single capillary can be defined by space charge model [17].The model considers transport of ion due to concentration gradient, electric potential and applied pressure and describes fluid flow and potential distribution inside the capillary. The model assumes Poisson-Boltzmann solution for the radial ion distribution inside the capillary. The model considers ion distribution as in a steady equilibrium state without any influence by the fluid flow. This condition does not allow the model to reveal any variation in ionic concentration in the capillary axial direction. This model fails to show any axial ion distribution and results in incorrect salt rejection. Instead, a model consisting of Poisson-Nernst-Planck and Navier-Stokes equations, offers a better proposition for the solution of such system. The model couples the Poisson equation to the Nernst-Planck through ionic concentrations and then solves the potential and concentrations simultaneously. A number of analytical [18] and numerical results were published on Poisson-Nernst-Planck model in different range of applications from membrane filtration [18]

N. Quddus,[12] develped a model based on Poisson-Nernst-Planck and Navier-Stokes equations to analyze salt rejection in a flow of an ionic solution through a wavy capillary and to study the influence of amplitude and frequency of surface waviness on the flow. A capillaryreservoir system is used to eliminate the end effects that occur at capillary entry and exit. The influence of capillary end geometry on salt-rejection was ignored in the past studies. This is mainly due to the assumption of infinite capillary length for solving such problems .

Although many studies have improved our understanding of ion transport in nanopores, many vital issues of ion transport in complex systems still remain unaddressed. Real membranes, chemical or biological in nature, contain pores having different size or charge. Although the effect of physical heterogeneity of capillary wall was addressed in terms of wavy or sinusoidal capillary wall [10-12], charge heterogeneity of pore wall is seldom addressed.

In this paper, the effect of charge heterogeneity of the pore wall on ion transport is investigated. A finite element consisting of coupled Navier-Stokes, continuity, Nernst-Plank and Poisson equations are solve to evaluate fluid flow, potential distributions and ionic fluxes in a circular cylindrical pore. The pore wall is considered having alternate positive and negative charged patches. Different patch width to channel radii ratios are considered to examine the effect of charge heterogeneity on the ionic distributions across the channel. Such effect of wall charge heterogeneity on ion transport can be exploited in many nanofluidic diodes, biological membrane and many other chemical and biological applications.

2. MATHEMATICAL MODEL

The schematic of the reservoir-channel configuration is shown in Fig.1. The flow of an aqueous electrolyte solution in a straight circular cylindrical microchannel of radius *a* and length *L* is considered. External applied pressure drives the ionic solution is from one reservoir to another. Nonhomogeneously charged channel wall is considered. Under an applied pressure, fluid velocity depends on pressure as well as electric potential difference across the channel. Navier-Stokes equations with a body force term that taking account the electrostatic force on the fluid can describe such flow. The electric field (E=−□ψ) inside the channel is coupled to Navier-Stokes equation to give the average fluid.

$$\rho\left(\frac{\partial u}{\partial t}+u.\nabla u\right)=-\nabla p+\mu\nabla^2 u-\rho_f\nabla\psi \quad (1)$$

where is ρ the fluid density, $u=(u.v)$ is the fluid velocity vector with *u* and *v* being the radial and axial velocity components, respectively, μ is the viscosity of the fluid, p is the pressure, ρ_f is the free charge density, and ψ is the electrical potential. The charge density was related to the electrical potential by the Poisson equation,

$$\nabla^2\psi=-\frac{\rho_f}{\varepsilon}. \quad (2)$$

$$\rho_f(=\sum ze\,n_i) \quad (3)$$

where ε is the dielectric permittivity of the liquid, is free charge density, z_i is the valence of the i^{th} ionic species, *e* is the elementary charge, and n_i is the ionic number concentration of the i^{th} species. As this model is dealing with very dilute solutions, permittivity and other fluid properties are considered to be uniform and constant in the domain. Ion transport in the electrolyte solution subjected to induced electrical fields is described by ionic conservation equation,

$$\frac{\partial n_i}{\partial t}=-\nabla J_i \quad (4)$$

where J_i is the ionic flux vector and is given by,

$$J_i=n_i\,u-D\nabla n_i-\frac{ze n_i D}{k_B T}\nabla\psi \quad (5)$$

where D is the diffusivity, *T* is the temperature and k_B is the Boltzmann constant. All governing equations are nondimensionalized. The characteristic length is chosen to be the Debye length, . The definition of the Debye length for a symmetric *(v:v)* binary electrolyte is $\kappa=\sqrt{2z^2e^2n_\infty/\varepsilon T k_B}$. All symbols with a superscript (*) represent non-dimensional parameters which are listed below,

$$\mu^*=\frac{D}{\varepsilon}\left(\frac{ze}{k_B T}\right)^2\mu;\ \rho^*=\frac{\rho}{\varepsilon}\left(\frac{ze}{k_B T}\right)^2 D^2;$$
$$p^*=\frac{\rho}{k^2\varepsilon}\left(\frac{ze}{k_B T}\right)^2;\ u^*=\frac{u}{kD};\ n_i^*=\frac{n_i}{n_\infty}$$
$$\psi^*=\frac{ze}{k_B T}\psi;\ \nabla^*=k\nabla;\ \tau=k^2 Dt$$

By substituting above non-dimensional parameters, Non-dimensional forms of Navier-Stokes and Poisson equations can be written as,

$$\rho^*\frac{\partial u^*}{\partial\tau}=-\nabla^* p^*+\mu^*\nabla^{*2}u^*-.5(n_p{}^*-n_n{}^*)\nabla^*\psi \quad (6)$$
$$\nabla^{*2}\psi=-0.5(n_p{}^*-n_n{}^*) \quad (7)$$
$$\frac{\partial n_{i^*}}{\partial\tau}=-\nabla^*(n_i{}^*u^*-\nabla^* n_i{}^*-n_i{}^*\nabla^*\psi) \quad (8)$$

(ii) Boundary conditions

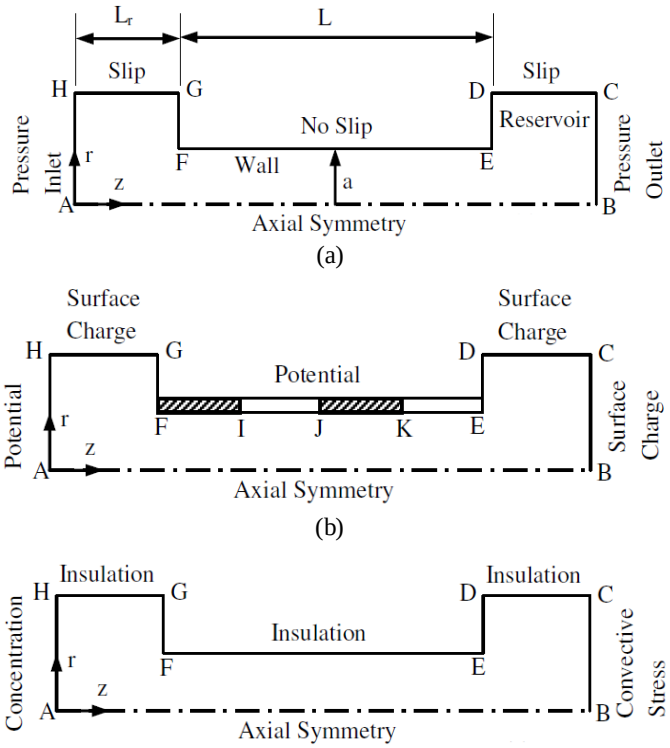

Fig.1: Boundary conditions for (a) Navier-Stokes,(b) Poisson, and (c) Nernst-Plank equations

It is assumed that for both positive and negative ion diffusivities are to be equal. A non homogeneous surface potential boundary condition is assumed for the channel wall (EF). No-slip condition for fluid velocity on the channel wall is assigned. Insulation or symmetry condition is also assigned at channel wall.

Channel Wall:

$$u^* = 0;\ \psi = 1.-1;$$
$$n.\left[n_i\, u - D\nabla n_i - \frac{z_i e n_i D_i}{k_B T}\nabla\psi\right] = 0 \qquad (9)$$

At the reservoir entry plane (AH), a constant pressure,potential and concentration is assigned.

Channel Entry:

$$P^* - \rho_1\psi - 0;\ n_i^* - 1 \qquad (10)$$

At reservoir exit (BC) convective flux condition is assigned.

Channel exit:

$$P^* = 0;\frac{\partial\psi}{\partial x} = 0;$$
$$n.\left(D\nabla n_i - \frac{z_i e n_i D_i}{k_B T}\nabla\psi\right) = 0 \qquad (11)$$

For reservoir walls (FG and DE) that are adjacent to the channel, zero charge (potential gradient zero), insulation and no slip boundary conditions were chosen. For other walls (CD and GH), zero charge density, insulation and slip-symmetry conditions were assigned. Symmetry boundary conditions are assigned at the axis of symmetry (AB) for potentials and velocity and concentration.

3. GRID SENSITIVITY TEST

A commercial finite element package COMSOL Multiphysics 3.4 was used to obtain the solution. Triangular quadratic Lagrange elements were employed to discretize the computational domain. Fine

meshes were used on the channel wall and symmetry axis to capture the sharp change of potential in EDL. Relatively coarse meshes were used in reservoir region. Mesh sensitivity analysis was carried out and approximately 30,000-35,000 elements were decided upon to obtain the result. Conformance of numerical solution with analytical solution is shown in Fig.2.examples of the diagrams are given below.

4. RESULTS

The coupled Poisson-Nernst-Planck and Navier-Stokes (PNP-NS) model considers ionic transport due to concentration gradient, electric potential and applied pressure and describes fluid flow and potential distribution inside the channel.

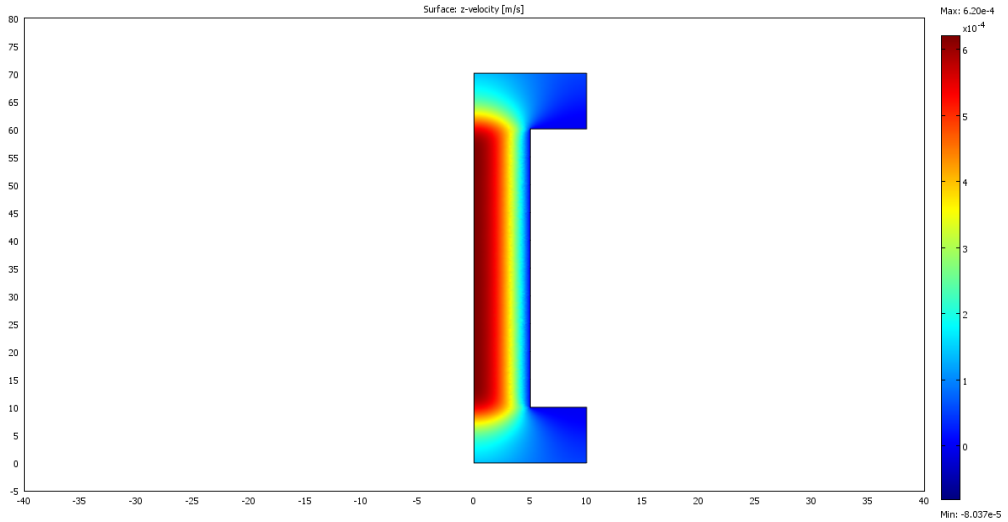

Fig. 2: Simulation of velocity field

The model is validated against known analytical solution for flow in cylindrical channel with uniform wall charge. The analytical results are limited to symmetric electrolyte in a straight long channel with low surface potential on the channel wall for steady state condition. Variations of the potential and ionic distributions in the axial direction are neglected. Solution of the linearized Poisson-Boltzmann equation and Stokes flow with electrical body force in the axial direction with a constant pressure give velocity distribution inside the channel is given as [13],.

$$v(r) = \frac{a^2 p_z}{4\mu}\left[1-\left(\frac{r}{a}\right)^2\right] - \frac{\varepsilon\psi_p}{\mu}\left[1-\frac{I_0(\kappa r)}{I_0(\kappa a)}\right]E_z \qquad (12)$$

where a is the channel radius, p_z is the pressure gradient, E_z is the electric field in the z-direction, and I_0 refers to the modified Bessel function of zeroth order of the first kind.The numerical solution of the axial velocity profiles at the mid-section of the channel were obtained and compared with that of analytical results, as shown in Fig. 3.Numerical simulations were conducted for three different scaled channel radii, $\kappa a = 1,5,10$. To obtain the analytical solution low potentials $\psi^* = 1$. It is evident from Fig. 3 that obtained numerical results for the velocity profiles are in good agreement with the corresponding analytical profiles.

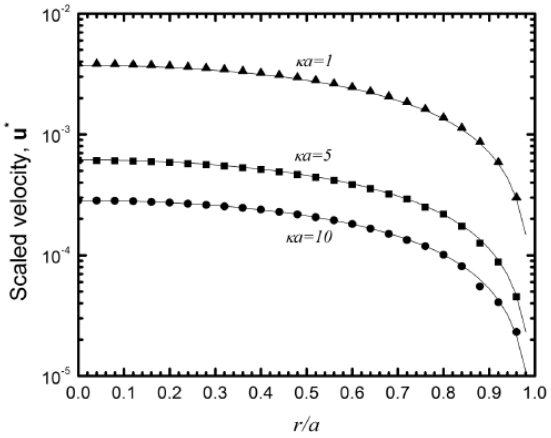

Fig. 3: Comparison of the velocity profiles at the midsection of the channel. Solid lines represent the analytical solution obtained from eq.(12) while the symbols indicate the corresponding numerical results

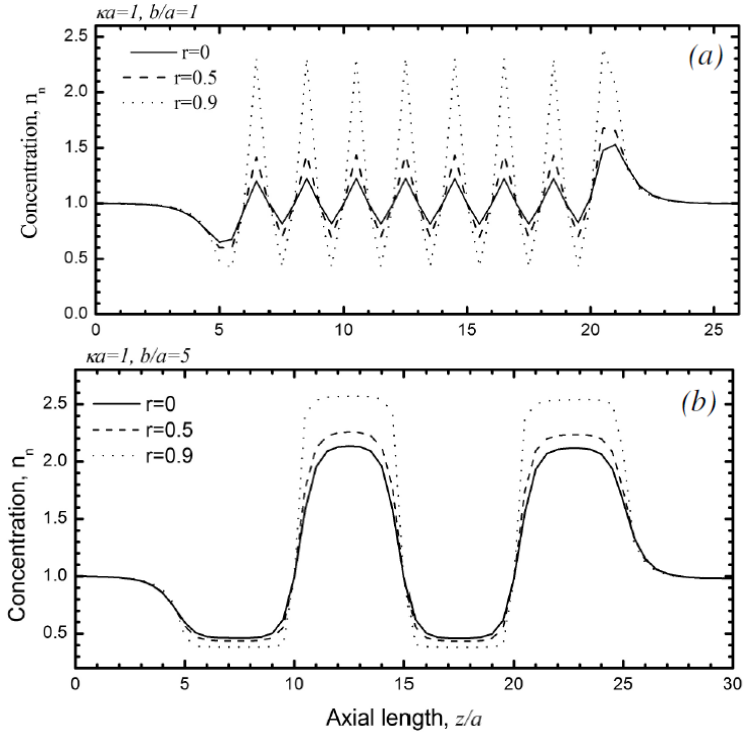

Fig. 4: Concentration distribution for negatively charged ion (n_n) along the channel length (z/a) at different radial distances ($r=0, 0.5, 0.9$). Results are shown for ratio of charged segment width to channel radius, $b/a=1$ and $b/a=5$, and for $\kappa a=1$.

The effect of charge heterogeneity of channel wall on the ion transport in the channel and ion rejection across the channel was investigated. An axi-symmetric section of a long circular cylindrical channel with two reservoirs at both ends is considered, as shown in Fig. 1. The ionic solution is flowing under applied pressure. The pore wall is assumed to be alternately charged. The pore length is subdivided into even segments and adjacent segments are assigned opposite charge. The scaled potential of $\psi^*=1$and $\psi^*=-1$are considered for channel wall segments for all analysis. Consideration of non-equilibrium condition of ion transport allows ionic flux to be dictated by convection, diffusion and induced electric potential. In Fig.4, concentration distributions of negatively charged ions along axial distance (z/a) are shown for different radial distances for $\kappa a=1$. In Fig. 4(a), the width of each

charged segment to channel radius ratio is considered to be 1(=*b*/*a*). Ionic concentration near the wall (*r=0.9*) was observed to be significantly larger than that near the center of the channel (*r=0.0*). However, the nature of the variation of the concentration along the axial direction at different radial distance remains identical. For *b*/*a=5*, as shown in Fig. 4(b), the difference in concentrations at different radial distances are not significant as that for *b*/*a=1*. The accumulation of counter ions near positively charged segment of the wall (say from length 10 to 15 in Fig. 4(b)) is quite high. This causes a polarization of concentration across the channel.

Fig. 5 shows similar variation of concentration along the axial distance of the channel at different radial distances. Results are obtained for κ*a=5* and *b*/*a=1* and *b*/*a=5*. The nature of variation of concentration for two *b*/*a* ratio is similar. At *r=0* the concentration becomes very small while near the charged wall high counter-ion accumulation was observed. However, unlike κ*a =1*, for κ*a =5* at *r=0* low n_m concentration implies the ion rejection across the channel would not be significant.

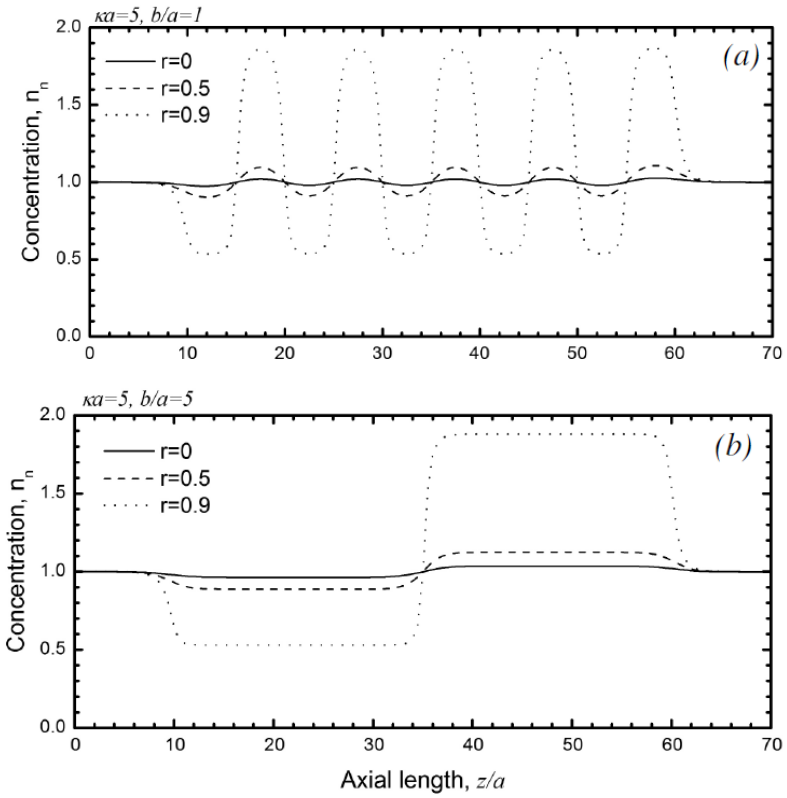

Fig. 5: Concentration distribution for negatively charged ion (n_m) along the channel length (*z*/*a*) at different radial distances (*r=0, 0.5, 0.9*). Results are shown for ratio of charged segment width to channel radius, *b*/*a=1* and *b*/*a=5*, and for k*a=5*.

5. CONCLUSION

An electrokinetic ion transport model is used to analyze the effect of charge heterogeneity of the nanopores on the ion distribution inside the pore and ion rejection across the pore. Such results are useful in design of device or tools having artificial charge heterogeneous pore like nanofluidic diode, nanofiltration membrane, or understanding natural processes such as glomerular filtration membrane, transportthrough lipid bilayers.

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IMPROVEMENT OF INDUSTRIAL LAYOUT PLAN CONSIDERING THE MATERIAL HANDLING COST

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ABSTRACT: The material handling industry manufactures and distributes the equipment and services required to implement material handling systems. The material handling system (MHS) is a fundamental part of a Flexible manufacturing system since it interconnects the different processes supplying and taking out raw material, work pieces, sub products, parts and final products. Due to the automated nature of the whole production process, the MHS must respond in concert with timeliness for all requirements of the processes and systems. There are many modeling techniques are available nowadays to optimize the material handling such as Graph Theory, Bloc Plan, CRAFT, Optimum Sequence and Genetic Algorithm. But we have developed a completely new modeling technique to optimize the material handling time in the industry. In this paper we have shown the applications and features of the new modeling technique. We have also compared this new model with the conventional models.

Keywords: Material handling, Genetic Algorithm, layout, Cost optimization.

1. INTRODUCTION

Rapid increasing of demand in production, industrial factories need to increase their potentials in production and effectiveness to compete against their market rivals. At the same time, the production process needs to be equipped with the ability to have lower cost with higher effectiveness. Therefore, the way to solve the problem about the production is very important. There are many ways i.e. quality control (QC), total quality management (TQM), standard time, plant layout to solve the problems concerning productivity. Plant layout problem (FLP) concerns the optimal placement of a set of departments with known dimensions within the facility area, in order to minimize the operating cost and maximize the system efficiency. Layout involves the minimization of the material handling cost and ensures a smooth flow of work, material, and information through a system. The layout and design of that space impact greatly how the work is done—the flow of work, materials, and information through the system. The key to good facility layout and design is the integration of the needs of people (personnel and customers), materials (raw, finishes, and in process), and machinery in such a way that they create a single, well-functioning system. As part of a productivity improvement program in a manufacturing company we conducted a project to optimize the layout design of the production line at the shop floor of this company aiming at overcoming the current problems attributed to the inefficient layout. It was decided to apply a number of layout modeling techniques to generate a near optimal layout based on formal methods that are rarely used in practice. The modeling techniques used are Graph Theory, Bloc Plan, CRAFT, Optimum Sequence and Genetic Algorithm. These layouts were then evaluated and compared using three criteria namely Total Area, Flow * Distance and the Adjacency Percentage. Total Area refers to the area occupied by the production line for each model developed. Flow * Distance calculates the sum of products of the flow and the distance between every two facilities. Material handling equipment is, like the name implies, the equipment needed to handle the material at issue. Tompkins et al. classifies the material handling equipment into four different categories:

i. Containers and unitizing equipment.
ii. Material transport equipment.
iii. Storage and retrieval equipment.
iv. Automatic data collection and communication equipment

The material handling equation system equation (figure 1) is a tool that can assist the work of developing alternative material handling system design. Material handling system equation: Materials + Moves + Methods = Recommended system.

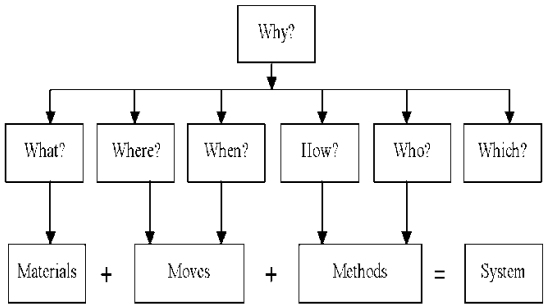

Fig.1: System equation for material handling.

The first generic Systematic Layout Planning approach, developed by Muther [3], is still a useful scheme specially if supported by other approaches and assisted by computer. Construction approaches, Hassan and Hogg (1991) for example, build a layout from scratch while Improvement Methods. Bozer, Meller and Erlebacher (1994) for example, attempt to modify an existing layout for better results. Recent developments are mostly based on iterative meta-heuristic approaches such as Simulation Annealing (Chwif, Marcos,& Lucas, 1998; Sahin & Turkbey, 2009), Tabu Searching (Mckendall& Hakobyan, 2010), Ant System (Komarudin & W ong, 2009, 2010;Konak-Kulturel & Konak, 2010) and Genetic Algorithms (GAs)(Islier, 1998; Al Hakim, 2000; Aiello, Enea, & Galante, 2006; Diego, Santamarina, Alcaide, & Cloquell, 2009). The various modelling techniques used in this work are Graph Theory, CRAFT, Optimum Sequence, BLOCPLAN and Genetic Algorithm [4].

2. PROPOSED MODEL

Material handling cost of all of the possible models formed by interchanging machines or displacing machines in different possible spaces. Existing models try to minimize/optimize cost as possible but never guarantee about cent percent optimize or minimize the cost. This proposed developed model minimizes material handling cost cent percent from which it is not possible to minimize.

3. STEPS IN MODELING

Following steps are necessary for modeling:
1. Takes any arbitrary or existing layout
2. Prepares all of the possible layouts
3. Determines the cost for each layout
4. Takes the first cost and compares with cost of other layouts to determine if there is any layout that requires less cost
5. If a layout is found that promises less cost than the former taken for comparison, taken and is compared with the rests layouts to determine if there is any layout that requires less cost
6. Steps 4 and 5 are repeated again and again until reaching the last layout prepared and
7. The last layout that found after comparing are the result of this model
8. When there are many machines and/or spaces in which machines can be placed the above calculation is hard and time consuming. It may take more than 0.365 million of calculations for only having 6 spaces and4 machines. So it will need million billion calculations when spaces and machines will be increased. So making mistake is very possible and may take several months even several years when doing calculation manually. So it is necessary to do something that will do this calculation with tolerable time. To do this an algorithm has been developed that can do this work with tolerable time with the help of computer.

Developed algorithm:
A. Prepare all of the layout as possible and guess the first as A and the second as B
B. Determine the cost of all layouts found in the first step
C. Compare cost of A with the cost of B
D. If the cost of B is not less than the cost of A and there if there is more layer after B, put cost of B as cost of A and cost of next of B as cost of B and go to steps iii. But if there is no more layer after B, Take layout A as final cost minimized layout

E. Check if the cost of B is less than the cost of A and there is there is more layer after B, put cost of B as cost of A and cost of next of B as cost of B and go to steps iii. But if there is no more layer after B, Take layout B as final cost minimized layout

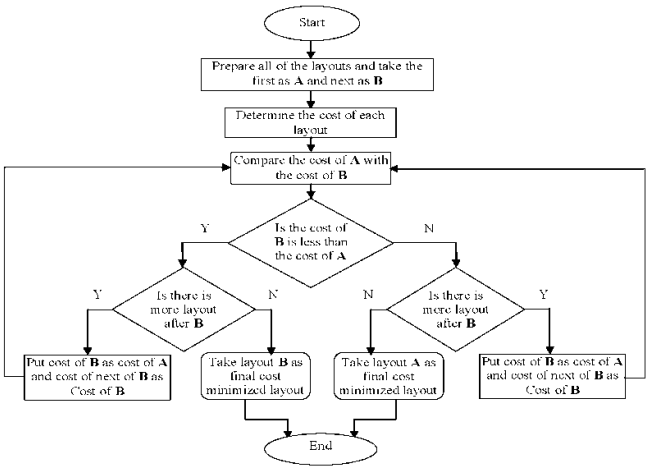

Fig.2: Algorithm for layout design model

Necessary Inputs for this program

a. Number of spaces: Number of spaces indicates the number of possible places in which machines can be placed.

b. Number of machines and their positions: In this case total number of machines is to be given. After that it is necessary to initialize the position of each machine.

c. Stability of machine: In some case it may be necessary to make one or more machines to be stable in a fixed position. So it is necessary to tell the computer that machines should be stable in the specific place/position.

d. Material flow: It is necessary to mentioned how much material will be flowed from which machine to which machine.

e. Distance between locations: To calculate cost of material handling between two machines (i.e. locations) distance between two locations is needed to know. So distances between all of two locations are record in this input.

f. Costs: Cost includes both of the fixed and variable cost for material handling.

g. Type of combinations:

a. All layouts: If it is necessary to see all of the layouts; it doesn't depend on the cost.

b. Only the desired layout: This gives the target layout with minimum cost of material handling.

4. APPLICATION OF NEW MODEL

The following figure presents the original layout of Bangladesh Cable Shilpa Ltd., Khulna. Here the specific numbers (1, 2, 3, 4, 5, and 6) address the space locations. And the arrows show the flow direction of material handling between machines.

Figure 3: Material flow diagram of output layout before and after applying the developed algorithm

Necessary Input for BCSL in this program

A. Number of spaces

The number of spaces in BCSL indicates is 6.

B. Number of machines and their positions

In BCSL total number of machines also 6 equal to space number.

C. Stability of machine

There is no stability of machines in this case.

D. Material flow

In machine shop there materials flow from one machine to another is shown in the following table

E. Distance between locations

To calculate cost of material handling between two machines (i.e. locations) distance between two locations is needed to know. So distances between all of two locations are recorded in this input shown in the following table.

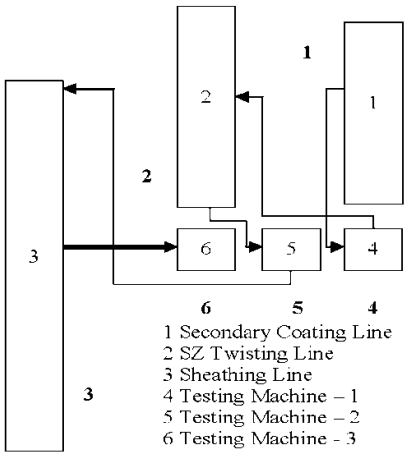

Fig.3: Layout of BCSL

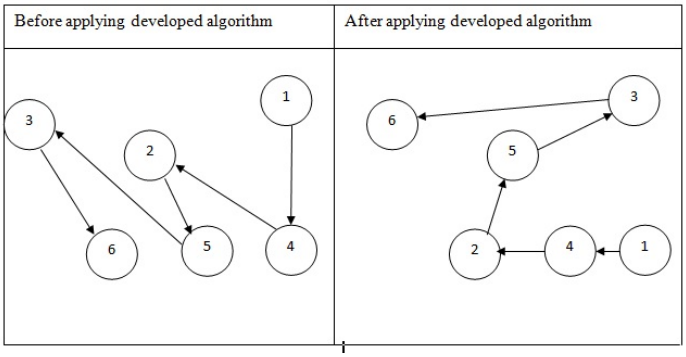

Table 1. Respective location of machine for initial layout

Position of machine	1	2	3	4	5	6
Machine number	1	2	3	4	5	6

Table 2. distances between locations in metre (Li, Lj)

Li\Lj	1	2	3	4	5	6
1		2	8	62	63	64
2			6	6	5	4
3				36	35	34
4					2	6
5						1
6						

F. Costs

BCSL follows fixed cost system.

G. Cost of per unit material handling per unit of distance = 0.0206 BDT/kg. Of material/metre.

H. Type of combinations

i. Only the desired layout is necessary.

ii. To get desired layout, only it is necessary when computer asks to press N for desired layout.

After giving all the data following output, as screenshot, is found.

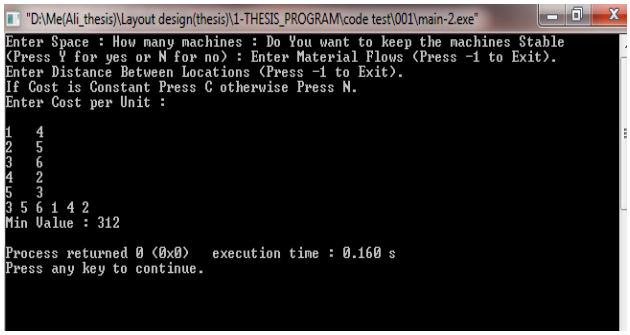

Fig.4. Screenshot of proposed output modeled by the computer program for cost minimized layout.

Table 3. The new rearranged layout according to the developed algorithm is shown below:

Position of machine	1	2	3	4	5	6
Machine number	3	5	6	1	4	2

5. COST CALCULATION

Cost of material handling for layout,

$$C = \sum_{i=0}^{M} \sum_{j=1}^{M} Gij * Lij * Cij \qquad (1)$$

Here, M= Total number of machines.
i, j= Machine number.
Gij=Amount of material flow from i^{th} machine to j^{th} machine.
Lij=Distance between the locations where i^{th} machine to j^{th} machine are located.

So, cost of mateial handling for initial layout,
$C_{initial}$ = (72*62 + 12*5 + 3*34 + 72*6 + 12*35) * 0.0206 TK.
= 112.847 TK.
and
cost of mateial handling for developed layout,
$C_{developed}$ = (72*62 + 12*4 + 3*35 + 72*6 + 12*34)*0.0206TK
= 112.414 TK
Above calculation is done for one cycle of production.
So the difference between initial and developed layout is,
= 112.847 TK. - 112.414 TK = 0 .433 TK
Percent of cost decrease is = 0.433/112.847 * 100%
= 0.383 %
So it can easily be said that the initial layout can be changed a little as found from the application of developed model.

6. RESULT AND DISCUSSION

Genetic Algorithm is widely used for modeling of layout problems; the new developed result shown in comparison with Genetic algorithms (GAs) [v]. The convergence of the GAs algorithm largely depends upon the genetic parameters, and it is significantly influenced by the number of individuals in the population and by the probability of mutation. the new developed algorithm and its application have been compared with those obtained in a work using the (GAs) for the better judgment. Since their inception, they have been applied numerous optimization problems with highly acceptable results. GAs is new approach to solving complex problems such as determination facility layout. The GAs contain the elements of the methods of blind searching for the solution and of directed and stochastic searching and thus give compromise between the utilization and searching for solution. At the ginning, the search in the entire search space and afterwards, by means of crossover, they arch

only in the surrounding of the promising solutions. So GAs employed random, yet reacted search for locating the globally optimal solution [vi]. The starting point in GA presented in this work was an initial population of solutions which as randomly generated.
Responsible for introducing solutions by selecting two random and exchanging parts a parent selection procedure work operates as follows:

1. Generate initial population consisting of members using random number of Generator.
2. Place all population members in main database.
3. Calculate the fitness C (Eq. (1)) of all population members.
4. Chose the population member whose fitness has minimum value compared with fitness of the other population members as the first parent.
5. Place chosen population member in separate database.
6. Repeat procedure (1-5) once more to produce second parent chromosome.

Table 4. First population consisting of 5 members

Serial/Location	1	2	3	4	5	6
1	1	2	6	4	3	5
2	6	1	2	3	4	5
3	2	3	1	6	4	5
4	6	5	1	2	3	4
5	4	5	1	2	3	6

Cost calculation for first population,
For member 1 cost is = (72*63 + 12*4 + 3*35 + 72*6 +12*1)*.0206 TK = 104.257 TK
For member 2 cost is = (72*5 + 12*64 + 3*62 + 72*35 +12*6)*.0206 TK = 80.46 TK
For member 3 cost is = (72*35 + 12*64 + 3*6 + 72*63 +12*4)*.0206 TK = 164.017 TK
For member 4 cost is = (72*35 + 12*6 + 3*63 + 72*6 +12*5)*.0206 TK =67.420 TK
For member 5 cost is = (72*8 + 12*6 + 3*1 + 72*62 +12*5)*.0206 TK = 106.605 TK

Table 5. Second population consisting of 4 members

Serial/Location	1	2	3	4	5	6
1	5	1	4	6	2	3
2	6	5	4	1	2	3
3	1	2	3	4	6	5
4	5	2	3	1	4	6
5	1	2	3	5	4	6

For member 1 cost is = (72* + 12* + 3* + 72* +12*)*.0206 TK =92.57 TK
For member 2 cost is = (72* + 12* + 3* + 72* +12*)*.0206 TK =125.41 TK
For member 3 cost is = (72* + 12* + 3* + 72* +12*)*.0206 TK = 112.414 TK
For member 5 cost is = (72* + 12* + 3* + 72* +12*)*.0206 TK = 113.412 TK

Now there is two parent chromosomes whose fitness are the best compared to the rest of the population. The probability that the fitness of one of two parents is total minimum of studied example is very small. The starting chromosome in new iteration isn't randomly generated. It is the chromosome obtained by crossover of two parents chromosomes discussed above. Consider a pair of parent chromosomes (P1, P2) shown below:

Table 6. Second population consisting of 4 members

P1	6	5	1	2	3	4
P2	5	1	4	6	2	3

The way of crossover implementing in this work was chose four central numbers of both parents i.e. (8,4,2,5) in P1 and (5,7,9,6)in P2, but we do not exchange it from P1 toP2 and vice versa (the procedure explained and used by Chan and Tansri [vii]; Mak,Wong and Chan [viii]). We only change their string in original chromosome of one parent in the way they are lined in the other. To be precisely, numbers 8,4,2,5 in P1 should be lined as 2, 5, 8,4 in P1, and numbers 5,7,9,6 in P2should

be lined as 9,6,5,7 in P2. At this stage genes cannot be found to exist in more than one position in the resultant chromosomes. The structures of the resultant chromosomes then become:

Table 7. Second population consisting of 4 members

P1	6	5	1	2	3	4
P2	5	1	4	6	2	3

Cost after mutation:
For P1 cost C1= (72*62 + 12*4 + 3*8 + 72*6 +12*6)*.0206 TK =103.82 TK
For P2 cost C2= 72*34 + 12*2 + 3*36 + 72*5 +12*4)*.0206 TK =74.65 TK
Crossover

Table 8. Second population consisting of 4 members

P1	**3**	5	**6**	4	1	2
P2	5	2	**6**	**3**	1	4

Cost after cross over,
For P1 cost C1= (72*2 + 12*5 + 3*35 + 72*34 +12*8)*.0206 TK =58.77 TK
For P2 cost C2= (72*34 + 12*2 + 3*36 + 72*4 +12*8)*.0206 TK =60.56TK ***

Table 9. Comparison between proposed and GA algorithm

Genetic Algorithm				Proposed Algorithm	
Expt. No.	Number of Trials	Material Handling Cost (TK)	% of Cost reduction	Material Handling Cost (TK)	% of Cost reduction
01	12	13.6	87.01	**6.43**	**94.3**
02	13	14.83	86.81		

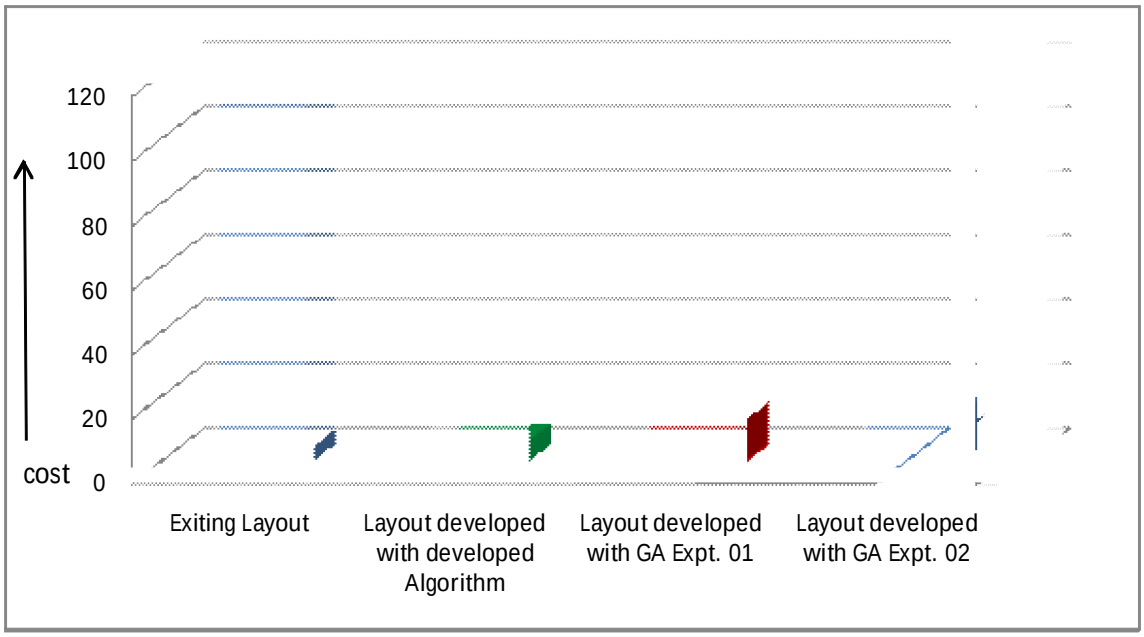

Fig.5. Competitive cost analysis

7. CONCLUSION

The main focus here is to prevent extra material handling cost in our industrial sector. Aiming to this, all the available methods had examined to optimize the material handling cost and finally a new algorithm has been proposed and the result has been shown by applying the algorithm with C++ programming. The effectiveness of the outcome has been depicted by comparing with Genetic Algorithm.

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TURNING AISI 1040 STEEL UNDER CLEAN AND ECO-FRIENDLY ENVIRONMENT: AN APPLICATION OF MINIMUM QUANTITY LUBRICATION TECHNIQUE

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ABSTRACT: Manufacturing by machining constitutes major industrial activities in global perspective. Like other manufacturing activities, machining also leads to environmental pollution. Since beginning of twentieth century people were concerned with possible harmful effects of various cutting fluid application. Turning is a machining process characterized by high specific energy requirement that utilizes single point cutting tool as the cutting medium. Generally, metal is removed by shearing action in the form of chips that results very high cutting zone temperature. This high temperature causes several problems so, it is essential to remove this temperature from tool work interface. There are several processes to reduce the cutting temperature. The conventional type coolant application during any machining operation is believed to reduce the cutting zone temperature. The conventional types and methods of application of cutting fluid have been found to become less effective with the increase in cutting velocity. Furthermore, the cost of treating the waste liquid is high and the treatment itself is a source of air pollution, chemicals present in this fluid causes health hazards. Also it was found that the cost associated with the use of cutting fluids is estimated to be about 16% of the manufacturing costs. Hence, minimum quantity lubrication cutting fluid application technique is used as an alternative cutting fluid application. Minimum quantity of lubrication (MQL) can be tried to reach the goal of minimizing the amount of cutting fluid in machining process. In this process, pulverizing of a very small amount of oil (50-500 ml/h) in a flow of compressed air. Some good results have been obtained with this technique. In this regard the present work has been carried out with a view to study the effects of vegetable oil based and water soluble oil based cutting fluid on the cutting performance of AISI 1040 steel, as compared to completely dry and wet in terms of cutting force, chip formation mode and dimensional deviation. Vegetable oil based cutting fluid performed much superior mainly due to reduction in tool work interface temperature, enabling favorable chip formation and improving dimensional deviation. It also provides lubrication in the tool tip and work surface interface

Keywords: Minimum Quantity Lubrication, cutting force, Chip formation mode, Chip reduction coefficient.

1. INTRODUCTION

Fruitful implementation of any manufacturing process, it is essentially needs to be technologically acceptable, technically feasible and economically viable. The fourth dimension that has been a great concern of the modern manufacturing industries and society is Clean and Eco-Friendly Environment for manufacturing process. With the growing demand for higher productivity, product quality and overall economy in manufacturing by machining and grinding, particularly to meet the challenges thrown by liberalization and global cost competitiveness, insists high material removal rate and high stability and long life of the cutting tools. But high production machining with high cutting velocity, feed and depth of cut is inherently associated with generation of large amount of heat and high cutting temperature. Such high cutting temperature not only reduces dimensional accuracy and tool life but also impairs the surface integrity of the product. High cutting temperature accelerates the growth of tool wear and also enhances the chances of premature failure of the tool by plastic deformation and thermal fracturing. The surface quality of the products also deteriorates with the increase in cutting temperature due to built-up-edge formation, oxidation, rapid corrosion and induction of tensile residual stress and surface micro-cracks. Therefore, it is essential to reduce the cutting temperature as far as possible. In industries, the machining temperature and its detrimental effects are generally reduced by: (i) proper selection of process parameters and geometry of the cutting tools, (ii) proper selection and application of cutting fluid, (iii) using heat and wear resistant cutting tool materials like carbides, coated carbides and high performance ceramics (CBN and

diamond are extremely heat and wear resistive but those are too expensive and are justified for very special work materials and requirements where other tools are not effective).

Cutting fluid not only cools the tool and job but also provides lubrication and cleans the cutting zone and protects the nascent finished surface from contamination by the harmful gases present in the atmosphere. But the conventional types and methods of application of cutting fluid have been found to become less effective with the increase in cutting velocity and feed when the cutting fluid cannot properly enter the chip-tool interface to cool and lubricate due to bulk plastic contact of the chip with the tool rake surface. Besides that, often in high production machining the cutting fluid may cause premature failure of the cutting tool by fracturing due to close curling of the chips and thermal shocks. For which application of high cooling type water base cutting fluids are generally avoided in machining steels by brittle type cutting tools like carbides and ceramics. But what is of more serious concern is the pollution of the working environment caused by use of cutting fluid, particularly oil-based type.

Manufacturing by machining constitutes major industrial activities in global perspective. Like other manufacturing activities, machining also leads to environmental pollution mainly because of use of cutting fluids. These fluids often contain sulfur (S), phosphorus (P), chlorine (Cl) or other extreme-pressure additives to improve the lubricating performance. These chemicals present health hazards. Furthermore, the cost of treating the waste liquid is high and the treatment itself is a source of air pollution. The major problems that arise due to use of cutting fluids are [Aronson 1995]: (i) environmental pollution due to breakdown of the cutting fluids into harmful gases at high cutting temperature, (ii) biological hazards to the operators from the bacterial growth in the cutting fluids, (iii) requirements of additional systems for pumping, local storage, filtration, temporary recycling, cooling and large space requirement, (iv. disposal of the spent cutting fluids, which also offer high risk of water pollution and soil contamination.

Since beginning of twentieth century people [Peter et al.1996; Welter 1978; Kennedy 1989 and Thony et al. 1975] were concerned with possible harmful effects of various cutting fluid application. It has been estimated [Bennett 1983] that about one million workers are exposed to cutting fluids in the United States alone. Since cutting fluids are complex in composition, they may be more toxic than their constituents and may be irritant or allergenic. Also, both bacteria and fungi can effectively colonize the cutting fluids and serve as source of microbial toxins. Hence significant negative effects, in terms of environmental, health, and safety consequences, are associated with the use of cutting fluids. The effects of exposure to the fluids on health have been studied for over 50 years; beginning with the concern that cutting fluid (oil) is a potential etiologic factor for occupational skin cancer (Epidemiological studies indicate that long-term exposure to cutting fluids can lead to increased incidence of several types of cancer). The international Agency for Research on Cancer has concluded that there is “sufficient evidence” that mineral oils used in the workplace are carcinogenic [Peter et al.1996]. Basically, workers are exposed to metal cutting fluids via three routes [Bennett et al. 1985]; skin exposure, aerial exposure and ingestion. Skin exposure is the dominant route of exposure, and it is believed that about 80 percent of all occupational diseases are caused by skin contact with fluids [Bennett et al.1985]. Cutting fluids are important causes of occupational contact dermatitis, which may involve either irritant or allergic mechanisms. Water mixed fluids generally determine irritant contact dermatitis and allergic contact dermatitis when they are in touch with workers skin. Non-water-miscible fluids usually cause skin disorders such as foliculitis, oil acne, keratoses and carcinomas. Iowa Waste Reduction Centre (1996) reported that besides potential skin and eye contact, inhalation is also a way to occupational exposure. Mists are aerosols comprised of liquid particles (less than 20 μm). During machining process, a considerable amount of heat is generated for which the cutting fluid may attain a temperature sufficiently higher than the saturation temperature. The vapor is produced at the solid-liquid interface as a result of boiling. Vapour may be generated also at the liquid-air interface when the fluid vapour pressure is less than the saturation pressure, namely as evaporation phenomena. Vapour generated then may condense to form mist. The non-aqueous components of the cutting fluid, such as the biocide additives, appear as fine aerosol that can enter the workroom air. Additionally, the cutting fluids impact with both stationary and rotating elements within the machine tool system, which leads to mechanical energy being transmitted to the fluid. Thus, the cutting fluid has higher surface energy and becomes less stable and disintegrates into drops (atomization). The spray from the fluid application also may generate mist. A

total fluid loss of 5 to 20 percent may occur due to evaporation, atomization, splashing and drag out processes. Whether formed by atomization or evaporation/ condensation, small droplets may be suspended in the air for several hours even several days in the workers breathing zones. These drifting droplets tend evaporate further. Inhaled particles (with aerodynamic diameters less than 10 µm) deposit in the various regions of the respiratory system by the complex action of the different deposition mechanisms. The particulates below 2.5 µm aerodynamic diameter deposit primarily in the alveolar regions, which is the most sensitive region of lung. The particulates in size ranging from 2.5 µm to 10.0 µm deposit primarily in the air-ways. The potential health effects of exposure to cutting fluid mists have been the subjects of epidemiological studies in the automotive industry. The mist droplets can cause throat, pancreas, rectum, and prostate cancers, as well as breathing problems and respiratory illnesses. One acute effect observed is mild and reversible narrowing of airways during exposure to cutting fluid mist [Kennedy 1989]. Pollution free manufacturing is increasingly gaining interest due to recent development of pollution-prevention legislation, European initiatives on product take-back or recycling, which affect many export industries in the US, and a growing consumer, demand for green products and production processes. Concern for the environment, health and safety of the operators, as well as the requirements to enforce the environmental protection laws and occupational safety and health regulations are compelling the industry to consider a cryogenic machining process as one of the viable alternative instead of using conventional cutting fluids.

The modern industries are, therefore, looking for possible means of dry, clean, neat and pollution free machining and grinding. Ample researches have been carried out and are still going on in this direction. Minimum Quantity Lubrication (MQL) by agents like soluble and vegetable oils appears to be a promising technique for effective cooling without the problems associated with conventional cutting fluid applications. But it is also essential to be assured that productivity and overall economy are not affected while deriving the environmental benefits of Minimum Quantity Lubrication (MQL). Rather it is necessary to explore the possible technological benefits of such Minimum Quantity Lubrication (MQL) and optimise it for maximum overall socio-economic benefits. In this regard the present work has been carried out with a view to study the effects of vegetable oil based and water soluble oil based cutting fluid on the cutting performance of AISI 1040 steel. The objective of the present work is to study to study the effects of vegetable oil based and water soluble oil based cutting fluid on turning of AISI 1040 steel, as compared to completely dry and wet in terms of (i) cutting force, (ii) chip formation mode and (iii) chips reduction coefficient.

2. EXPERIMENTAL CONDITIONS

An AISI 1040 steel rod of initial diameter, 75mm and length 400mm has been machined (turned) in a center lathe by High Speed Steel tool under dry, wet and MQL conditions. For MQL machining mixture of cutting fluid and compressed air jet was impinged from a specially designed nozzle towards the cutting zone parallel to the auxiliary cutting edges. The coolant used was water-soluble cutting oil fluid dispensed at a flow rate of 10 lit/hour and vegetable oil at a flow rate of 120ml/hour. The present experimental conditions are given in Table-1 and the photographic view of the experimental setup is shown in the figure 1.

Fig.1: Photographic view of the experimental set-up

Table 1: Experimental Conditions

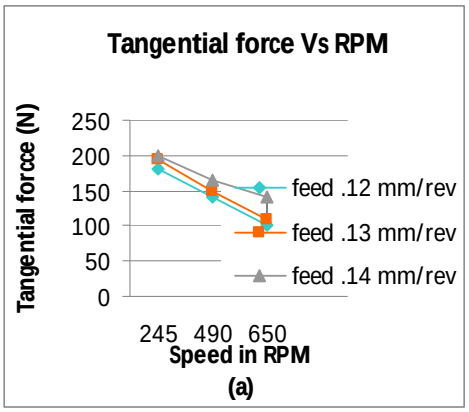
Machine Tool	Lathe Machine (China), 10 hp
Materials	AISI 1040 (Φ 75 X 400 mm)
Cutting Tool	HSS tool
Process parameters	
Cutting velocity (Vc) Feed rate (So) Depth of cut (t)	0.95, 2.00, 2.50 m/min 0.12, 0.13 and 0.14, mm/rev 0.5 mm
MQL Supply	Air- 8 bar, Lubricant- Vegetable oil, 120 ml/h through external nozzle having 1 mm tip diameter.
Environments	Dry condition Flood cooling with soluble oil and Minimum Quantity Lubrication Cooling

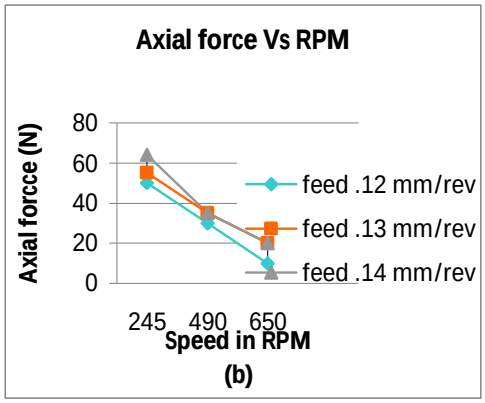
3. EXPERIMENTAL RESULTS AND DISCUSSION

During the experiment, a thin but high velocity stream of MQL was directed along the auxiliary cutting edge of the tool through an nozzle tip have an diameter 1 mm, so that the coolant reaches as close to the chip-tool and the work-tool interfaces as possible. Effectiveness of cooling and the related benefits depend on how closely the MQL jet can reach the chip-tool and the work-tool interfaces where, apart from the primary shear zone, heat is enervated. The positioning of the nozzle tip with respect to the cutting insert has been settled after a number of trials.

(i) Cutting force

The forces acting on the single point cutting tool are of fundamental important in machining any metal. For a conventional turning process there are three components of cutting (tangential, axial and radial) is developed. Figure 2(a),(b), (c); 3(a),(b), (c); and 4(a),(b), (c); shows different components of cutting force at different feed rate at dry, wet and minimum quantity lubrication environment. All the components of cutting forces (tangential, axial and radial) increase with increasing the feed rate at dry, wet and minimum quantity lubrication environment but these cutting forces decrease with increase spindle speed.





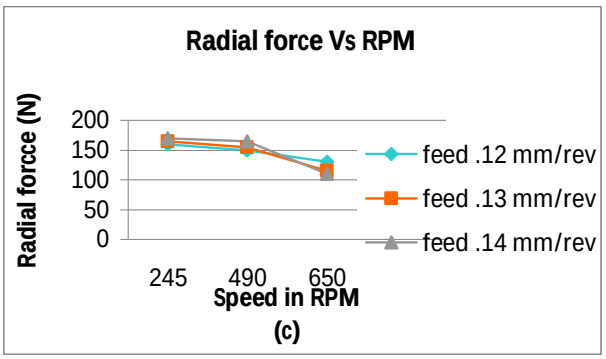
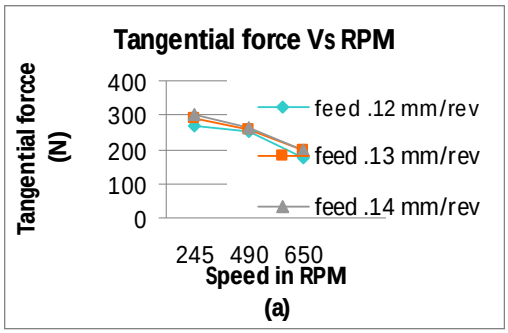
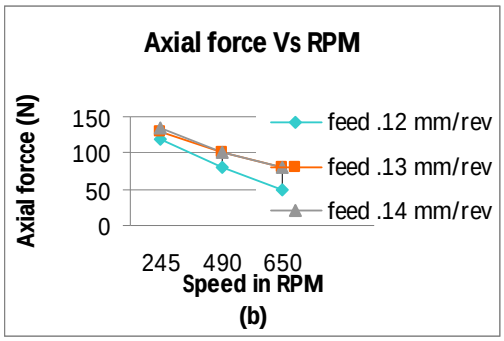


Fig. 2: Tangential, Axial and Radial forces vs spindle speed in different feed rate at dry condition.





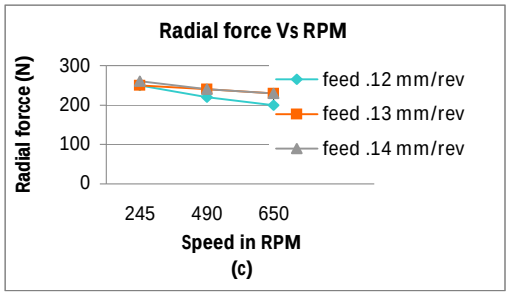
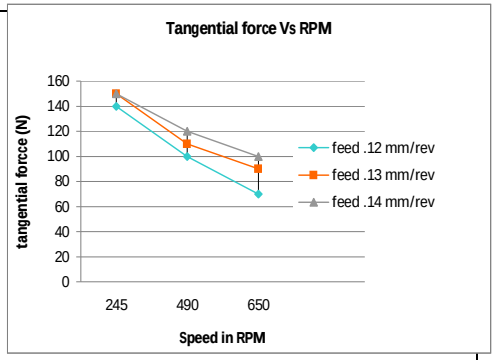
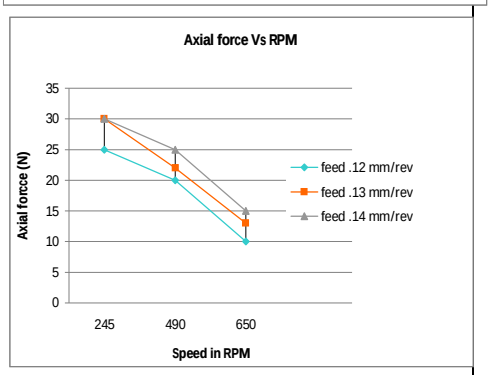


Fig. 3: Tangential, Axial and Radial forces vs spindle speed in different feed rate at Wet condition.





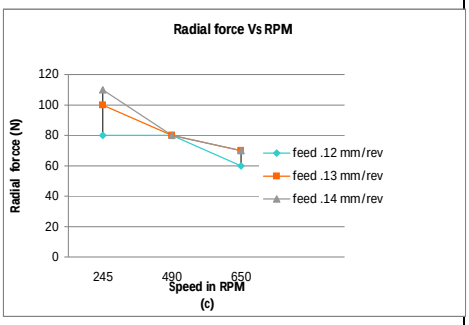


Fig. 4: Tangential, Axial and Radial forces vs spindle speed in different feed rate at MQL condition

Figure 5(a), (b) and (c) show that the variation of different components of cutting forces at different environments, Here at dry environment the magnitude of cutting force than wet and MQL condition. In MQL condition stream of MQL jet can reach the chip-tool and the work-tool interfaces, hence the magnitude of cutting force is lower than wet.

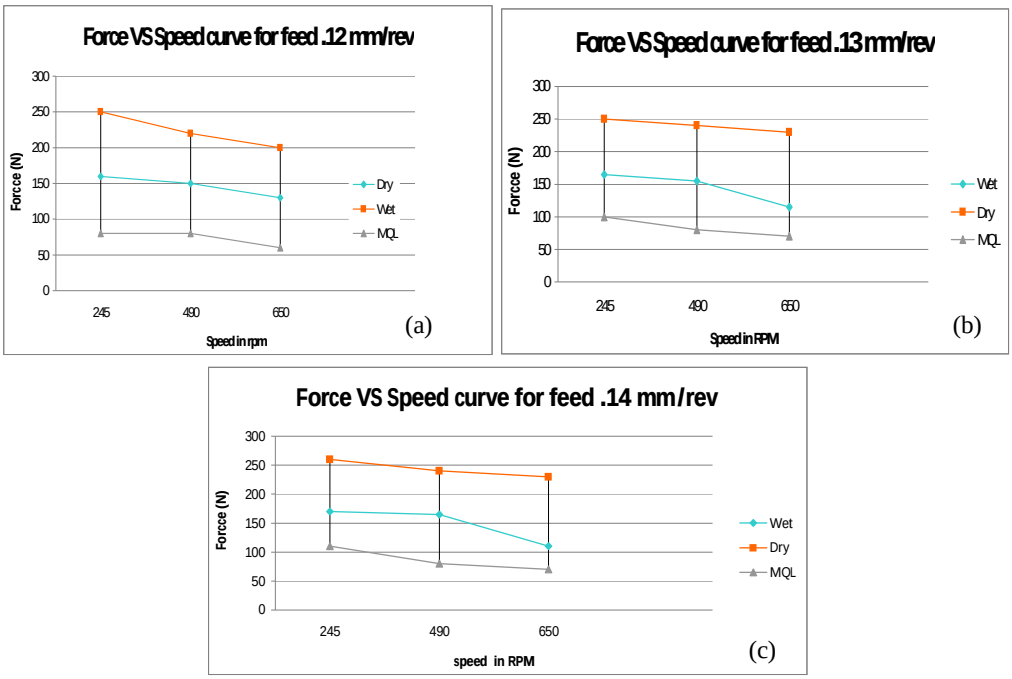


Fig.5: Variation of cutting force in different feed rate and different environmental conditions.

(ii) Chip reduction coefficient.

Machinability is defined as the ease with which the metal is cut satisfactorily. In general machinability is associated with removal of metal with moderate forces, the formation of rather small chips. Another important machinability index is chip reduction coefficient, ζ (ratio of chip thickness after and before cut). For given tool geometry and cutting conditions, the value of ζ depends upon the nature of chip-tool interaction, chip contact length. Figure (6) shows chip reduction coefficient at different feed rate condition.

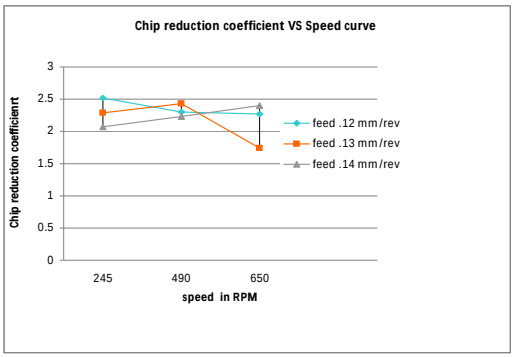


Fig.6: Variation of chip reduction coefficient at different feed rate.

(iii) Chips Formation mode:

The form, color and thickness of the chips also directly and indirectly indicate the nature of chip-tool interaction influenced by the machining environment. The chip samples were collected during the machining under dry, wet and MQL conditions. The chip samples collected while turning the AISI 1040 steel by the HSS under dry, wet and MQL by vegetable oil condition have been visually

examined and categorized with respect to their shape and color. Figure (7) shows such categorization of the chips produced at different feed rates, spindle speed and environments.

Depth of cut (mm)	Speed R(pm)	Feed mm/rev	Environment		
			Dry	Wet	MQL
1.50	250	0.12			
		0.13			
		0.14			
	490	0.12			
		0.13			
		0.14			
	650	0.12			
		0.13			
		0.14			

Fig.7: Formation of chips at different machining condition and environment.

4. CONCLUSION

Minimum Quantity Lubrication, if properly employed, can enable significant improvement in both productivity and product quality and hence overall machining economy even after covering the additional cost of MQL system. The experimentally observed role of MQL in turning AISI-1040 steel by HSS cutting tool may be summarized as follows:

(i) The minimum quantity lubrication enabled reduction in the three components of cutting forces (forces (tangential, axial and radial) depending on the process parameter. In the present experiment, MQL perfectly reached to the work-tool interface, hence the magnitude of cutting force is lower.

(ii) MQL provided significant improvements expectedly, though in varying degree, in respect of chip formation modes, surface characteristics throughout the feed range undertaken mainly due to

reduction in the cutting force. In MQL environment the chip formation modes is mainly due to shearing and chips colors are metallic colors.

(iii) The value of chip reduction coefficient is higher in MQL condition which indicates good machinability.

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A SIMPLE DUAL FLUSH CISTERN DESIGN AND ESTIMATING ITS EFFECT IN PERSPECTIVE OF DHAKA CITY

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ABSTRACT: Dhaka, the capital of Bangladesh, is one of the mega cities of the world. The population of the city is growing with rapid pace. The city inhabitants are affected by many problems from which water and electricity crisis are the major two. Though these problems cannot be solved overnight, we can mitigate the severity of these problems. This paper emphasizes on an easy way to reduce the severity of water and electricity scarcity of the city by suggesting the use of dual flush cisterns. This type of cistern is used in toilets to flush two different volumes of water for cleaning solid and liquid wastes. The proposed dual flush cistern can easily be fabricated, and the mechanism can also be used in the existing single flush cisterns with minimum modifications. As toilets are the most water users of any residence, this study shows that dual flush technology can reduce the water consumption; it helps to pump-in lesser amount of water to households and thereby reducing use of electricity to a great extent.

Keywords: Dual Flush, Water Conservation, Electricity Conservation, Green Technology.

1. INTRODUCTION

Dhaka is the capital city of the People's Republic of Bangladesh. It is a megacity and one of the major cities of South Asia located on the banks of the Buriganga River. Dhaka has an estimated population of more than 15 million, making it the largest city in Bangladesh. It is projected that it will become the third largest city by the year 2020. It is also hold its position in the ten most-populated cities in the world [1]. The population is growing by an estimated 4.2% per year, one of the highest rates amongst Asian cities [2]. This rapidly increasing population with unsystematic urban infrastructure of the city gives birth of many problems like water supply shortage, excessive ground water abstraction for meeting huge demand that follows to the groundwater table depletion, electricity crisis etc.

1.1. WATER CRISIS

Water is a basic human need. The basic water requirement standard for human needs is 50 l/p/d [3]. But the actual average water usage is above 100 l/p/d. So for a 5 member's family, there is the need of at least 100 × 5 = 500 liters of fresh water every day. As a result of increasing world population with a great pace, the need for fresh water is increasing rapidly. But the sources of fresh water are sinking off because of environmental changes, urbanizations and pollutions. As a result, there is an acute shortage of potable water worldwide. Dhaka is one of the cities of highest population growth rate in the world. So the demand of water is very high and it is continuously rising. DWASA is the main authority to supply fresh water to the Dhaka city dwellers that is unable to meet the rising demands for water year-around. The supply of water is always short and in some areas bad smells come from supplied water. During summer season ranging from March to May, severe water crisis hits the city as the result of power shortage and water table going down. During the period 2011-12 DWASA produced an average of 2180 MLD against the demand of 2240 MLD; i.e. the demand-supply gap is 60 MLD [4]. But if we count the huge system loss around 29.80% in the year 2011-12 between production and end-user level of DWASA [4], then the real demand-supply gap would be much greater.

1.2. GROUNDWATER DEPLETION

The water supply of Dhaka city is greatly depends on the ground water extraction. The ground water provides 87 percent of total water supply of the city with 622 deep tube wells and another 13 percent with 4 surface treatment plants [4]. The most severe consequence of excessive groundwater pumping

is lowering down the groundwater table. The groundwater table has dropped about 20 meters over the last seven years at a rate of 2.81 meter per year. If the ground water level goes down with this rate then it is predicted that the groundwater table will be lowering down to 120 meters by 2050 from the existing water table [5]. If groundwater levels fall too far, then the wells need to be deepen, drill new wells, or lower the pumps to reach the water levels. As the water levels decline, the rate of water yield also decline. Water production cost increases with decreasing groundwater level. Water must be lifted higher to reach the land surface than before. More energy will be required to drive the pump that would eventually increase electricity crisis. Water quality also worsens by excessive ground water extraction. Due to technical reasons, the DTW must be dig at a distance at least 2000 feet from any other DTWs. If this distance cannot be maintained then the production of DTW would be reduced [4]. But most of the DTWs in Dhaka city are not maintaining this distance.

1.3. ELECTRICITY SHORTAGE

Electricity is the backbone of modern civilization. All processes of progress and development are entirely relying on it. As like the other countries of the world, the electricity demand is increasing rapidly day by day in Bangladesh. But it is very unfortunate that the energy infrastructure of this country is very small to meet the current raising demand. Also it is very inefficiently operated and poorly managed. The demand-supply gap is always high. In summer season, the electricity shortage is so high that this produces immeasurable sufferings to the people. Due to the shortage of available generation capacity, actual target of electricity generation could never be achieved. Also the generating units available have become so old that they are operated at much lower capacity. Beside this, some power plants that use gas to produce electricity are sometimes unable to utilize their usual generation capacity due to the shortage of gas supply.

2. CONVENTIONAL FLUSHING MECHANISMS

A flush toilet is a toilet that disposes of human waste by using water to flush it through a drainpipe to another location. There are several types of toilets; the siphon toilet and the flap valve flushing toilet are the most popular gravity flushing toilets. The siphon type used a siphon in the cistern to supply the water to the bowl. Another siphon in the actual bowl outlet is used to drag the contents from the bowl, through the S bend and into the soil pipe. The flap valve system is relatively simple; the operation of the lever caused a valve in the bottom of the cistern to open, allowing water to flow down into the bowl. Both types use a ball-cock system to maintain the water levels in the cisterns and a lever on the side of the cistern to operate the flush mechanism. These types of toilets consume more than twelve liters of water per flush. If we multiply this with the number of times the toilet is flushed every day, we will easily get the idea of the large volume of water a toilet cistern consumes every day.

2.1 TRADITIONAL TOILETS IN DHAKA

After surveying several sanitary markets and homes in Dhaka city, it is found that almost all of the toilets in the city are fitted with conventional single button/handle flushing cistern, most of them are old fashioned and consumes huge amount of water (14 to 20 liters) with every flush. The flushing mechanism in most of the toilet cisterns are flap valve system. It is the simplest cistern flushing mechanism available in the market. Since flap valve cistern is cheaper than other cisterns, it is more popular though it consumes more water. People of Dhaka city are not conscious about the water consumptions by their toilet cisterns. Most of them don't know that the toilet cisterns are the most water user of the home. They are not aware about the dual flushing technology and its marvelous impact in conserving water as well as our ecology. By market survey, we have seen that dual flush cisterns are not available everywhere; they are only available in some aristocratic sanitary showrooms and the prices are too high to afford for the common people. So people are not willing to buy this. The objective of this research is to popularize the use of dual flush cisterns by providing some estimation of cost savings per month in the domestic water and electricity bills, and by proposing a cheap and simple design of dual flush cistern so that general people can use it in their toilets. Also, the proposed design can easily be incorporated in the existing single flush toilets with minimum modification.

3. DUAL FLUSH TECHNOLOGY

Toilets are the primary water user in the home. It is accountable for the most water consumption made by a home. Every flush consumes more than 14 liters of water. So by reducing water consumption of the toilets ultimately reduce the total water consumption of any home. In conventional toilets, there is only one option to flush whole water of the cistern whether to disposal of solid or liquid waste. But in case of cleaning liquid waste, there is no need of flushing whole water of the cistern, because cleaning liquid waste requires less water than cleaning solid waste. In dual flush technology, the cistern is designed as a way to provide two options for flushing, one is for flushing full volume of water for cleaning solid waste and another is for flushing relatively smaller volume of water for cleaning liquid waste. This mechanism is operated by a lever or buttons on the cistern. So the dual flush cisterns are the big water savers.

Dual flushing technology for toilet was first invented in Australia by Bruce Thompson in 1980, where lack of rain is common and water is often in short supply [6]. After that different types of dual flushing mechanisms were invented and till now the researchers are doing great jobs to make it more efficient and conserving more water. The dual flush toilet is now not only used in Australia, but is common throughout Asia, Europe and much of the developed countries. In a few of the countries, it's been made law that for homes newly built, dual flush toilets must be installed. Though it is a long time since many countries of the world have adopted this technology in their toilets for reducing water consumption, this concept is relatively new in Bangladesh. People of Bangladesh are not aware about this marvelous technology.

4. ESTIMATING THE EFFECTS OF DUAL FLUSH CISTERN

A dual flush cistern can save considerable amount of water, electricity and hence reduce the cost incurred by a consumer each month. To estimate how much water and electricity bill will be saved by using dual flush cistern, we conducted a simple study on a typical twelve storied building in Dhaka city. There was on average 5-members 48 families. We assumed that, every person flush the cistern average 8 times in a day i.e. 2 times for cleaning solid waste and 6 times for liquid waste [7]. Every flush consumes 14 liters of water in conventional toilets. But in dual flush system, cleaning liquid waste requires half flush i.e. 7 liters of water and cleaning solid waste requires full-flush i.e. 14 liters of water. So, water consumption saved by a person is {(14×8) - (14×2 + 7×6)} 42 liters/day i.e. 37.50% than conventional toilet flushing systems.

Number of members lived in the building = (5×48) = 240 persons.
Water savings = (240×42) = 10,080 liters/day = 302,400 liters/month.
A 10 HP pump was used to fill a storage tank of size 12′×10′×8′ in about 6 hours.
Electricity savings = [{(10×0.746*×6) / (12×10×8×28.3**)} ×10080] = 16.61 units/day = 498 units/month.

*1 hp = 0.746 kW
**1 ft^3 = 28.3 liter

Table 1. Water & electricity costs savings.

	Savings per month	Cost saving per month (Taka)*
Water	302,400 litres	1,815
Electricity	498 units	3,984
Total	-	5,799

**Water tariff Tk. 6/1000 litre [4], average electricity tariff Tk. 8/unit [8]*

From the Table 1, we see that by the use of dual flush cisterns instead of conventional cisterns, at least Tk. 5,799 is saved monthly and Tk. 69,588 is saved yearly from a typical flat-type building in the Dhaka city.

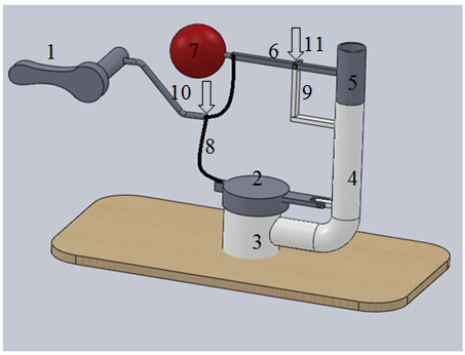
DWASA had 288,401 numbers of residential consumers at the end of the FY: 2011-12 [4]. If we assume there are 10 members use each water connections of DWASA and every member saves 42 liters of water per day by using dual flush cisterns, then total volume of water savings is 121 MLD.

5. DESIGN AND FABRICATION OF DUAL FLUSH CISTERN

5.1. OBJECTIVES

The main objective of our research is to design a simple type dual flush cistern which can reduce the water and electricity consumption in large extent and can ease water and electricity crisis of Dhaka city. As most of the toilets in Dhaka city are flapper valve type, we used this technique to design our dual flush cistern. We used a simple mechanism to lower the price and to make it affordable for most of the users. Another objective of our design was to make a mechanism which can be retrofitted in the existing cisterns.

5.2. COMPONENTS



1: Handle
2: Flap valve
3: Water outlet
4: Overflow pipe
5: Extension of overflow pipe
6: Float arm
7: Float ball
8: String

Fig.1: Proposed dual flush mechanism.

The mechanism shown in the Figure 1 is basically a flapper type flushing mechanism which was slightly modified to make a dual flush system. In the Figure 1: 1, 2, 3, 4 and 8 are the components of conventional single flush cistern. We have added components 5, 6, 7 and 9 to make it a dual flush cistern. The string 8 was fastened with the handle 1 at the point 10. By this way the handle 1 was coupled with flap valve 2 and float arm 6. The float arm 6 is pivoted at point 11 on an arm 9 which is fixed with the overflow pipe 4. The extension of overflow pipe 5 is fixed with float arm 6 and it sits water tightly on the overflow pipe 4. So the extension of overflow pipe 5 can be selectively opened or closed by the action of the handle 1.

5.3. WORKING PRINCIPLE

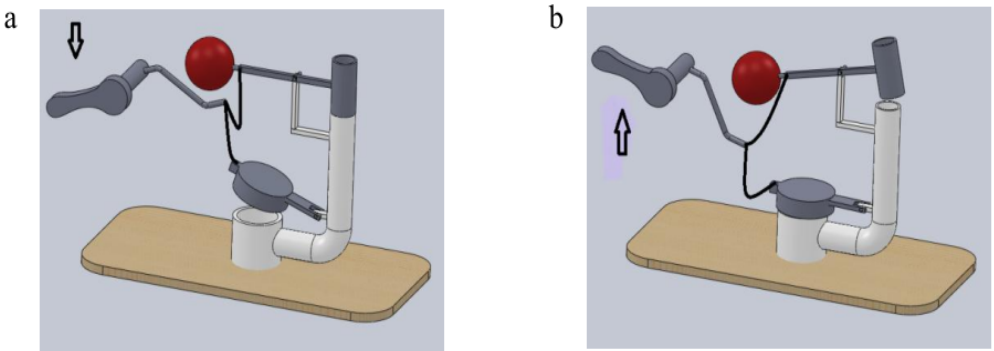


Fig.2: Working modes of the dual flush mechanism: (a) Full flush; (b) Half flush.

In the Figure 2(a), for full flush mode, when the handle is rotated in the downward direction, it pulls up the flap valve by the string connection. So full water contained in cistern is flushed through the water outlet. In the Figure 2(b), for half flush mode, when the handle is rotated in the downward direction, it pulls down the float arm and at the same time opens the extension of the overflow pipe. As a result, water up to the opening of overflow pipe remains in the cistern and the upper portion of water get flushed through the opening. When water is coming from the inlet mechanism and start filling the cistern, it closes the extension of the overflow pipe by the float action of the float ball. It is noted that in this design, we overlook the water inlet mechanism which includes tank fill valve. The valves are of two main designs: the side-float design and the concentric-float design. For our cistern design, concentric float fill valve is more preferable than the side-float fill valve as it occupies less area. Figure 3 shows the mechanism fabricated according to the proposed design.

Figure 3: Photograph of the fabricated cistern parts: inside the cistern (left); hinged assembly (right).

6. CONCLUSION

Due to gradually increasing population, it is very difficult for DWASA to meet the demand for water. Moreover, DWASA almost entirely rely on the groundwater for supplying fresh water to the city dwellers. The excessive extraction of groundwater makes the groundwater table to decline and eventually the water yields also decline. So DWASA needs to lessen its dependency on groundwater by establishing new surface water treatment plants. But the city's nearby rivers are so polluted that they cannot be treated to produce fresh water and also establishment of surface water plants need huge amount of investments. So it is high time spreading the awareness among people about water savings. As dual flush cisterns can cut off big percentage of water consumption made by home, it could mitigate (partly) the current severity of the water crisis problem.

In addition to water savings, dual flush technology can provide much more facilities to its users. It can also reduce electricity consumption of pumps because of lifting less water to the tank then before. Due to less water consumption, pumps also need to be run fewer times than before which will improve pump's lifetime and efficiency. Less water consumption means less sewerage production which is beneficiary for the municipal authority also.

The dual flush cistern shown here is the simplest dual flushing mechanism; more complex and efficient mechanisms were also been invented which have more water saving capabilities. But for the current perspectives of Bangladesh, this type of dual flush cistern can make a pivotal role in spreading this technology over the common people because of its simple manufacturing procedures, low price and retrofitting capabilities i.e. conversion of single flush cistern to dual flush without eliminating existing one.

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GREEN SHIP RECYCLING: BANGLADESH PERSPECTIVE

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ABSTRACT: Since last few decades, ship recycling has been playing an important role for the economy of Bangladesh. But the performance of this industry in terms of occupational safety, health and environmental issues is not up to the mark. In this paper, an overview of the present practice of ship recycling in Bangladesh has been highlighted. The impact of upcoming regulations on this industry has been discussed and also SWOT analysis of present ship recycling industry has been performed. Finally some conclusions have been made for the sustainable development of this industry in the long run.

Keywords: Green Ship Recycling, Hong Kong Convention, International Maritime Organization, Beaching Method, Hazardous Materials, Health and Safety.

1. INTRODUCTION

Ship recycling includes all activities for complete or partially dismantling of a ship in order to recover components and materials for reprocessing and re-use. When dismantling activities of ships are done complying environmental and safety regulations of national and international standard fully, then it is called green ship recycling. Ship recycling meets a key sustainability requirement in recycling of resources and it is also considered as an environment-friendly activity since it reduces the need for mining particularly for production of steel from pig iron and also saves energy and emits less CO_2.

There are various factors that determine the decision to scrap a ship. One of the main reasons comes from the economic point of view especially when maintenance cost exceeds the income from the ship. Sometimes recession in shipping industry lowers the freight rate and accelerates scrapping of ships. In addition, when new ship designs appear and fuel efficiency improves, old scrapping volumes are increased simultaneously. New environment and safety regulation or policies that enter into force affect a change in scrapping volume as well. For example, phasing out of single-hull oil tankers by 2015 will keep scrapping volumes up until when only double hull tanker can sail on the sea. On the other side, when freight market remains strong, the shipping companies try to retain their ship to accommodate increasing commodities for transport and thus scrapping volume reduces.

Until 1970s, ship recycling was a common industrial activity both in the United States of America and in Europe. Specialized salvage docks, equipped with cranes and other heavy equipment, were used to scrap the ships, providing material for the steel industry. Increase labour costs and stringent environmental regulations caused the scrapping industry to be concentrated at the docksides in Taiwan and South Korea in the 1970s. But those countries lost interest in ship recycling as it was no more cost-effective and they rather focused on using their shipyards for building ships in the 1980s. Since then ship recycling further shifted to South Asian Countries like India, China, Pakistan and Bangladesh, where health and safety standards are minimal and where workers are cheap and desperate for work. Bangladeshi industrialists also took the opportunities of this lucrative business which resulted importing more and more ship to Bangladesh. Since then ship recycling has been playing a significant role for the economy of Bangladesh by supporting steel industry, shipbuilding industry and other heavy & light engineering industries and it has also been generating huge employments for the country [1].

Although the age of ship breaking in Bangladesh is more than 3 decades, but primitive working conditions and the lack of necessary control mechanism generally cause the scrapping yards as a source of environmental and occupational health problems. Again adopted preventative measures of scrapping yards are still below standard and thus it brings negative image for the country every now and then.

The objective of this paper is to highlight the general practice of ship recycling industry in Bangladesh at first. The possible impact of upcoming regulation on ship recycling industry in Bangladesh has been discussed. Also the efforts made by other regions to reform the industry in the wake of upcoming international regulation have been highlighted. A brief overview about strength, weakness, opportunity and threat of the industries in global perspective has been discussed. Finally some conclusions have been drawn so that present ship recycling industry can be turned into sustainable and green industry in the long run.

2. METHODS OF SHIP RECYCLING

There are four general methods to dismantle ships; beaching, slipway, alongside and drydock.

Beaching
In this method, taking the natural advantage of very high tidal differences, the ships of different sizes are beached in a long uniform inter tidal zone. The ship is generally sailed with its maximum speed using its own power during the high tide and forced to be beached over the flat muddy land. Then unused or partially spent materials are recovered from the ship. The structure of the ship is cut into small pieces by using gas cutting and then pieces are pulled up near to the scrapping yard for further processing. This method is widely used mainly by in developing countries at Chittagong in Bangladesh, Alang in India, and Gadnani in Pakistan, where the environmental regulations and labor rights are rather weak or not existing.

Slipway
Slipway method is similar with the beaching method in the way that ships are stranded both in the land and the sea. A big advantage over beaching is that slipway recycling is typified by no tide, which enables to predict and control the contaminants by ships. The steel pieces are removed from the ship by mobile crane on the shore. As the ship becomes light, it is dragged up to the shore to continue further processes. It is found at Aliaga in Turkey.

Alongside
In this method, the ship is anchored alongside in the sheltered water at wharf. Then pieces are taken apart from the top to bottom (top-down approach) until only the double bottom is left. The pieces broken are carried by mobile cranes on the shore. The ship remained with double bottom is continued to break until either lifted out in one piece or sent to dry dock for final cutting. This ship recycling method at Zhang Jiagang in China is rated as being superior than beaching method practiced by South Asian countries.

Drydock
Drydock method is to dismantle all the parts of the ship piece by piece at the drydock. So, it is called as the safest and cleanest ship breaking method where the chances of polluting waters by accident are zero and the dock is cleaned before the next ship comes to be recycled in order to avoid accumulations of contaminants. But this method is relatively more expensive than other methods to build and maintain drydock and it is only found in some European countries.

Figure 1 shows the dominance of South Asian Countries (Bangladesh, India and Pakistan for ship recycling of ships from year 2005~2012. Figure 2 shows the contribution of ship recycling capacity in pie chart for year 2012. Even in last three years (2010~2012) two thirds or more of these ships are scrapped in these three developing countries, where mainly beaching method is used [2]. If for the time being, methods followed by China, Turkey & other European countries are considered as Green Ship Recycling (GSR) capacity, still then combined maximum share is only 33%. That means lion's share of scrapping of ships still depends on traditional beaching method.

3. GREEN SHIP RECYCLING-IDEAL CASE

Irrespective of methods followed for recycling, there are some common steps that should be taken care in order to perform green recycling in a yard through protecting both labor and environment. These steps are: pre-arrival activity, pre-cleaning activity, dismantling activity and storage-transport-disposal activities. Each step involves some general issues that must be addressed properly. In pre-

arrival stage, complete information about hazardous materials on ship must get by ship-recycling facilities before accepting it for dismantling. Also local authorities and environmental monitoring authority must be satisfied about recycler's infrastructure/ facility to comply environmental regulations. At the same time a comprehensive sequential plan of dismantling operations has to be fixed ahead of starting dismantling including the procedure to identify and label different hazardous materials and their locations. On arrival of the vessel, it is also important to identify and verify the hazardous material on the ship with the supplied IHM. Most important step in pre-cleaning stage is to handle hazardous material in safe and sequential manner following the ship recycling plan. The hazardous material should be stored in a leak proof storage so that there is no possibility of contamination to the surrounding environment.

In green ship dismantling process, it is important to follow the safety and health management system, guideline & procedure to avoid accident that leads to spills hazardous materials to environment. Special care should be taken before entering confined and enclosed spaces and also to avoid explosion and fires caused by unsafe use of torches and cutters. While interim storage of re-usable, recycled and waste items, proper care should be taken to label and protect it from outside weather. One of most important steps of green recycling is the disposal of waste in a environmental sound manner specially asbestos containing materials, PCBs, Oil-fuel-oily residues and other hazardous waste. In addition to these actions, contingency plan and monitoring programs of hazardous material should be prepared to tackle any accident or accidental spills while scrapping.

Continuous and constant monitoring from different responsible authorities for green recycling facilities is essential and also third party should be allowed to verify the environmental compliance of the facilities [3].

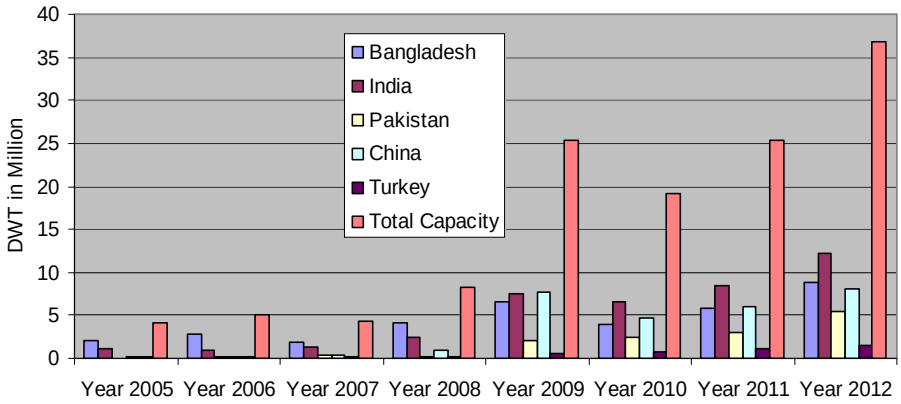

Fig.1 : Capacity of major ship recycling nations around the world

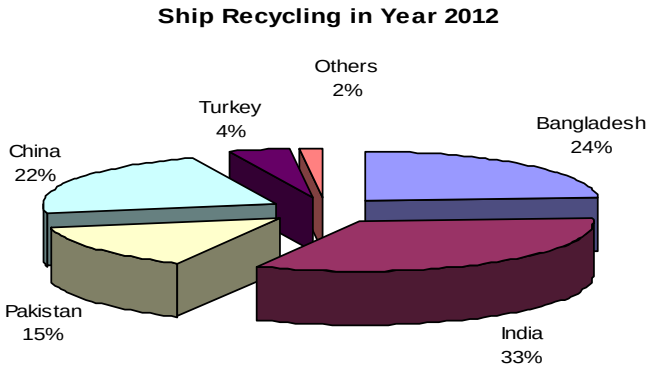

Fig.2: Contribution of ship recycling in Pie Chart for year 2012

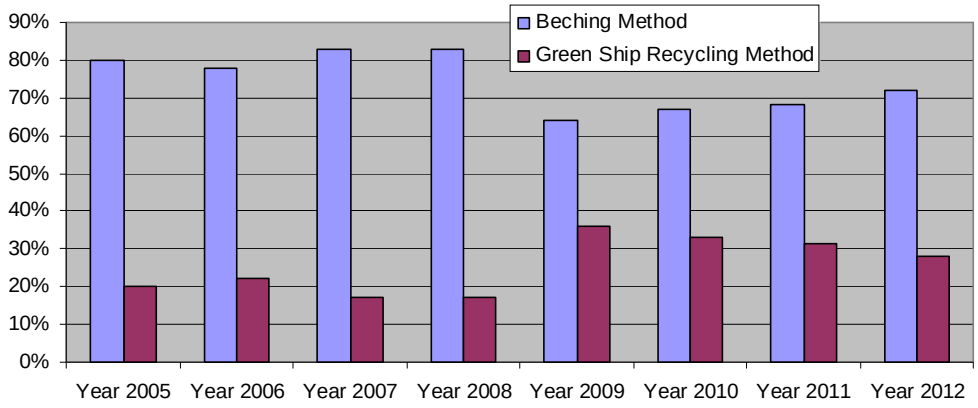

Fig.3: Share of recycling capacity by beaching and Green Ship Recycling method

4. PRESENT PRACTICE IN BANGLADESH

The process of ship recycling starts in Bangladesh with the acquisition of the ship by a purchaser (specialized broker or the operator of the ship breaking yard) when the ship owner decides to end the economic life of the ship. Ministry of Industry issues NOC after receiving documents like yard environment clearance certificate, ship detail particulars, MoU between two parties and Inventory of hazardous materials on board. Yard owner open L/C upon receiving NOC from Ministry of Industry. Later ship breaker submits the copy of opening L/C along with fees for necessary inspection of the ship. A team comprises of member from NBR, Dept. of Explosive, Dept. of environment and technical personal from ministry of Industry inspects the ship usually located at outer anchorage of Chittagong port. Inspection team submits their report to the ministry of industry after the visit and upon submission of Ship Recycling Facility Plan (SRFP) and valid certificate from the trade body by ship breaker, permission of beaching is given. At last cutting permission is given after submitting the following documents:

- Ship Recycling Plan(SRP)
- Yard Environment Clearance Certificate
- Certificate from Bangladesh Navy
- Workers' Registration
- Proof of removal of remaining oil from all bunker tanks
- Gas test certificate from dept. of Explosive

The inherent problems faced by current ship recycling industry of Bangladesh have been elaborately discussed in reference [1]. It is very difficult to make 100% green by present beaching method, but there are many areas where improvement can be made so that each recycling facilities have safe working environment and secure safety measure in controlling environment pollution. Although different Govt. authorities are involved with present ship recycling practice, but their monitoring over ship recycling industries is very poor. Even they do not have enough competent persons who can deal this ship recycling industry properly. As a result, overall up gradation of environmental and occupational health involved in this process is going at snail's pace and the present status of ship recycling in Bangladesh is far behind than ideal green ship recycling practice.

5. UPCOMING REGULATION AND ITS IMPACT

The ship recycling problem has been gathering great attention from the international society for few decades due to its highly risky, hazardous and unsafe working procedure particularly practiced by South Asian Countries using beaching method. International Maritime Organization (IMO) has been trying to implement some guidelines/regulations/ conventions for qualitative improvement of ship recycling industry around the globe since 2003. The 'Hong Kong International Convention for Safe and Environmentally Sound Recycling of Ships' is one of them. The Hong Kong Convention (HKC) was adopted in May 2009 and has started ratification from September 2009 and it will enter into force after 24 months upon fulfillment of some requirements. It is applicable to all merchant ships

greater than 500 gross tonnage (GT) as well as to all ship recycling facilities. The European Commission (EC) is also going to enforce the European Regulation on Ship Recycling by the end of 2013. One of the key issues of both regulations which directly affect the ship recycling industry is the authorization of ship recycling facilities. Many ship recycling yards which are not up to the mark may be eliminated from this industry due to the restricted authorization of ship recycling facilities.
When HKC comes into play, it is expected that a sea-change will occur in the business of ship recycling industry. Even though Bangladeshi ship breakers are generally highest payers among ship recycling nations while purchasing ships, they will face difficulty to bring ships from outside without having necessary approval of their ship recycling yards. For example: for breaking a European owned vessel, it is the obligation of the owner/cash buyer to ensure that the vessel which is going to a particular ship recycling facility has got the necessary infrastructure and approval/authorization from reputed organizations like classification societies so that environmental issues, safety and health of the workers are strictly maintained by that ship recycling facility. After framing the Ship Breaking and Ship Recycling Rules [4], there have been some positive changes in ship breaking industry in Bangladesh. The Norwegian Agency for Development Cooperation (NORAD) is working in Bangladesh for capacity building in ship breaking industry. At the same time, it is necessary to keep an eye on the activities/up gradation of main competitors like India and China. It is no doubt that without achieving the minimum standard complying HKC in terms of health, safety and environmental issues, it is very difficult to stay in this business in near future.

Figure 4 shows China ship recycling capacity from 2005~2012. It is seen than China is expanding its capacity in both shipbuilding and ship recycling industry enormously over the past few years. China has already attained no. 1 position in ship building and they have already reputed as a green ship recycling nation and average global share of ship recycling capacity is around 24% in last three years. Big shipping companies like Danish Maersk and Swedish Stena are sending ships to Chinese Ship recycling yard for taking advantage of green recycling of their ships. On the other hand, Japan has slipped to no. 3 position in global shipbuilding (share now around 17%) and they are experimenting to introduce modern ship recycling approach so that this new technology can be used in the existing shipbuilding capacities which are anticipating to lose competitiveness in near future to China[5].

Indian ship recyclers are preparing themselves to elevate their level to comply with HKC. They have already got centrally operated TSDF (Treatment, storage and disposal facilities) which are mandatorily used by all 160-170 ship breaking yards located at Alang. Some breakers have taken very positive attitude to up grade their level complying with HKC. Class NK is working closely with at least half a dozen ship recycling yards at Alang for the approval of ship recycling facilities. Experts from Japan regularly visit these yards to see ins and outs of the activities related to ship breaking. They analyses the GAP for the specific breaking yard and recommend the additional requirements to comply with HKC and once shipyard fulfill the necessary requirements, they will be certified as HKC compliant ship breaking yard.

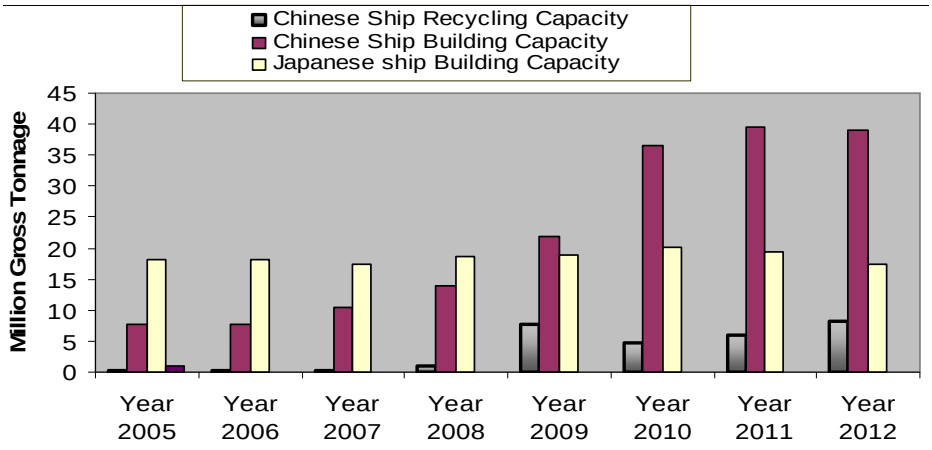

Fig.4: Shipbuilding and ship recycling capacity of China and Japan

6. SWOT ANALYSIS

On the basis of the existing problems, present development and future perspective, strength, weakness, opportunity and threat can be summarized as follows:

Strength • Cheap and available workforce • Bigger yard area • Geographical benefit of big tidal difference	Weakness • Non availability of central TSDF • Lack of awareness about health, safety and environment • Lack of extensive training facilities for workers
Opportunity • Proper infrastructure for handling and disposal of hazardous waste • Requirement to create mass awareness about SHE issues • Up gradate as green recycling industry to ensure sustainable development in the long run	Threat • Non-compliance of rules and regulation • Expansion of Green ship recycling facilities by other countries like China • Long term health hazard and environmental pollutions

7. CONCLUSIONS

Ship recycling in Bangladesh is playing important role for the economy of this country. We should always keep an eye so that its forward movement is not hampered by any upcoming regulations. To hold the position in world ship recycling, there is no other alternative but to upgrade the facility complying HKC in order to move towards green ship recycling practice. On the other hand, it is not possible to comply with HKC overnight. Before going to get facility approval of the yard, it is necessary to fill up all of laggings like infrastructure development for upstream and downstream waste management, health and safety issues of the workers as per green ship recycling practice. If the process can not be started right now, there is a possibility of losing business of ship recycling of Bangladesh in near future.

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A NOVEL EMBEDDED PACKAGING TECHNOLOGY FOR ULTRA-THIN FLEXIBLE RFID CHIPS

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ABSTRACT: The ultra-thin embedded die technology is an enabling technology in microelectronics industry for its ability to produce packages with reduced footprint, low profile, light weight, and conformity. This technology can be successfully utilized in the development of flexible printed circuits to satisfy the demand for reliable and high density packaging solutions with huge market potential such as RFID smart forms, smart labels, smart tickets, banknotes, security documents, etc. Most of the current work in this area is directed toward handling, embedding, and interconnecting the ultrathin chips. Relatively little attention is paid to another critical process step–placing the flexible and very fragile ultrathin die onto the flexible substrate reliably and in a cost-efficient manner, suitable for high throughput assembly. The cost of packaging using LEAP is lower compared to the conventional pick-and-place methods while the rate of packaging is much higher and independent of the die size. Highly flexible and imperceptible dice are possible only at a thickness of less than 50 μm, preferably down to 10-20 μm or less. Presented are results from the experimental study on the electrical performance of ultrathin (≤ 50 μm) silicon dice embedded into a polymer substrate and bumped using three different techniques – electroplating, wire bonding, and sputtering. The reliability of different packages was evaluated through a series of thermal and mechanical cyclic stress tests.

Keywords: Laser-assisted die transfer, ultrathin die, embedded die, ultra-thin chip, flexible microelectronics

1. INTRODUCTION

Advanced microelectronic packaging concepts such as wearable, conformal and sometimes disposable electronics have recently received significant attention in the microelectronic industry. In these types of packages, flexible microchips with a thickness equal or less than 50 μm are embedded into flexible substrates. Embedding of passive and active electronic components into organic substrates has been made possible by introduction of ultrathin chips, offering various advantages such as good electrical performance, miniaturization, and low cost of packaging [1]. Realizations method of embedded chips was first reported by research teams from Fraunhofer IZM and TU Berlin [3, 4]. Later, this technology was successfully demonstrated for fabrication of multi-stacked chip packages [5]. Various die embedding techniques were also developed by research groups in Belgium [6-8], Finland [9], and South Korea [10].

Flexible electronics is still an evolving and highly dynamic area compared to the traditional electronics packaging technology where discrete electronic components are attached to rigid, laminate-based printed wiring boards (PWB) using the surface-mount or pin-in-hole methods. Fabrication of flexible microelectronic packages is a challenging job as mere replacing the rigid board with a flexible substrate does not serve the functionality. The majority of IC packages and other commercially available discrete electronic components are designed for assembly onto a rigid board using pick-and-place equipment. Bulky, heavy and rigid IC packages are not meant to be supported by a thin, flexible substrate. Their use would compromise the ideal property of a flexible electronic device – its flexibility. In order to make a package flexible, the discrete components must be very small in size and flexible. These properties will allow the components to be embedded in the flexible substrate.

Cost is of a paramount importance especially for the disposable electronics. Cost of silicon is often times the largest contributor to the total cost of a disposable electronic device such as an RFID tag

[9]. The cost of the semiconductor die scales with area raised to the 1.5 – 2 power [5]. Therefore, reducing the die size by half would reduce the cost of silicon by a factor of 8 to 16. Cost depends also on the die thickness. Thinner wafers also provide more slices from the ingot which eventually leads to less cost per wafer. The overall cost is also determined by the substrate material. Polyimide, which is an expensive material, is routinely used today due to its excellent electrical and mechanical properties, including high-temperature processing capabilities. Cheaper materials such as PEN or PET can reduce the substrate costs by a factor of 5–10 [10]. The application of these materials demands use of printed conductors instead of etched copper [11].

The objective of this work was to develop a novel method of embedding ultrathin RFID chips into liquid crystal polymer (LCP) substrate to demonstrate a wearable RFID tags that can be easily used for many purposes, namely military applications, smart banknotes, legal documents or even tickets in a bid to stop counterfeiting.

2. LASER-ENABLED ADVANCED PACKAGING (LEAP) TECHNOLOGY

2.1 PRINCIPLES

The Laser-Enabled Advanced Packaging (LEAP) process described in this paper is a unique technology for high-throughput, low-cost contactless assembly of ultra-thin RFID chips onto various rigid and flexible substrates. LEAP has been development at Center for Nanoscale Science and Engineering (CNSE) in North Dakota State University, USA. This technology can easily be used for embedding of ultra-thin chips in the flexible substrates [1]. The target application area includes disposable flexible electronic devices for military use. The additional passive components such as resistors, capacitors, inductors and the power supply can be surface mounted on the top and bottom surfaces of the flexible substrate. All components should be positioned at the middle of the substrate because this is where the neutral plane is located if the bending radii are greater than two times the substrate thickness in order to minimize the tensile and compression bending stresses in the components and conductors.

LEAP is a comprehensive wafer-to-product electronic packaging technology where the die is embedded and the vias are plugged using the tmSLADT and PTF-I methods (described later in the paper), shown schematically in Fig. 1. LEAP is comprised of methods for wafer handling and dicing, substrate preparation, die assembly, die interconnection, and product packaging.

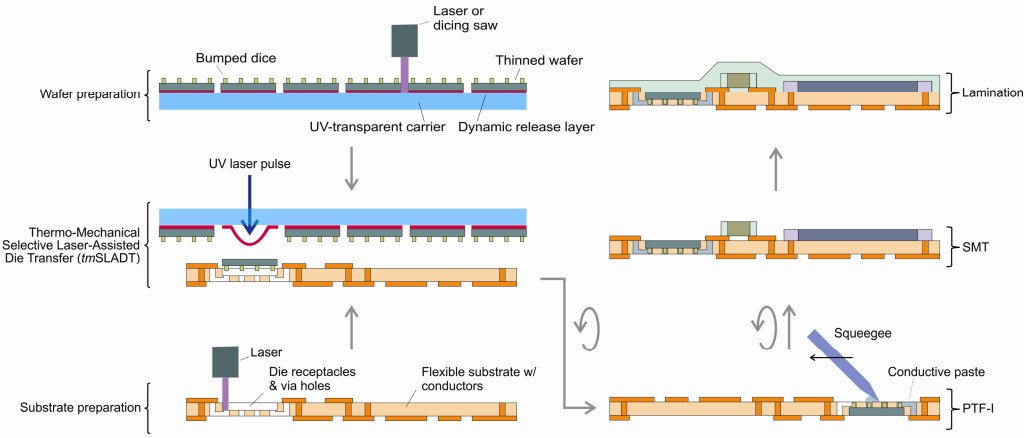

Fig. 1. LEAP process flow.

The LEAP process sequence starts with bonding the thinned RFID wafer to an UV-transparent fused silica carrier so that the circuitry plane faces down with the help of Dynamic Releasing Layer (DRL). Next, the wafer is bumped and laser diced. The diced wafer is now ready for die transfer by the Thermo-Mechanical Selective Laser-Assisted Die Transfer (tmSLADT) method. In a separate operation, die receptor and via holes are laser drilled in the flexible substrate with the patterned conductor lines. After the laser die transfer, the Polymer Thick Film Inlaid (PTF-I) technique is used to plug the through-hole vias with conductive paste and connect the dice to the conductor lines.

Alternatively, the vias can be plugged with stencil printing. The last processing steps include pick-and-place assembly of the discrete components and laminating a conformal coating over the package.

2.2 WAFER PREPARATION

2.2.1 Wafer dicing

Due to the thinness of the dice needed for flexible electronics and the bonding of the wafer to the carrier, stresses induced by the traditional diamond-coated dicing saw can crack the wafer or create microcracks, damaging the circuitry of the dice. The jet of cooling water streaming used in the dicing process could also potentially remove the dice and affect the adhesion of the wafer to the carrier. As an alternative option, Laser dicing can be used which not only reduces the amount of stress imparted on the die, but does not require a jet of water streaming on the sample.

The wafer was scanned 70 times with a high speed (400 mm/s) and high repetition rate (80 kHz), using a flat-top 355 nm HIPPO laser in order to reduce the amount of debris produced. An average power of 3.0 W was used and the pulse energy was calculated as 37.5 μJ. Even though the debris was minimized, a protective coating [2] was applied to prevent debris on the die bumps. A thin layer of photoresist was coated on the wafer, prior to dicing, and was stripped afterwards, shown in Fig. 2.

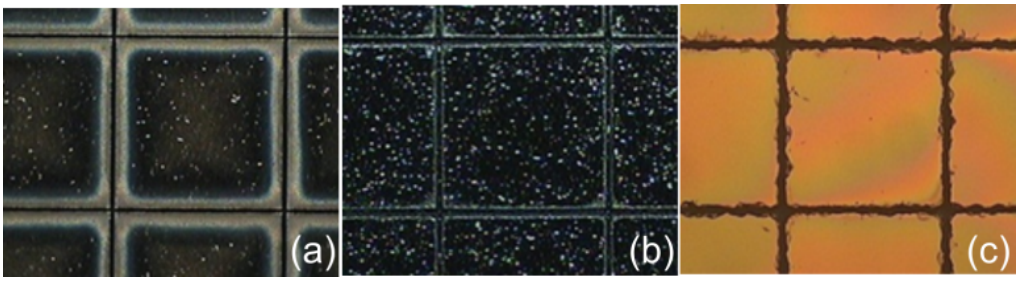

Fig. 2. Optical microscope pictures of (a) the wafer immediately after dicing showing the debris haze around the cuts; (b) the wafer after stripping the photoresist (the dots on the sample are intrinsic to the silicon and were observed before dicing.); (c) the bottom of the wafer after dicing.

2.2.2. Die Bumping

In previous works, it was suggested that the wafer should be bumped prior to thinning [3, 4]. In reality, there is a possibility of damaging the bumps during wafer thinning [5]. Another problem is the difficult control of the thinning process because thicker material is required to support the wafer's front side and protect the bumps [6]. The method used in this wok eliminates this problem by bumping the wafer prior to laser dicing.

2.2.3 Gold stud bumping

Stud-bump bonding (SBB) technology, first developed by Matsushita [7], proved useful and reliable to overcome the thermal stress problem in the microelectronics assembly process. From a design point of view, gold bumps can carry higher currents than solder bumps and can be used for power applications. Stud-bumped dice can be assembled using anisotropic conductive adhesives at ambient or moderately high work temperature that helps reduce thermal damage to the chips. The use of conductive adhesives eliminates solder defects such as flux residues that may cause problems with underfill adhesion and corrosion [8] and still represents the lowest-cost assembly for lower-density products [9]. Kumano et al. [10] reported chip-on-flex (COF) using SBB flip-chip technology. The interconnections between electrodes and the substrate were fabricated as a two-stepped Au bumps using the conventional wire-bonding method.

In our experiments, Au pillars were fabricated using a K&S 8028 wire bonding machine located in a Class 10000 cleanroom. A 25 μm (1-mil) diameter AW-9 Au wire (K&S) was used to make the studs on the 80×80 μm bond pads of a test die. The AW-9 wire was chosen based on the results reported by Wei et al. [8]. They showed that the AW-9 wire has the benefits of wider bonding window, lower force and power requirements, and better bondability than traditional wires. After the initial screening experiments, five parameters (separation height, bump height, smoothing speed, fab diameter, and bond force) were selected for a further optimization study with an objective

maximizing the length of the studs. A 2^5 full factorial design with a total of 32 experiments was carried out with these parameters. Their optimum values were identified and then used to fabricate 76-µm tall stud bumps as the one shown in Fig. 3.

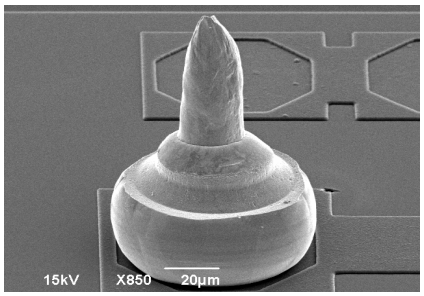

Fig. 3. 76-µm tall Au studs bumped on a test die.

2.2.4 SUBSTRATE PREPARATION

Laser drilling of the through-hole microvias needed to reach the embedded die is a critical process step [11]. In our approach, the via holes were drilled before the die was attached, which simplifies the laser via drilling process significantly. In the package design, the vias that reach the copper conductors are laser drilled as blind vias (Fig. 4a). The substrate preparation started with lamination of the Cu-plated side of the substrate with PC1515 dry-etch film by DuPont. The thickness of the laminate layer was 1.5 mil (40 µm), intended to provide extra thickness to the substrate (50 µm thick) in order to allow the laser micromachining of a 50-µm deep receptor hole for the transferred IC. The process was completed on an Optek Laminator with preset temperature and pressures for 10 seconds preceded by vacuum pull for 25 second.

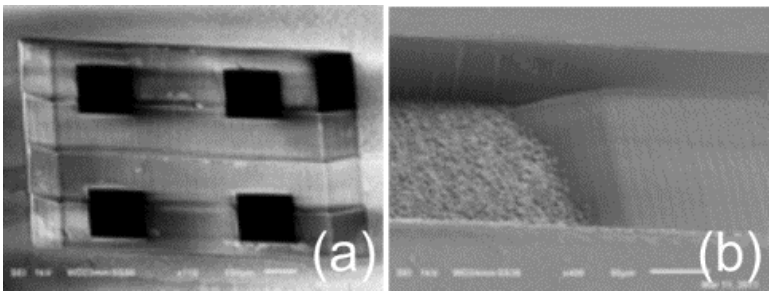

Fig. 4. SEM photographs of (a) a laser ablated receptor hole and vias (top side of the substrate); and (b) a dual step trench on the bottom side of the substrate, showing the exposed through the substrate Cu pad (the grainy area).

In the next step the as prepared "sandwich" was transferred to an Optek short-pulse 248 nm excimer laser system for receptor hole and trench micromachining. Typical ablation parameters were 10 bursts at a rate of 50 Hz with a pulse energy of around 140 µJ measured at the sample stage. Stage speed was set at 100 µm/sec giving ablation rate of about 16 µm per pass in both the substrate and laminate material. The targeted dimension on the bottom of the receptor hole was 740 x 740 µm (die size is 680 µm square). Dual step, 200-µm wide trenches for interconnecting the die to the Cu traces were ablated into the substrate material on the opposite side with varying depth - targeted at 25 µm over the receptor hole and through the whole substrate thickness over the Cu trace in order to expose the copper material as shown in Fig.4b. Vias were drilled in the last micromachining step to connect the receptor hole on one side with the trench on the other. Based on the targeted receptor hole and trench thicknesses the via depth was in the order of 15 µm. Micromachining debris are cleaned in an ultrasonic cleaner for 5 min prior to device fabrication.

2.2.5 LASER-ASSISTED DIE ASSEMBLY

The use of a laser for the transfer and placement of discrete components onto a receiving substrate was first reported by Holmes and Saidam [12, 13]. Recently, LIFT has been applied to the transfer of semiconductor bare dice. Karlitskaya and coworkers have developed a simple model that predicts the

fluence threshold for the release of 200 × 200 µm by 150 µm thick Si tiles adhesively attached to a sacrificial PVC tape [14]. In a subsequent study [15], the authors described similar experiments for laser transfer of 300 × 300 µm by 130 µm thick Si tiles in two distinct modes – ablative and thermal releasing, using a relatively long pulse infrared and green (532 nm) lasers. In a number of publications, Piqué and coworkers have reported LIFT of individual InGaN LED bare dice (250 × 350 µm) using a series of very low fluence UV laser pulses [16], a single-pulse transfer of various electronic components (bare dice and SMDs) with sizes ranging from 0.1 to over 6 mm^2 in area [17-19]and multilayered polymer/metal capacitor stacks [20]. Recently, Sheats [21] has described a process in which, in order to release the die, the release layer is heated up to a temperature of 100 – 150 °C by optically irradiating it with a dose similar to that used in optical lithography. Although this process does not use a laser, it is very similar in nature to the thermal releasing process described by Karlitskaya *et al*. [15].

The basic concept of the technique known as "Laser Induced Forward Transfer" (LIFT) includes using a polymeric sacrificial layer to attach the components to be transferred to a laser-transparent carrier. The sacrificial material coated on the opposite side of the target substrate is heated or ablated by a laser pulse to generate gases that propel the component towards a receiving substrate placed in close proximity. LIFT is a unique contactless technology for placement of small-size individual components on surfaces that may not be compatible with the traditional pick-and-place equipment. It is the most promising, if not the only one feasible, method for a high-volume assembly of small size, ultra-thin semiconductor bare dice. LIFT, if properly controlled, can safely assemble components with footprints of 2.6 × 2.6 mm to 100 × 100 µm and thicknesses as small as 10 µm [22]. It is also capable of much higher speed of placement – 100 components per second compared to 1-2 components per second for the conventional pick-and-place machines [15, 22]. Some of the problems with this technology come from the fact that the laser release process is still not fully understood, therefore, difficult to control in order to achieve the desired results in terms of precision, transfer rate, and die survivability.

In this work, an advanced version of LIFT technique has been invented and applied successfully to realize the flexible package, referred as Thermo Mechanical Selective Laser Assisted Die Transfer (tmSLADT©) technique. The tmSLADT process for placing ultra-thin semiconductor dice provides a distinct advantage over previously proposed LIFT methods by containing, within the two-part Dynamic Releasing Layer (DRL), the volatile plume of gas generated by laser ablation (Fig.5). A laser pulse vaporizes a shallow region of the absorbing/actuating layer which generates a pocket of high pressure gas. The elastic properties of the remaining absorbing/actuating layer and the adhesive layer allow the pocket of gas to expand, forming a blister. This blister response of the DRL provides a mechanical actuator for placing dice on an electronic substrate.

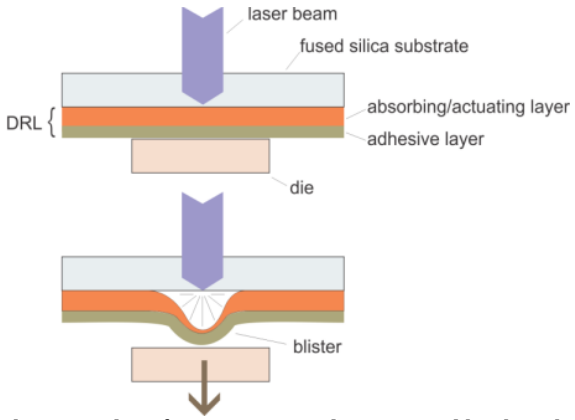

Fig.5. The principles of *tm*SLADT are demonstrated by the schematic.

The tmSLADT is a rapid, more deliberate and repeatable process than the ablative LIFT technique discussed previously. Also, the blister-actuator provides the bonded discrete component with sufficient kinetic energy to overcome surface forces which may hinder the thermal LIFT technique as

die aspect ratios become smaller. Evaluation of the *tm*SLADT concept performed with 65 μm thick Si tiles indicates the non-optimized method is promising for placing ultra-thin dice (Fig.6). A tile transfer rate as high as 90% was observed. A *tm*SLADT median lateral translation of dice after placement, from their initial bonded position, of 50 μm was demonstrated with a 195 μm gap between the releasing and receiving substrates.

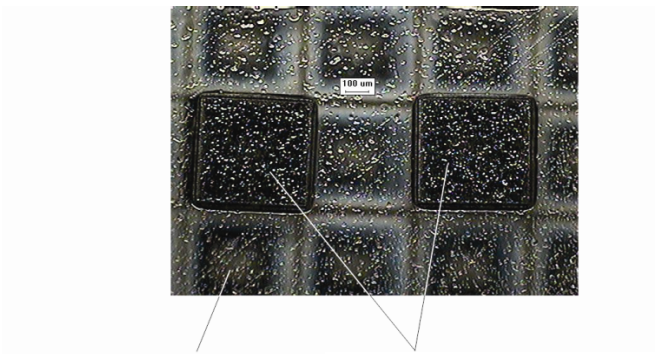

Fig.6. Two 65um thick Si tiles after *tm*SLADT. In this optical photograph the receiving substrate lies in the focal plane. The tiles were transferred from the releasing substrate, which is in the background.

2.2.6 DIE EMBEDDING AND INTERCONNECTION

Interconnection: PTF-I

The ultra-small form factor of the electronic components along with a reliable and inexpensive high-density interconnect technology are the key factors in bringing flexible electronics to the next level of miniaturization without compromising performance and substantially increasing production cost. The common thick-film methods used today to fabricate conductive trace patterns on flexible boards are largely ineffective for resolutions below 50 μm. Thin-film technologies can fabricate high resolution patterns; however, they are prohibitively expensive for the low-cost flexible electronics applications. To address this need, a modified mill-and-fill interconnect technology, referred to as polymer thick film-inlaid (PTF-I) was developed by our team [23, 24], in which trenches with the desired width, depth and configuration are formed and then filled with a conductive paste to produce after curing a high-resolution conductive trace pattern (Fig.7).

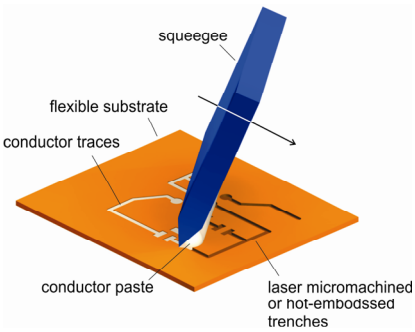

Fig. 7. A schematic illustrating the PTF-I process.

In our proof-of-concept experiments, high-precision conductive traces with an excellent edge definition, linewidths of less than 20 μm and a distance between lines as low as 6 μm were fabricated (Fig. 8). The minimum linewidth was only limited by the laser micromachining capabilities and the size of the metal particulates in the PTF. Arguably, no other thick-film method can match this process's capability for fabricating conductive traces with such high quality, high density, and high precision, at low cost and high throughput. This method is currently under investigation in the Holst

Centre in the Netherlands. This group has demonstrated lines with a width of 50 µm and a thickness of around 30–50 µm [25]. A recent paper by the same group provides more recent results [26].

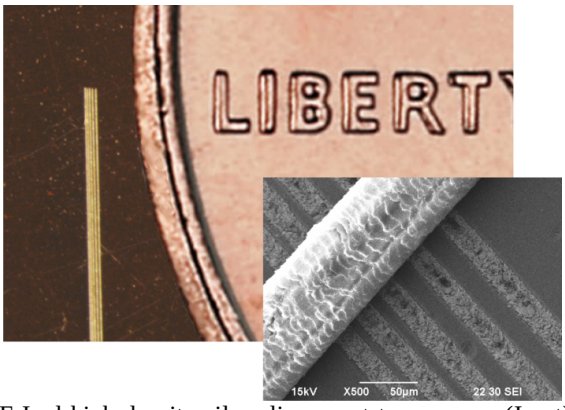

Fig.8. Close-up of PTF-I-ed high-density silver lines next to a penny; (Inset) a high-magnification SEM photograph of the same conductor lines compared to a human hair.

Material

A conductive paste was developed having low electrical resistivity and suitable for application on polymer substrates by the PTF-I method described before. This was achieved by using a mixture of acrylate oligomers as binder, tert-butyl acetate as solvent and micron-sized silver flakes as conductive filler. The use of small size conductive particles was especially important because previous PTF-I experiments with off-the-shelf conductive pastes indicated that small linewidths are possible but only if the particle size was very small [23].

To test the mechanical properties of the material, 25-mm long, 100-µm wide trenches were laser micromachined into a polyimide substrate and PTF-I filled with the paste. 25 samples were prepared and the material was sintered at 150°C overnight after which resistance measurements were taken. The mean line resistance measured was 1.81 Ω with a variance of 0.04 Ω and standard deviation of 0.2 Ω. The substrates were then subjected to bend tests (100 repetitions each) onto a 50-mm diameter mandrel and the resistance was measured after each test. In the first test the Ag filled trenches were facing the mandrel, essentially subjecting the Ag conductor lines to compression and in the second test the trenches were facing away from the mandrel surface thus stretching the Ag material. The measurements after the first and second bend tests showed mean resistances of 1.86 Ω and 1.90 Ω, respectively. The variance and standard deviation were 0.05 Ω / 0.07 Ω and 0.22 Ω / 0.26 Ω, correspondingly. A complete line filling and no cracking or delamination was observed in the lines under optical microscope and SEM imaging (Fig. 9)

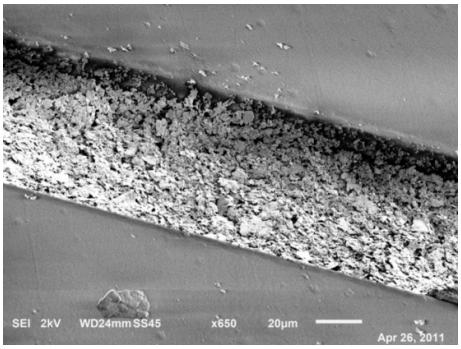

Fig.9. SEM of laser ablated trench in polyimide substrate PTF-I filled with Ag ink after sintering showing no cracking in the material or delamination from the walls of the trench.

2.2.7 Process demonstration

A partial demonstration of the concept illustrated in Fig. 1 was performed utilizing the methods previously discussed in this article. This demonstration was the fabrication of a prototype passive RFID tag with an embedded ultra-thin RFID chip. Copper-etched Alien Technology® Squiggle® RFID tags served as the starting point. The substrate features, including the embedded die pockets and antenna trace interconnects, were laser machined with a 248 nm wavelength Optek excimer laser.

After micromachining the substrate features, the tag was prepared and cleaned according to the methods described in the "Substrate preparation" section. Next, a small bead of Loctite 3627™ die attach epoxy (about 100 µm in diameter) was dispensed at the bottom of the receptor hole. An Alien Technology® HIGGS-3 chip was then laser transferred into the substrate pocket by means of the *tm*SLADT method. The die attach epoxy was then cured at 125°C for 6 minutes after die placement to fix the IC in place. Next, polyimide tape was used to laminate the die in its pocket. Polyimide tape was used for convenience but may be substituted with a different type of material. In the next step, the laser machined trenches were PTF-I filled with the in-house prepared Ag ink and cured at 150°C for 4 hours.

Fig.10. A fully functional flexible electronic device (an RFID tag) fabricated using the LEAP technology.

3. RELIABILITY

For evaluating assembly reliability, the thermal cycling test was conducted in an ESPEC TSD-100 temperature shock chamber according to the specifications of the JESD22-A140C test standard. Cycling took place between +125°C and -55° C with a dwell time of 10 min and a transition time of less than 1 min. The test was accelerated so that the package could be exposed to two full cycles per hour. This particular temperature range was chosen because it is considered as a good benchmark for harsh conditions [27]. A half of the total number of samples, i.e., 45 samples, were mounted to a glass substrate and put in the thermal shock chamber. The packages were affixed to the substrate with Kapton® tape. After 100 cycles, the samples were taken out of the chamber and their resistance was measured again. The packages were dry etched to clean the oxides prior to the conductivity measurements.

The reliability of the packages when subjected to cyclic mechanical stresses was evaluated using the bending test, which involves bending the sample to a given radius r. This test is considered the most direct and appropriate method for evaluating films for flexible electronics [28]. The test was carried out on 45 samples. The samples were taped on a cylinder of 50 mm diameter. The flexible substrate was bent backwards 100 times so that the trenches were subject to compression. Then the substrate was bent forwards 100 times so that the trenches were subject to tension. The resistance measurements were taken after each type of bending.

4. CONCLUSIONS

The embedded ultrathin die packages provide the flexibility and reliability required for the successful implementation of the flexible electronics concept. The laser-enabled "thinned wafer-to-finished product" electronics packaging method reported in this paper is an enabling process that shows promise of overcoming this obstacle and will ultimately contribute to assembling flex substrate electronics with embedded ultrathin dice at significantly lower cost and a higher production rate. The experimental study revealed the importance of embedded ultrathin die bumping to achieve better reliability of the package. The RFID packages were subjected to cyclic thermal and mechanical testing. None of the embedded dice failed the cyclic testing. This result is even more remarkable considering the fact that no underfill material was used when embedding the dice in the flexible polymeric substrate. The geometry of wire-bonded stud bumps provided the most favorable conditions for plugging the via holes and creating a large interface contact area between the conductive paste and die. The results from this study can be utilized in the fabrication of high density flexible microelectronic devices with a wide range of applications in a number of areas. Green biodegradable substrates, moisture-resistant materials and structures, and alternate interconnection methods are some of the possible focus areas for future research in order to improve the commercial potential and the reliability and performance of the embedded ultrathin dice and extend their applications.

ACKNOWLEDGEMENT

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ASSESSMENT OF COMPETITIVENESS AND COUNTRY CONDITIONS FOR LPG MARKET OF BANGLADESH: BY PORTER'S (1998) FIVE FORCES AND NATIONAL DIAMOND MODEL

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ABSTRACT: International business expansion is a complex process. It is important to know overall market situation remarkably competitiveness of the existing companies for a specific product, the country situation and condition where a company wants to invest. These are determinant to know how a market could react for new entrance. The aims of this qualitative research are to explore the competitiveness among existing LPG companies and overall condition of Bangladesh by applying "Five Forces" and "National Diamond Model" of Michael Porter's (1998). Regarding the competitive business environment this research has identified its level and the key factors of existing competition. This research has illustrated that how existing LPG companies utilize their inherent resources and enhances capabilities to compete with other competitors in dynamic and challengeable country condition and environment. This research has also investigated potentiality and opportunity of LPG market such as the demand growth rate, market share, government policy etc. Finally this research has applied the concept of existing market competitiveness to assess required potentiality and strategy for a new company to enter into the market.

Keywords: LPG, Market Competitiveness, Five Forces, National Diamond

1. INTRODUCTION

Before entering into a new market every company makes an assessment about the market and the country. There are many theories from various researchers to conduct assessment of foreign market. To assess and understand internationalization process of business Michael Porter's (1998) "Five Force" and "National Diamond Model" are most popular. These two concepts are regarded as very effective concept to analyze the market and foreign country. Porter (1998) has identified five competitive forces that analyze every industry and every market and these forces determine the intensity of competition and hence the profitability and attractiveness of an industry. Pearce and Robinson (2005) and Johnson and Scholes (2002) mentioned that Porter's model provides an easy and simple approach for industry analyses. This model also provides an opportunity to take important decisions like whether to enter in a particular industry or to leave it. This is also a very simple tool in the hands of strategists to determine the profitability position of a firm. According to Recklies (2001), "Porter's (1998) Diamond Model determines factors of national advantage and it suggests that the national home base of an organization plays an important role in shaping the extent to which it is likely to achieve advantage on a global scale and this home base provides basic factors, which support or hinder organizations from building advantages in global competition". "Porter (1998) focuses on competition or rivalry is a diversion from traditional economic thinking" has been reported by Stone and Ranchhod (2006). Before assessment of competitiveness and country condition this research has investigated the potentiality and opportunity of LPG. It has been found from investigation that presently there are around 2.0 million domestic gas consumers who consume around 10 per cent of the total natural gas production and the annual growth rate of this consumption is 10% (2012). On the other hand petroleum products are continuing to penetrate these rural and suburb fuel market. About 80% of the total imported kerosene is used mainly in rural and suburb for residential cooking, lighting. About 39 million tons (BBS 2003) of fuel wood and tree residues were used for residential cooking. This research has explored that an increase in the supply of LPG could replace the current natural gas, kerosene and gradually reduce the demand for charcoal, fuel wood and others biomass. The main objectives of this research are to assess the market competitiveness and country condition to introduce LPG business here. The market and country assessment works have been conducted by applying Michael Porter's Five Forces and National Diamond Model. This qualitative research has explored the key factors of existing competition and utilization patter of their self resources within this country condition.

2. LITERATURE REVIEW

2.1 The Competitive Environment and Porter's (1998) five forces

The Porter's (1998) five forces model is a simple tool that supports strategic understanding where power lies in a business situation. It also helps to understand both the strength of a firm's current competitive position, and the strength of a position a company is looking to move into. All five competitive forces jointly determine the intensity of industry competition and profitability and the strongest force or forces are governing and become crucial from the point of view of mode formulation (Porter 1998, p6). The five forces are given below

2.1.1 Threats of new entrants (Barriers of Entry)

New entrants to an industry bring new capacity, the desire to gain market share. The threat of entry in an industry depends on height of entry barriers that are present and on the reaction entrants can expect from incumbents (Porter 1998, p8). It is important to assess the barriers while entering in a market, because that could create some problem during the entry. Low entry barriers create high competition in the market and vice versa. There are six major sources of barriers to entry. Economies of Scale: Economies of scale refer to declines in unit costs of a product (or operation or function that goes into producing a product) as the absolute volume per period increases. Economies of scale deter entry by forcing the entrant to come in at large scale and risk strong reaction from existing firms or come in at a small scale and accept a cost disadvantage, both undesirable options (Porter 1998, p7). Product Differentiation: Product differentiation means that established firms have brand identification and customer loyalties**.** Differentiation creates a barrier to entry by forcing entrants to spend heavily to overcome existing customer loyalties (Porter 1998, p9). Capital Requirements: The need to invest large financial resources in order to compete creates a barrier to entry, particularly if the capital is required for risky or unrecoverable up-front advertising or research and development (R&D). Even if capital is available on the capital markets, entry represents a risky use of that capital which should be reflected in risk premiums charged the prospective entrant (Porter 1998, p10). Switching Costs: It is one-time costs facing the buyer of switching from one supplier's product to another's. Switching costs may include employee retraining costs, cost of new ancillary equipment, cost and time in testing or qualifying a new source, need for technical help as a result of reliance on seller engineering aid, product redesign (Porter 1998, p10). Types of switching costs also include exit fees, search costs, learning costs, cognitive effort, emotional costs, equipment costs, installation and start-up costs, financial risk, psychological risk, and social risk. Access to Distribution Channels: A barrier to entry can be created by the new entrant's need to secure distribution for its product. To the extent that logical distribution channels for the product have already been served by established firms, the new firm must persuade the channels to accept its product through price breaks, cooperative advertising allowances, and the like, which reduce profits (Porter, 1998, p10). Cost Disadvantages Independent of Scale: Established firms may have cost advantages not replicable by potential entrants no matter what their size and attained economies of scale. If costs decline with experience in an industry and if the experience can be kept proprietary by established firms, then this effect leads to an entry barrier (Porter 1998, p12). Government Policy: Government can limit or even foreclose entry into industries with such control as licensing requirements and limits on access to raw materials (Porter 1998 pp.12-13).

2.1.2 Bargaining Power of Buyers

The company will have to face a threat from the buyer as the buyers in the market can act as a vital force. Large volume buyers are particularly powerful in industries with high fixed costs when the customers are few in number and switching to another company's product are easy for them and then the customers are considered to be powerful (Porter 1998, pp.28 -32).

2.1.3 Bargaining Power of Suppliers

Suppliers can exert bargaining power over participants in an industry by threatening to raise prices or reduce the quality of purchased goods and services (Porter 1998, p25). When the company is supposed to design their product according to suppliers demand as the suppliers output is unique then the suppliers are considered to be powerful. If number of suppliers is large, then the suppliers become weak as the company have more options (Porter 1998 pp.28-32). The supplier groups become more powerful when it does not depend heavily on the industry for its revenues

2.1.4 Threats of Available Substitute Products or Service
In case of availability of greater substitutes, the firms are not able to raise the price as that could cause the customers to switch to another product. In this situation, the companies are under pressure of reducing the price as there are possibilities of switching (Porter 1998, p32).

2.1.5 Intensity of Rivalry among Existing Competitors:
Rivalry among existing competitors takes the familiar form of jockeying for improve position-using tactics like price competition, advertising battles, product introductions and increased customer service or warranties. In most industries, competitive moves by one firm have noticeable effects on its competitors (Porter 1998, p17). When a large number of existing rivals with equal power while the industry growth is slow, then this can be considered as high level of competitive pressure (Porter 1998, p33). This is only one of several forces that determine industry attractiveness (Porter 1998, p18).

2.2 Home country situation and Porter's (1998) National Diamond Model
Besides potential market the target country play a vital role to take decision of business. The country where the business will be started should fulfill some basic requirements. These requirements are vary with types of business and views. According to Porter (1998, p166), there are four major factors or determinants of national or home-base that create the national environment in which companies can get advantage in particular industries. Each factors of the diamond or the diamond as whole effects the requirements of international success.

2.2.1 Factor Conditions
This refers to the 'factors of production' that go into making a product or service. In this category of factors those affects in competitiveness are a) basic factors- inherited by the nation as a physical (geographic location, natural resources, water quality and climate) and human resources (quantity, skills and costs of workforce) and b) advanced factors – which are created and contribute to achieve higher level of competitive advantage (knowledge resources, infrastructure, available capital

2.2.2 Demand Conditions
According to Porter (1998), demand conditions in a country are also perceived as a source of competitive advantage for a country and demand as a factor explaining trade is not new. The nature of the domestic customers can become a source of competitive advantage. A more demanding local market leads to national advantage. The industry needs to respond the sophisticated home demand by rapid improvement of product.

2.2.3 Related and Supporting Industries
According to Porter (1998), it is the external economies of related and support industry clusters, such as networks of specialized input providers, institutions and the spill-over effects of local rivalry, that become the true source of competitive advantage.. When local supporting industries and suppliers are competitive, home country companies will potentially get more cost efficient and receive more innovative parts and products.

2.2.4 Firm Strategy, Industry Structure and Rivalry
According to Porter (1998) the main emphasis of firm strategy, structure and rivalry is that the strategy and structures of firms depend heavily on the national environment and that there are systematic differences in business sectors in different countries that determine the way in which firms compete in each country and ultimately their competitive advantage. Besides structure and management systems of firms in different countries can potentially affect competitiveness. If rivalry in the domestic market is very fierce, companies may build up capabilities that can act as competitive advantages on a global scale. Porter offer two additional areas from which companies can draw competitive advantages:

2.2.5 Chance
Porter (1998) defines chance events as the ones that have little to do with circumstances in a nation also largely outside of the control of firms. Chance events could be significant shifts in exchange rates, world financial markets, unexpected demand growth in local or international , wars or

decisions taken by foreign governments. Chance plays its role by altering the four main conditions in the diamond model.

2.2.6 The role of Government:
Porter (1998) asserts that the government can have a role in all determinants of national competitiveness, but that the role can be negative as well as positive and that its role will always be partial not sufficient in itself to make a national industry competitive.). This determinant also influences the nature of rivalry of the company within the country. Sometimes government determines the nature of business competition or state intervention in the industry.

3. LPG MARKET OF BANGLADESH

3.1 Demand Growth Rate and potentiality

Till now two feasibility studies regarding LPG as cooking fuel in Bangladesh has been done in earlier. A Canadian company RMT Engineering Ltd conducted a feasibility study in 1989 to determine the demand of LPG in Bangladesh.RMT determine 2,589,600 LPG cylinder potential urban household in Bangladesh in 1995 with a yearly growth rate of 4% and these potential urban per household will use 1.45 cylinder LPG (1 cylinder LPG=12KG) per month. In the year 1995 LPG demand in this country for urban household cooking with a growth rate of 4% over 1989= 2,589,600 x 1.45 x 12.5 x 12/1000 MT = 563,238 MT. A USA based company Martech International Inc was appointed to conduct a feasibility study on the demand of LPG in 1997. Martech has the projected the LPG demand of Bangladesh in the year 1997, 2000, 2005 and 2010 were respectively 675,503MT, 745,124 MT, 889,347 MT and 1,060,656 MT. According to Ministry of Mineral and Energy Resources present LPG demand is 0.5 million ton annually. However current market players official claim it is nearer to 1 million MT. Basundhara LP Gas Ltd estimates that within affordable prices at Tk 400-600 LPG can bring more in another 10,00,000 users within a couple of years and LPG demand will be more than 1 million only for domestics purpose. However there is availability of about 0.1 million tons (MT) of LPG annually. About 90-95% of total LPG is being used for domestics and commercial cooking purpose and rest small portion is being used for light workshops, as autofuel in vehicles. The state-owned LPG bottling company is now supplying 20% of the total market demand, while five private companies import the remaining 80 of LPG.

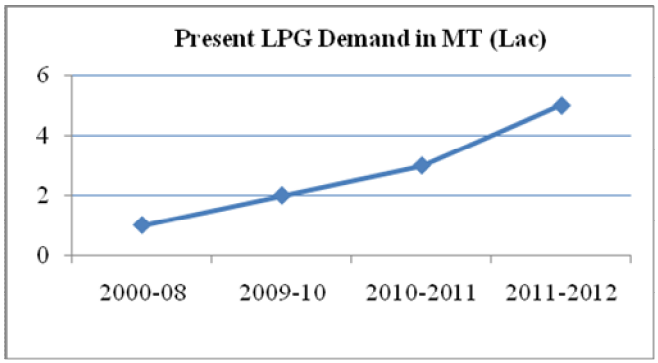

Figure 3.1: Present Demand of LPG
(Source: Bangladesh Petroleum Corporation, Domestic LPG Demand, 2012)

According to population census 2011 the average family size is 4.4. Fifty-four percent of the households were used to cook twice (Morning- Afternoon/Evening) a day. About one third (32%) of the households cooked thrice (Morning-Afternoon-Evening) a day and most of them purchased fuel for cooking. After market survey it has been found that a family consisting of four members consumes 1 to 1.5 cylinders per month. With the increasing rate of urbanization the dependency in LPG increased but it is not only confining in urban area as well as in suburb and rural area also. It has been found that the dependency on piped natural gas, firewood and kerosene is reducing remarkably in urban area. This is happening due to shortage, low pressure and uncertainty for supply of piped natural gas. Besides firewood accessibility is gradually shrinking and the price of kerosene is going up, lack of other fuel options and improvement of more regular cash incomes the popularity

of LPG is increasing rapidly. This country is looking for an alternate fuel to mitigate this cooking fuel crisis.

3.2 Present Market Players

There are 7 companies now involve in LPG bottling business besides two state own LPG production plants. LP Gas Company Limited: This is a state owned public limited company. The LPG plant in Chittagong has bottling capacity of 10,000 MT of LPG per year though its average production is 15,000 MT per year over the last five years. LPG extracted from crude oil fractionation process in Eastern Refinery Limited is the main raw materials of this plant. LPG obtain from Rupantarita Pakritik Gas Company Limited (RPGCL) by Natural Gas liquid (NGL) condensate processing is used in LPG bottling plant at Kailashtila, Sylhet having capacity of 7,000 MT per year. Presently this company has been supplying on an average over 21,000 MT of LPG. Premier LP Gas Ltd: Premier LP Gas Ltd in Bangladesh is a subsidiary of France Company named Total raffling and marketing. It is engaged in LPG import, storage and distribution in the cylinders and in the bulk tanker in Bangladesh under the brand name TOTALGAZ. Kleenheat Gas Limited: Kleenheat Gas is a major stakeholder in a multi-national joint venture between Wesfarmers Ltd of Australia with a 55% holding share, Elpiji Group of Malaysia and Palmal Group of Bangladesh. Kleenheat Gas is brand name of Wesfarmers Limited for marketing and distribution of LPG. Bashundhara LP Gas Limited (BLPGL): Bashundhara LP Gas Ltd is one of the subsidiaries of the Bashundhara Group and the first local private LPG bottling company in Bangladesh. To increase supply of LPG, BLPGL has already signed an agreement with the Malaysian government owned oil and gas company Petronas. BLPGL has targeted to raise our production to 100,000 MT. Linde Bangladesh Limited former BOC (Bd) Ltd is a member of the Linde Group. Recently Premier LP Gas Ltd has bought this plant. Summit Surma Petroleum Company Limited (SSPCL): Summit Surma Petroleum is a unit of the Summit Group of Bangladesh. In the year 2007 Picnic Corporation Ltd, the largest cooking gas producer in Thailand acquired a 90% stake in Summit Surma Petroleum Company with the purchase of shares from Cosmopolitan Traders Private Limited. Picnic will rebrand Summit Surma Petroleum to Picnic Bangladesh and targeting to increase its market share up to 30% within the next several years. SSPCL has projected to sale LPG about 12,000 tons annually. Jamuna Spacetech Joint-Venture Ltd (JSJVL): Jamuna Spacetech Joint Venture Ltd is an Indian-Bangladeshi venture. Spacetech Equipment Structural Limited, India, a Bombay based company, specializing in LPG gas storage tanks and pipelines, owns a 10 per cent share and Bangladeshi company Jamuna Enterprise holds a 90 per cent share in the venture. This company is expecting to meet most of the LPG demand of this country with an annual production of 1.9 million LPG filled of 12.5 kg and rest amount to export to neighboring country. Table shows present LPG production, capacity, market share, types of various LPG Company.

Table 3.1: Production capacity and market share of LPG Company

Sl	LPG Company	Capacity MT/Year	Current Production MT/Year	Market Share %	Type
1	Bashundhara LP Gas Limited	36000	30000	33.33	Local Private
2	Kleenheat Gas Limited	15000	15000	16.67	Joint Venture
3	LP Gas Ltd	23500	21000	23.34	Public
4	Premier LP Gas Ltd	50000	12000	13.33	Foreign Private
5	Summit Surma Petroleum Ltd	12000	8000	8.89	Joint Venture
6	Jamuna Spacetech Joint-Venture Ltd	8000	4000	4.44	Joint Venture
7	Linde Bangladesh Limited	5000	0	-	Foreign Private
	Total	**149500**	**90000**	**100**	

Source: Bangladesh Petroleum Corporation, 2012

3.3 New Project of BPC and new license for LPG business

Steps have been taken to build liquefied LPG storage and bottling plant by the governments at Mongla with the production capacity of 100,000 tons per year based on imported LPG from the international market (BPC). Besides, the BPC has recently started to build another LPG plant under Public Private Partnership (PPP) at Kumira near Chittagong seaport with 100,000 tons yearly capacity. Government consents to give 22 new licenses to private entrepreneurs to set up LPG bottling plants (BPC). Most of the companies that got license for LPG bottling plant have no experience in the LPG bottling or LPG related business. There is also absence of technical knowhow and no experience to conduct of any LPG plant. Most of these firms are fully dependent and seeking bank loans for installing the plant which is very time consuming and a long run process. The information also found that some of these companies are even trying to sell the licenses. Few companies have advanced in LPG project they are: Few companies have advanced in their LPG project such as Omera Petroleum Ltd, Index Power & Energy Ltd, Orion Group.

3.4 LPG business related Supporting Company

LPG cylinder, valve, seal, hose, regulator and many types of equipment related to bottling plant are integral parts for LPG business. Beside local and international technical supporting companies are also available here and many renowned international companies have their office and service station. There are three manufacturing plants in the country to produce LPG cylinders and few local company produce valve, seal etc that maintain international standard. Large portions of the equipments are imported by many companies and so there is availability of all of these parts. Few local companies import cylinder from China, Brazil etc. The LPG cylinder manufacturing companies are following. T. K. Gas Cylinder Ltd is one of larger cylinder manufacturing company currently produces 400 cylinders every day but it has capacity to produce 300,000 LPG Cylinder per year. Bashundhara Steel Complex Limited (BSCL) has installed production capacities of 100 thousand cylinders of different size a month. It is also expected that the existing LPG marketing companies will get sufficient cylinders for enhancing the supply of the LPG at the market and rest excess cylinder will be exported to the north-east region of India, Nepal, Bhutan and Sri Lanka. JamunaSpacetech JV produces 600 cylinders a year. They have also plan to increase production.

4. ANALYSIS AND RESULTS

4.1 The Market and Porter's (1998) five forces

In spite of having a high demand of LPG more than 0.5 million MT annually only about 0.1 million MT is available. Therefore, there is an acute crisis of LPG in existing market. Production in economies of scale create a strong barrier for entry of a company as LPG has been imported from overseas country and large quantity production can reduce price. To involve in competition there is no way instead of reducing price of LPG. Therefore, production in economies of scale will force any company to enter into this market with a large production capacity. In this present market situation no impact of branding has been found and till now people are not interested and conscious about LPG brand but they are concern for cheap price and availability. Remarkable evidence of customer loyalty to any LPG brand has not found so product differentiation cannot create a high impact in entry. LPG handling terminals and bottling plants are builds with high technology along with a huge amount of capital investment is required. Besides to survive in the market there may requirement of expansion of plant size and capacity in future which lead to more investment. Such kind of huge capital investment for LPG business offers a big challenge and matter of anxiety to start business. All types of unrecoverable cost associated with installations of equipments, land and factory infrastructure development, ancillary equipment, contract, transport, salary and training have made switching cost very high for any company. The requirement of high initial cost to start LPG production which is unrecoverable creates a high switching barrier for entry decision. Distribution system of LPG is very easy in this country and all company possesses their own distribution channel and transport vehicles. Beside there are also few independent LPG carrying lorry supplier that can be hired on trip basis. Good communication system makes the business easier but bad transport infrastructure create a little bit suffering for distribution system. Company which has no previous LPG business experience will be affected by the factor of cost disadvantages independent of scale. Existence of multinational experienced companies offers barrier of cost disadvantage independent of scale and few companies are enjoying a little benefit from government organization for location and raw materials. Most of them have already gathered a good experience of LPG business and familiar

with social environments. Company that has previous LPG business experience can easily overcome those factors by self business strategy, experience of cost minimization etc. Government policy of Bangladesh is very liberal and always welcomed for entry of a foreign company. After all present condition shows that sufficient supply and lower price can be a crucial mode to grasp the market. Due to shortage of LPG supply and unavailability substitute of cooking fuel in the market the bargaining power by customer is low. Price of all fuel such as kerosene, biomass are increasing. There is also shortage of cooking fuel. Price of petroleum fuels, electricity and gas is regulated by Energy Regulatory commission of Bangladesh and these fuels are highly subsidized. However, in case of LPG there is no price restriction and any company can have their own price plan. Government does not give any direct subsidy for LPG. Present situation has compelled people to buy LPG with high rate.

Except raw LPG only cylinder, regulator valve, hose pipe, clamps etc are main component that distinctly related to LPG business. There are three large LPG cylinder manufacturing plant along with many importers import cylinder and other accessories from foreign country. Besides pressure regulator valve, hope clamp etc importers, suppliers and manufacturer are available in this country. Presence of available local and international suppliers have made the bargaining power of the suppliers is low in this LPG market. Besides only 7 companies are exist in this market which makes the supplier weaker and suppliers are fully depends on those companies. There is no strong influence that can be created yet by supplier in price, production quality, design etc.

Banned and shortage of natural gas connection, lower per capita electricity production, absence of uses of solar energy, high price of kerosene, unavailability of biomass has created limited scopes of substitute fuel especially in town and suburb. About 66% increase of LPG demand between the FY 2011 to 2012 indicate that there is not availability of substitute. Besides present LPG companies are not capable to meet the present demand of LPG.

There are 8 LPG bottling plants of 7 companies are existing in this current market. Recently 22 new companies have got license for LPG business but they are long far from entering into market within few years. A local company Bashundhara LP Gas Limited is the highest market share holder in Bangladesh (33.33%) which is almost one third of the total market. However, presence of international LPG giant player TOTALGAZ, Picnic Corporation Ltd, Kleenheat Gas Ltd has made this sector more challenging. Each company deserves the capacity to invest more, can increase their production and capable to bring a rapid change in strategy of business and in price. State owned company LPGCL sells LPG cylinder within very cheap price comparatively from others private companies. Being a least developing country most people are price sensitive so there is limited scope to gain high profit by increasing retail price too much high. For a little price difference people will prefer to buy the low priced LPG. As an example LPGCL sell a 12.5 kilogram cylinder to dealers at Tk.631 and retail price is TK.800 within 40 KM range of a depot but others company's cylinder retail price is more than TK.1500. These existing 7 competitors in the market have made high possibility of substitutes of similar product and high competitions. At a glance the strength of Porter's (1998) five forces are given in table:

Table 4.1: Porter's (1998) five forces analysis

Five forces	Strength
Entry Barriers	Moderate
Bargaining power of customer	Low
Bargaining power of suppliers	Low
Availability of substitute	Low
Existing competitive pressure	Moderate

4.2 The Country and Porter's (1998) National Diamond

Applying Porter's (1998) National Diamond theory it has found that Bangladesh has a preferable factors condition. Geographic position makes this country very lucrative for business person and world politics. It can play vital role as a business zone and economy of south Asian countries. However, small and large natural calamities almost visit this country but overall climate is very good as it is in tropical zone. About 33.35 millions (2008) industrial labor force has created availability of

cheap and highly competent skilled labor, technical person. Wide range but bad infrastructure of road transport system relatively good water and air ways offers a good probability to conduct business. Tele communication infrastructure is very good.

Demand condition in the country seems to be very high. Having a population of 150 million, 522 urban centers containing 23.39% of total population and 32.17 million household is showing a great opportunity of LPG for domestic purpose only. Presently more than 0.5 million MT of LPG demand with a good increasing rate of consumer is showing the smooth growth of the market. From the feasibility study of Martech international Inc it was estimated that the demand will be 1 million in the year 2010. Authorities of all private LPG bottling companies also claim that actual demand is more than 1 million. Even though per capita income is low, it could not create any obstacle in the growth of the LPG demand. It is becoming a dire need in the town and city because people want to switch fuel and to enjoy cost effective, health and environmental benefit from LPG. The popularity of LPG is spreading rural area also.

There is availability of related and supporting industries and suppliers of LPG business in Bangladesh. Adequate LPG business supporting companies are able to provide the producers with extra competitive advantages and opportunities to run LPG business here. The main supporting industries with LPG industry are: logistics, energy, equipment manufacturer, IT, banking and finance, insurance, business consulting and environmental services. A good number of giant multinational companies are providing technical support. Kosan, ABB, Siemens as well as many Chinese and local companies are playing a vital role by providing a huge technical support to all local companies. Homemade and imported world class cylinder and others element such as hose, seal, regulator etc manufacturer and suppliers are available. T.K, Basundhara, Spachtech are producing world class cylinder and their production capacity enough high to export excess cylinder to neighboring country. Others supporting industries are playing a very important role for the overall development of the LPG sector. Existence of developed network of dealer and suppliers in the country makes it possible to offer less competitive environment.

In the LPG market there are 7 companies competing themselves to capture market share and lowering product costs as well as to take advantage on the market with lowering prices. This competition forces them to introduce and change mode, compel them to adopt new production plan and increase production capacity. They are alert enough to response with the change in market demand. Presently LPG sector is dominated by local companies holding about 60% of total market share. Presences of few numbers of multinational giant companies have created more competition among existing companies and difficulties of starting business, more capital investment. They are enjoying fast turnover of invested capital compared to other products. The private-operated firms are developing very fast but lack of huge capital and technological knowhow most of them have desired to start joint venture. Present existing companies are mainly focused on the domestic market and few companies are expected to expand it in south Asia. Existing rivals are pushing each other to lower costs, improve quality, innovation of modes and the prospects for international expansion, success. Existing firms have their own variety of structures and modes. The social structure of this country might be able to have an effect on the management style.

This country is suffering from energy crisis and banning of piped natural gas connection, lower alter fuel options, high price of kerosene and shortage of biomass fuel providing LPG sector a huge chance to growth. The government of Bangladesh has made energy policy where a lot of emphasis on the importance of the development of private sector and private investment for LPG. Present energy policies are very reasonable, convenient and give a great support for the development of the emergence of new technologies or investments of foreign companies in the Bangladeshi market. Recently the government has announced a reduced, reform taxes and import regulations, in order to stimulate the growth of the private sector and foreign investment in LPG sector. High import duties and a tax structure that constrain the growth and development of the private LPG sector in Bangladesh are minimized. Bangladesh had been experiencing a slow development in terms of LPG growth in last decade. This may due to availability of biomass, low income, unconsciousness, lower living standard and illiteracy. However, in last few years the demand of LPG has increased in a unique rate as cooking fuel. Considering present energy crisis and as an alternate cooking fuel the government provides a favorable fiscal environment for LPG business. This favor helps to get fast

returns on this investment through rapid growth of LPG demand. LPG consumption at rural household in Bangladesh is limited but in the urban, suburb household and restaurants the demand is 0.5 million MT though there is no subsidy on LPG retail price. Reductions in taxes and duties about 3% from 15% also no tariff barrier with the inherent benefits of using LPG will make it enable to become a more competitive fuel leading to economic growth. Present policy of government is very suitable for the company that wants to invest in this country as policy has made easy entry facilities and many rational options.

5. CONCLUSIONS

The objectives of this research are to know present competitiveness and country situations for LPG business. Michael Porter's (1998) five factors have been applied to assess competitive environment of the LPG market and it has found that all the factors such as entry barriers is moderate, bargaining power of customer is low, bargaining power of suppliers is low, availability of substitute is low and existing competitive pressure is moderate. Generally the stronger the power of buyers and suppliers the stronger the threats of entry and substitution, the more intense competition is likely to be within the industry. Realizing the nature of each of these forces an organization can take necessary insights to enable them to formulate the appropriate strategy also to be successful in their market. Michael Porter's (1998) national diamond model has been analyzed to assess the country condition. These four major factors or determinants such as: factors condition, demand condition, related and supported industries and finally firm's structure, strategy and rivalry shows positive aspect for which a LPG company can takes decision to start business and conduct business in Bangladesh. From the overall points of view this research found that price and adequate supply of LPG are the key factors of present competitiveness. After analysis all data, it reveals that future of LPG is very bright and LPG market of Bangladesh is very potential. Present energy demand situations, government policy, moderate competitiveness among LPG companies are ensuring a good prospect to invest in LPG sector.

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AN ANALYTICAL MODEL FOR SINGLE UNIT HEAVY TRUCK ROLLOVER ACCIDENTS IN BANGLADESH

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ABSTRACT: Run-Off-Road (ROR) crashes have always been a serious safety concern around the world as they account for a large number of fatal crashes and fatalities each year. Running off road may occur as an aftermath of single vehicle accident or any other accidents. Single vehicle ROR accident results in either overturning on the shoulder or hitting off road objects. Accident data analysis shows that in Bangladesh, more than 21% overturning accident involves heavy trucks. Drivers are often blamed for these accidents due to reckless driving. But it is not as simple. Overturning of vehicles is due to the result of complex interaction among vehicle loading pattern, speed, road geometric features etc. Considering these facts, a rollover model is developed which correlates special vehicle loading features such as loading width, height and load shifting with overturning accident in terms of rollover threshold. This paper highlights the model development process and model analysis.

Keywords: Heavy Truck, Rollover model, Loading height, Load shifting

1. INTRODUCTION

Road traffic accidents and the consequent deaths are the most concerning issue in the transportation sector of the world. Being a developing country Bangladesh is not an exception. The road safety situation in Bangladesh is very severe by international standards. It has been rapidly deteriorating with increasing number of road accidents as well as deaths. Rapid growth in population, motorization and urbanization has a direct consequence on road accident. Accident and casualty statistics of 13 years (1998-2010) shows that among various types of accidents overturning accident is about 9% of total accidents and is responsible for 15% of total fatalities. Heavy vehicles usually buses and heavy trucks are mostly involved in this type of accident. More than 21% overturning accident involves heavy truck (1). (2) stated in his thesis that Single vehicle run-off-road (ROR) crashes involve vehicles that leave the travel lane and encroach onto the shoulder and beyond and either overcorrects, overturn, hit one or more of any number of fixed or non-fixed objects, or otherwise result in a harmful event to the vehicle occupants or other persons. According to road accident classification system in Bangladesh, overturning off road and hit object off road fall in the category of ROR crashes as stated. Analysis in Microcomputer Accident Analysis Package (MAAP5) demonstrates that overturning of vehicles to the left of carriageway on straight road comprises of about more than half of the single vehicle ROR crashes in Bangladesh (1). In this writing only overturning to the left on straight road is termed as rollover and considered for modeling.

2. MOTIVATION BEHIND MODEL DEVELOPMENT

According to the Accident Report Form (ARF), excessive speeding and reckless driving (both are related to driver's behavior) are the prime causes of rollover type ROR crashes. Actually, these two

are the general causal factors behind every road accident. As the accident reporting system in Bangladesh as well as the ARF is lacking specific geometrical data like height of shoulder drop-off, pothole depth etc. and vehicle related data like loading height, width etc., it necessitates rollover accidents to be analyzed analytically.

Rollover of vehicles may not be the sole result of driver performance, rather it is due to the result of complex interaction among vehicle loading pattern, tire characteristics, improper super elevation, cross slope, shoulder drop off, vehicle speed etc. Vehicles with high centre of gravity (CG) are more prone to rollover accident. The lower the position of CG the lesser is the chance to overturn. The location of CG of a vehicle largely depends on the loading height and weight. Heavily loaded vehicles with high height usually have higher CG. While the vehicle is in motion, it undergoes continuous jerking and vibration effect from the potholes and rough road surface. If the loading is loosely fastened and is of high height, bulging and shifting of load occurs. Due to this, the horizontal component of CG gradually shifts towards the direction of roadway slope that makes a vehicle more prone to overturn.

Shoulder drop off is another factor to rollover. It can reduce vehicle stability and impede a driver's ability to handle a vehicle. When left wheels go onto the shoulder, the drop-off causes load difference between left and right tires. In effect, the resultant moment increases due to tilting of vehicles. Consequently a rollover moment develops.

Considering these facts, an analytical model is developed which relates these factors with rollover of heavy truck and presented in this paper.

3. DERIVATION OF THE MODEL

The model is based on the 'Quasi-Static Rollover Model'; a fundamental model in vehicle dynamics. The quasi-static model deals with rollover threshold while the vehicle is in a steady state turn. Gillespie (1992) explains the pros and cons about the model. According to the model, rollover threshold is a function of the 'Track Width' and the 'Center of Gravity Height' in the case of 'Rigid Vehicle'. It is expressed as 'Static Stability Factor (SSF)'.

$$\textit{Rollover Threshold or SSF} = a_y / g = T/2h \quad (1)$$

Where is a_y the lateral acceleration, g is gravitational acceleration, T is track width of vehicle and h is the centre of gravity height of the vehicle

To determine and quantify the effect of 'Shoulder Drop-off' with/without pothole on it and the effect of 'Bulging/shifting of Loading' on rollover threshold, some extra parameters are included in the model.

Let us assume that a heavy truck is moving forward on the left lane. At any instant of movement, the driver of the truck rotates the steering to the left to avoid any surprised situation, to give way to overtaking vehicle, or to avoid side friction from the opposing vehicles. This situation is illustrated in Figure 1 as position (1). For the steering to the left, the front left wheel encroaches onto the shoulder [position (2)]. At this moment, the driver abruptly rotates the steering to the right to re-enter to its original path [black color front wheel in position (2)]. Meanwhile the rear left wheel also goes on shoulder [position (3)]. At position (3), lateral acceleration develops due to the cornering forces and it acts in the opposite direction of turning (in this case to the left). Figure 2 illustrates the forces and reactions acting on a heavy truck while the vehicle is in position (3).

According to the Figure 2, the cross slope angle with horizontal is α and the shoulder slope angle with horizontal is β. The height of loading above the carrier is 'b'. The loading expands in both side of carrier with distance 'a' and hence the total freight top width is w+2a. Let us assume that for bulging, the left portion of loading is shifted '2a' distance towards left from previous position. The right side of the loading is also moved '2a' towards left. For simplification of calculation, the side of the actual loading is assumed straight and after bulging, the shape is assumed semi parabolic. The centre of gravity of the body is designated as CG'. Though initially the centre of gravity lies at the mid of the loading width, for bulging of loading, it is shifted x' distance towards left from the mid-

track position. The new position of CG is calculated with the help of center of gravity theorem of composite body.

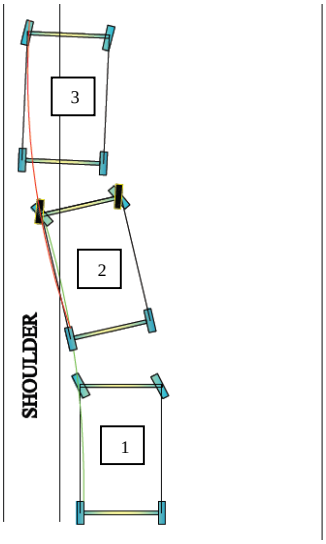

Fig.1: Schematic Diagram of Vehicle Leaving off and Returning to Roadway

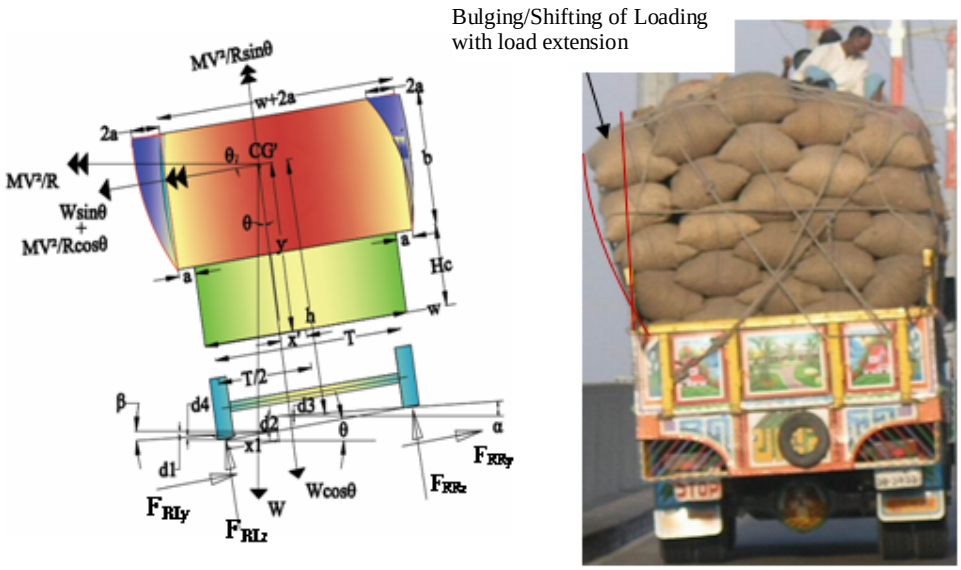

Fig.2: Forces and reactions of a heavy truck in rigid vehicle model (left) and bulging/shifting of load on a truck (right)

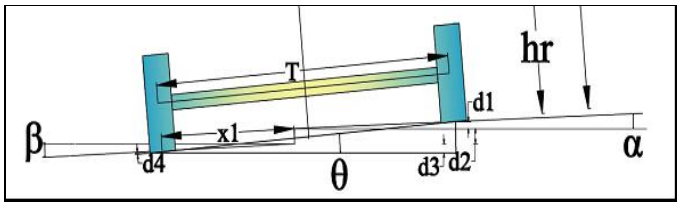

Fig.3: Calculation of inclination angle

The weight (W =mg) of the truck acts vertically downward through the CG. The weight and the lateral force (MV^2/R, where R is the radius of turning) are divided along and vertical to the roll plane (the plane connecting left and right wheels). Taking moment at contact point of left tire, we get,

$$[W.\cos\theta - (MV^2/R).\sin\theta].(T/2 - x') - F_{RRz}.T - [W.\sin\theta + (MV^2/R).\cos\theta].h = 0 \quad (2)$$

Where,
h = y' + height of truck bed form level ground
Inclination angle (θ) is calculated using Figure 3,
$\sin\theta = (d1 + d2 + d3 + d4) / T$
$\Rightarrow \theta = \sin\text{-}1[((T - x1)\sin\alpha + x1\sin\beta + d2 + d4) / T]$
At the instant when overturning is about to occur, $F_{RRz} = 0$, equation (2) can be written as,
$[W.\cos\theta - (MV^2/R).\sin\theta].(T/2 - x') - [W.\sin\theta + (MV^2/R).\cos\theta].h = 0$
$\Rightarrow [Mg.\cos\theta - (Ma_y).\sin\theta].(T/2 - x') - [Mg.\sin\theta + (Ma_y).\cos\theta].h = 0$ [As V^2/R is the lateral acceleration]
$\Rightarrow g.\cos\theta.(T/2 - x') - g.\sin\theta.h = ay.\sin\theta.(T/2 - x') + ay.\cos\theta.h$
$\Rightarrow a_y/g = [\cos\theta.(T/2 - x') - h.\sin\theta] / [\sin\theta.(T/2 - x') + h.\cos\theta]$

Dividing both side by cos θ yields

$$a_y/g = [T/2 - x' - h.\tan\theta] / [h + (T/2 - x').\tan\theta] \quad (3)$$

The term a_y is the lateral acceleration in g's and usually known as the 'Rollover Threshold'. This equation establishes the critical overturning criteria.

Implication of Critical Overturning Criteria:

- Comparing with rollover threshold of quasi-static rigid body model (equation 1), the numerator of equation (3) clearly shows that it is less than T/2; at the same time, the denominator indicates that it is of larger value than h. Therefore the rollover threshold of this very model is obviously has a lower value which indicates higher probability of overturning.
- The larger the inclination angle, which is positively related to shoulder drop-off, the lesser is the value of rollover threshold.
- The greater the horizontal shift of centre of gravity, the lesser is the value of rollover threshold.

Theoretically, rollover occurs when Overturning Moment, MO > Stabilizing Moment, MS. Little change in inclination angle, cg height or horizontal shift of cg from the equilibrium state may lead to a rollover. Overturning moment and stabilizing moment are calculated using the following equations according to Figure 2.

$$M_O = [W.\sin\theta + (MV^2/R).\cos\theta].h$$
$$M_S = [W.\cos\theta - (MV^2/R).\sin\theta].(T/2 - x')$$

Where R is the radius of turning and is calculated using 'Cornering Equation' of vehicle dynamics for a given values of gross weight and speed as described by Gillespie (1992).

$$\delta = 57.3(L/R) + (W_f/C_{\alpha f} - W_r/C_{\alpha r}) * V^2/Rg$$

where,
δ = Steering angle at the front wheels (deg), W_f = Load on front axle (lb), W_r = Load on rear axle (lb), $C_{\alpha f}$ = Cornering stiffness of the front tires (lb/deg), $C_{\alpha r}$ = Cornering stiffness of the rear tires (lb/deg), L = Wheel base (ft), R = Radius of turn (ft), V = Vehicle speed (fps), g = Gravitational acceleration (32.2 f/s^2)

4. MODEL ANALYSIS AND RESULTS

To determine the effect of loading height and overloading condition based on whether the vehicle overturns or not and to get the value of rollover threshold, calculations are performed in MS Excel 2007. For the calculation purpose, initial values are so chosen for some model parameters that those would fall in the range of current practice and trend in Bangladesh.

- Roadway crowning is assumed to be 3% i.e. cross slope angle, α = 1.72 degrees
- Shoulder slope is assumed to be 5% i.e. shoulder slope angle, β = 2.86 degrees

- Shoulder drop-off is assumed 4 inch
- Overall height of vehicle is included as variable with values 12 ft (3.65 m) to 17 ft (5.2 m) considering Bangladeshi practice.
- Wheel track, width of vehicle and wheelbase is selected as per standard dimension (Baseline Vehicle is TATA LPT 1613).
- Carrier height is chosen as 4 ft (1.2 m).
- To determine the value of radius of turn of the wheels, steering angle at front wheel is assumed 5°.
- Four types of loading condition are chosen for the model; one for standard vehicle with GVW 35640 lb (16.2 ton) and three others are overloaded vehicle with GVW 55000, 66000 and 77000 lb (25, 30 and 35 ton respectively).
- Speed is chosen as 25 ft/s (27.5 km/h).

Table 1. Summary of the Model Analysis

	Gross Vehicle Weight 16.2 Ton					Gross Vehicle Weight 25 Ton				
	Overall Height (ft)	Rollover Threshold a_y/g	Overturning Moment (in-lb)	Stabilizing Moment (in-lb)	Rollover Occurs (Y/N)	Overall Height (ft)	Rollover Threshold a_y/g	Overturning Moment (in-lb)	Stabilizing Moment (in-lb)	Rollover Occurs (Y/N)
Load Extension = 0 inch	12	0.298	927169	1576145	N	12	0.282	1594863	2260436	N
	13	0.280	972085	1531260	N	13	0.263	1679340	2176000	N
	14	0.264	1016967	1486409	N	14	0.246	1763772	2091610	N
	15	0.249	1061816	1441590	N	15	0.231	1848158	2007265	N
	16	0.235	1106632	1396804	N	16	0.217	1932501	1927731	Y
Load Extension = 1 inch	12	0.293	928467	1551342	N	12	0.277	1597777	2216245	N
	13	0.275	973510	1503215	N	13	0.258	1682591	2126000	N
	14	0.259	1018475	1455828	N	14	0.241	1767270	2037054	N
	15	0.244	1063375	1408978	N	15	0.225	1851842	1949042	N
	16	0.230	1108220	1362530	N	16	0.211	1936327	1899027	Y
Load Extension = 2 inch	12	0.289	929699	1525942	N	12	0.272	1600612	2170965	N
	13	0.270	974858	1474585	N	13	0.253	1685754	2074922	N
	14	0.254	1019896	1424688	N	14	0.235	1770676	1981451	N
	15	0.239	1064841	1375833	N	15	0.220	1855433	1889813	N
	16	0.225	1109710	1327752	N	16	0.206	1940061	1869794	Y
Load Extension = 3 inch	12	0.284	930869	1499965	N	12	0.267	1603378	2124629	N
	13	0.265	976134	1445392	N	13	0.247	1688843	2022801	N
	14	0.249	1021239	1393009	N	14	0.230	1774006	1924839	N
	15	0.233	1066224	1342179	N	15	0.214	1858948	1844281	Y
	16	0.220	1111112	1292494	N	16	0.200	1943721	1840060	Y
	Gross Vehicle Weight 30 Ton					Gross Vehicle Weight 35 Ton				
	Overall Height (ft)	Rollover Threshold a_y/g	Overturning Moment (in-lb)	Stabilizing Moment (in-lb)	Rollover Occurs (Y/N)	Overall Height (ft)	Rollover Threshold a_y/g	Overturning Moment (in-lb)	Stabilizing Moment (in-lb)	Rollover Occurs (Y/N)
Load Extension = 0 inch	12	0.277	2048787	2569111	N	12	0.274	2617946	2753930	N
	13	0.258	2160513	2457398	N	13	0.255	2764907	2685880	Y
	14	0.241	2272244	2345679	N	14	0.238	2912102	2685820	Y
	15	0.226	2383984	2308966	Y	15	0.222	3059540	2685757	Y
	16	0.212	2495735	2308970	Y	16	0.208	3207232	2685692	Y
Load Extension = 1 inch	12	0.272	2054113	2512382	N	12	0.269	2629621	2680559	N
	13	0.253	2166599	2393092	N	13	0.249	2778621	2650938	Y
	14	0.236	2278956	2277167	Y	14	0.232	2927635	2647652	Y
	15	0.220	2391229	2275004	Y	15	0.216	3076748	2644983	Y
	16	0.206	2503451	2273219	Y	16	0.202	3226019	2642768	Y
Load Extension = 2 inch	12	0.267	2059440	2454195	N	12	0.263	2641685	2623363	Y
	13	0.247	2172701	2327314	N	13	0.244	2792850	2615116	Y
	14	0.230	2285703	2244662	Y	14	0.226	2943812	2608625	Y
	15	0.214	2398533	2240355	Y	15	0.211	3094732	2603377	Y
	16	0.200	2511249	2236808	Y	16	0.197	3245718	2599041	Y
Load Extension = 3 inch	12	0.262	2064786	2394583	N	12	0.258	2654192	2590789	Y
	13	0.242	2178844	2260102	N	13	0.238	2807665	2578452	Y
	14	0.224	2292515	2211480	Y	14	0.221	2960724	2568775	Y
	15	0.209	2405927	2205052	Y	15	0.205	3113601	2560976	Y
	16	0.195	2519165	2199771	Y	16	0.191	3266455	2554550	Y

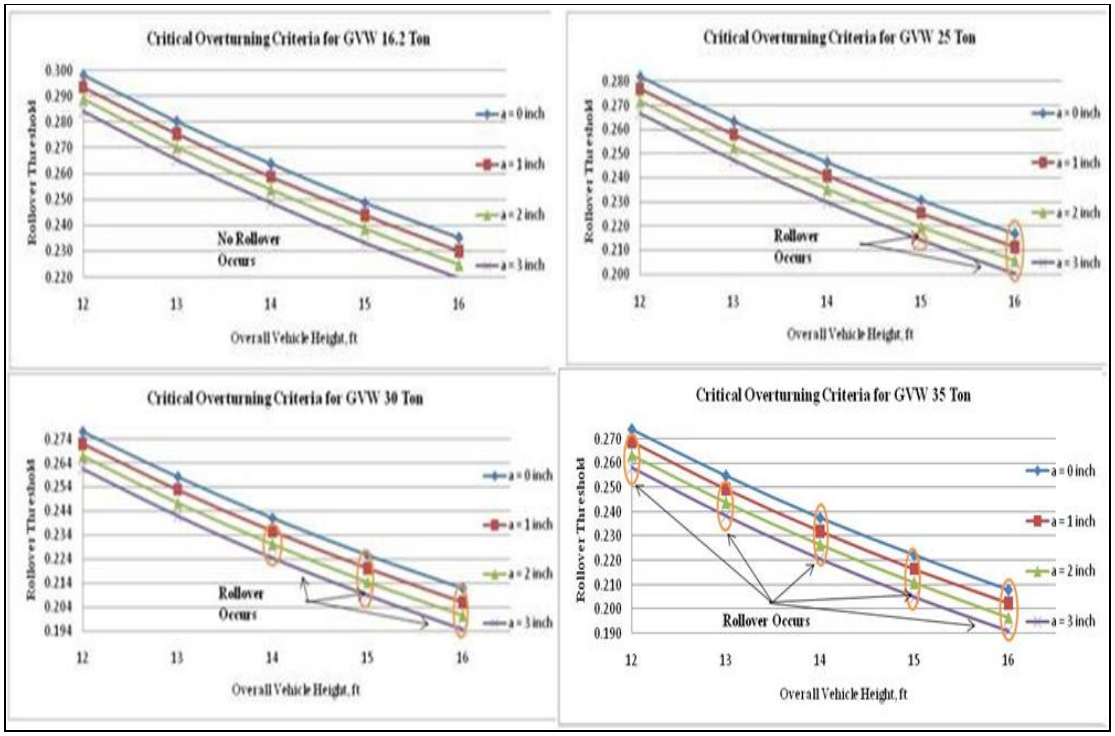

Fig.4: Critical overturning criteria for different loading conditions with variable height and load extension

Figure 4 illustrates the effect of different loading conditions on rollover threshold for various load extensions with variable height. Rollover threshold decreases with increase in vehicle weight (i.e. load weight), vehicle height (i.e. load height) and load extension. The larger the weight, height and load extension the lesser is the value of roll threshold and at certain point critical condition occurs.

It is clearly seen from Figure 4 that there will occur no rollover for standard load condition (GVW 16.2 ton) even with high height and large load extension. For GVW 25 ton, 16 ft height yields critical condition for any load extension. For GVW 30 ton, height of 15 ft or more yields critical condition for any load extension. Load extension of 2 inch or more is critical for 14 ft height. For GVW 35 ton, rollover occurs for 14 ft height with any load extension. However, 12 ft height and 1 inch load extension is very critical in this case.

5. CONCLUSION

In terms of the transportation system, socio-economic condition, driver behavior, road geometric condition, vehicle loading condition etc. Bangladesh is a country with some special peculiarities that differs a lot from the others. Hence, in providing suggestions according to the results of the rollover model, some Bangladeshi practices are considered. The specific recommendations are:

- Vehicle must not be overloaded in such a way that the gross vehicle weight exceeds 30 ton.
- Overall vehicle height must be restricted to 14 ft or less.
- Load extension of more than 1 inch must be prohibited.

The research is based on rigid vehicle model, no suspension effect or inertial effect is considered and it is not validated through field experiment. To come closer to reality, in future the model should be modified and transient roll effect of vehicle body as well as roll and yaw moment of inertia would be considered.

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CONSTRUCTION AND TESTING OF A CONTROL SYSTEM FOR GAS RICE-COOKER

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ABSTRACT: Natural gas is one of the most important energy sources to provide heat and electricity in Bangladesh. In domestic sector it is best suitable because of its better combustion characteristics although there might be controversial opinions of its use in this sector. But natural gases are wasted in different ways because of unconsciousness and unnecessary use of it is a common practicein this sectors. To optimize the wastage of gas, a control system can be developed which will automatically shut off the gas supply when not required. On the other hand, the scarcity of electricity forced us not to use it for cooking purpose. Therefore, it is necessary to reduce the use of an electric rice cooker and make it easy to cook rice with a gas rice cooker. An attempt hadbeen made to develop a control system fora gas rice cooker that controls the gas supply and work like an electric rice cooker. The design of the control system involves the use of a magnetic temperature controller that works like a sensor. A cooking switch is connected with the magnetic temperature controller. An electric gas solenoid valve is connected to the gas supply line which is normally in the off position. A simple circuit has been developed. When rice is cooked properly and water exhausted, the temperature at the inside bottom of the cooking pot is about 100°C, which increases rapidly. When the magnetic temperature controller detect the outside bottom temperature of the cooking pot to its operating temperature, the magnet falls and turned off the cooking switch. The electrical circuit is broken up and the gas supply is cut off through the solenoid valve.

Keywords: Natural gas, Gas rice-cooker, Magnetic temperature controller, Solenoid valve, Control circuit.

1. INTRODUCTION

The most of the energy demand in domestic sector of our country is met by biomass fuels. In some part of the country where there is supply of natural gas, it is used for domestic purposes. It is one of the most important energy sources to provide heat and electricity in our country. It is best suitedin domestic purposes because of its very good combustion characteristics and smokeless flame although there might be controversial opinions to use it for domestic purpose or nor. But natural gases are wasted in different ways because of unconsciousness and less cost compared to other alternatives. Unnecessary use of gas is a common practice, particularly in domestic sectors. Even it happened that to avoid ignition of gas burner sometimes the burner is kept lit for all the time. This sometimes causes accidents. To optimize the wastage of gas, a well-designed control system can be developed which will automatically shut off the gas supply when it is not required. On the other hand, the scarcity of electricity forced us to find alternatives and not to use it for cooking purpose. Even officially there is no permission to use electric heater for cooking purpose. Therefore, it is necessary to reduce the use of an electric rice cooker and make it easy to cook rice with a gas rice cooker.

In every engineering and industrial application control system is necessary for operating any machine, engine or any electrical and mechanical device. The general or traditional concept of manual controlling process may also be used. But in manual controlling highly skilled and much more man power is needed but proper operation may not be carried out all the time because of human error. Moreover, long period is required for the operation. As a result, high operation and maintenance cost is required for expected services. But in modern technological concept various automatic control systems may be applied to overcome the problems mentioned above and also the limitations of manual controlling. It reduces the time and cost of the operation. By using automatic control system proper operation can be achieved with less man power and hence with less cost. So, the automatic control system is necessary besides the manual controlling to ensure accuracy of operation, less time and increased human comfort.

With the passage of time and technological development, modern controlling system has been adopted which reduces human work and time. Such type of system increases human comfort and keeps the life easy and standard at high level. In domestic purposes technologies are also widely used to keep life style at a comfortable level. The rice cooker has made life easier to cook it without having any concentration to take care of the rice. In domestic gas burner modern technologies can also be adopted. Rice cooking has traditionally been a process which requires attention to ensure that the rice has been cooked properly or not. To make rice cooking convenient and easy a control system for rice cooker can be developed. The tediousness of cooking particularly for those who are in service will be greatly reduced by the development of such rice cooker. It helps a lot to save their time and also the conventional way of cooking rice is not advantageous and efficient from the energy point of view. These limitations created the necessity to improve the rice cooking process instead of traditional process [1].

The most dedicated home rice cookers are of electrical type which is operated by electricity. But for many industrial and commercial purposes such electric rice cookers are not appropriate and therefore require an alternative. Electricity is the highest level energy and its production requires various processing and also costly methodologies, so from energy point of view using it for heating purpose is not a wise idea. For heating purposeit is convenient to use gas. Therefore, gas rice cooker may be the best alternative and good option. The time required for cooking in a gas rice cooker might be less because of its intense heat and it can be conveniently used in both urban and rural areas. The gas rice cookers are of pressure-cooker type and are so designed that they are convenient for easy rice-serving and easier cleaning. It is expected that the performance of a gas rice cooker would be better than that of an electric rice cooker if it is properly designed.

An attempt had been made to develop a control system for domestic gas rice cooker that controls the gas supply and work like an electric rice cooker. The design of the control system involves the use of a magnetic temperature controller that works like a sensor. A cooking switch is connected with the magnetic temperature controller. An electric gas solenoid valve is connected to the gas supply line which is normally in the off position. A simple circuit has been developed for this purpose in series connection. When rice is cooked properly and water in the cooking pot is exhausted, the temperature at the inside bottom of the cooking pot is about 100°C, which increases rapidly. When the magnetic temperature controller detect the outside bottom temperature of the cooking pot to its operating temperature the magnet falls which eventually turned off the cooking switch. This causes the circuit connection to be broken up and the gas supply through the solenoid valve is cut off.Thus, with this control mechanism the turn off of the gas supply will be automatic when rice is cooked properly, sono manual help is required. Moreover, the gas rice cooker is so designed that when the cooking pot is detached from the magnetic temperature controller, automatically the gas supply will be disconnected which eventually prevent the wastage of gas and protect the whole system from unwanted accidents.

2. DESIGN CONSIDERATION

(i) Principle of Operation of Magnetic Temperature Controller:

As mentioned earlier, in gas rice cooker the magnetic temperature controller is used as sensor which detectsthe temperature of the outside surface of the utensil. The magnetic temperature controller has a magnet on which a spring (called inner spring) is fitted to keep isolate the metal plate from the magnet. In normal position, the spring force is not higher than the magnetic force and therefore it keep the circuit to open position. The magnet, metal and the inner spring is covered with tin around which the second spring (called outer spring) is situated. When the magnet is heated and it reaches to the ‘curie’ temperature it loses its magnetic property to grip any other magnetic substance and behaves like a normal metal [2]. If the temperature of the magnet increases then it’s attracting force decreases slowly.

When the upper surface of the magnetic temperature controller i.e. the thermostat surface becomes hot by somehow, then the heat transfers to the metal by conduction process. When the magnetic temperature controller is in cooking condition, the metal and the magnet are in continuous contact. As cooking continues a heat transfer to the magnet through conduction via the metal. Since, the

magnet is in contact with the metal so it heated continuously and at some point the temperature of it reaches the 'curie' temperature. This is the temperature at which the magnet gradually loses its magnetic property. At this point the spring exerts a force which is greater than the magnetic force. In such position the weight of the magnet also works towards the downward direction. Simultaneously, the inner spring pressure also works towards the downward direction. Ultimately the magnet falls down and the circuit is open. The schematic of the working mechanism of such a magnetic temperature controller is shown in Figure 1.

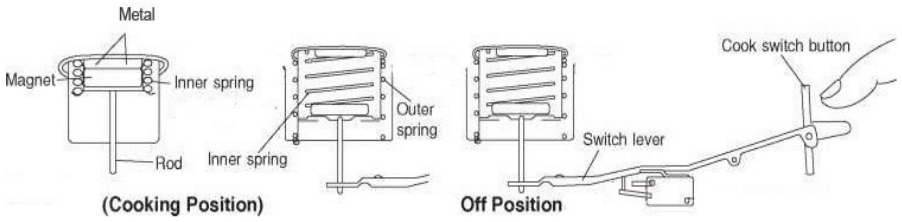

Fig.1: Operating system of Magnetic temperature controller

(ii) Control System:

To operate the gas rice cooker and to control the gas supply a control system hasbeen developed which will automatically turn 'OFF' the gas supply. For this purpose a magnetic temperature controller is used as a sensor. Below the sensor a switch is connected. Two wires are connected with a micro switch at the two ports which is separated by insulator. In the micro switch there is two bimetal on the other part. A step down transformer is used to change the high voltage to low voltage. When the bimetals are in contact then an 'ON' signal goes to the relay circuit which works as a switch. Thus, the relay circuit turned 'ON' which conveys an 'ON' signal to the solenoid valve and the solenoid valve turned 'ON'. In this a way the gas is supplied through the solenoid valve. On the other hand, when the inner spring force is greater than that of magnetic force due to the increase of temperature of the magnet, the magnet falls down which disengage the bimetal and a 'OFF' signal goes to the relay circuit which turn 'OFF' the supply of electricity through the relay circuit. Thus,no electricity is conveyedthrough the solenoid valve andultimately the gas supply turned 'OFF'.

3. CONSTRUCTION OF THE SYSTEM

For the construction of a domestic gas rice cooker at first a magnetic temperature controller is fitted within the gas burner in such a way that a small portion of the sensor is above the burner and most of the portion is inside the burner hole which is shown in Figure2. One portion of thelink (rod) of the magnetic temperature controller is connected with the magnet and the other portion of the rod is connected to the cooking switch. There is a micro circuit connected with the cooking switch which has two ports separated by an insulator and two bimetal which may be in attached or detached position. An electric connection is given to the micro switch. When the bimetal of the micro switch are in attached position an 'ON' signal goes to the relay circuit. Normally the relay switch is in 'OFF' position which occurs when the bimetal are in detached position. With a step down transformer, capacitor, relay circuit, diode and the micro switch are connected in series. If the relay circuit is in 'ON' position then an 'ON' signal goes to the solenoid valve which is normally in the 'OFF' position.

AC 220V power supply is given to the step down transformer which converts it to AC 12V, 1000µF supply. This 12V AC supply is rectified by the diode and converts to DC 12V [3]. This supply goes to the relay circuit. When the micro switch bimetal are in attached position a signal goes to the relay which turned 'ON' the relay circuit. The relay circuit is just like a switch whose output is AC 220V and connected to the solenoid valve in series which is also AC 220V supply. When the relay circuit is turned 'ON' then the solenoid valve also turned 'ON'. But when the bimetal of micro switch are in detached position then no signal conveys to the relay and the same for the solenoid valve. In such

position the solenoid valve is in turned 'OFF' position. In this manner the control system works which is shown in Figure 3.

4. EXPERIMENTAL PROCEDURE

For the experimentation of this constructed domestic gas rice cooker at first a cooking pot of a conventional rice cooker is taken. Rice and sufficient amount of water is kept inside the cooking pot and kept it over the gas burner. There was no gas line in the lab, so a LPG cylinder is used as gas source. In this situation, the potdepresses the central thermostat i.e., the magnetic temperature controller. The central thermostat outer spring is compressed. In this case when the cooking switch button is pressed to turn'ON' then the following situation occurs:

i) The switch lever pushes the rod which will allow the magnet to meet the metal.
ii) The bimetal are in attached position which convey signal to the relay circuit to turn 'ON'.
iii) The relay circuit conveys 'ON' signal to the solenoid valve to switch 'ON' and the gas supply starts
through the solenoid valve.

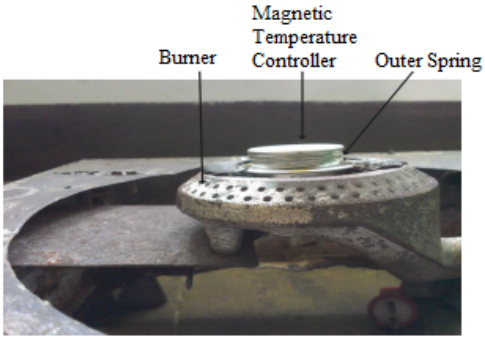

Fig. 2: Photographic view showing the position of Burner and the Sensor

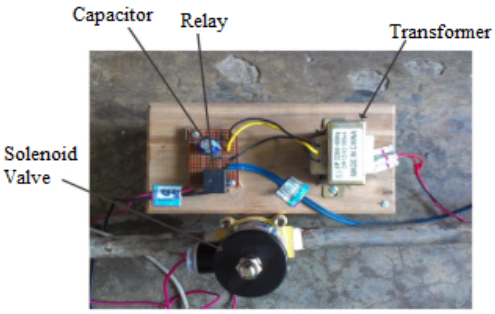

Fig. 3: Photographic view of Control system

The magnetic temperature controller that was selected for this work ranges between 140-150°C. Under no load condition, the temperature controller was tested and it confirmed its operating temperature range as mentioned above.By making turned 'ON' the regulating switch, the gas flow is started through the gas burner and manually fire is put to ignite the burner. In this situation the cooking pot becomes heated and this heat is conducted to the thermostat surfaces. From the thermostat surface heat is transferred to the metal surface. When the metal is heated thereby the magnet is heated and itreduces its ability to attract metal. When cooking is in process, the temperature at the inner surface of the cooking pot is nearly about 100°C until the water completely evaporates. In this situation the temperature detected by the thermostat surfaces also remains constant. It took few minutes to boil the rice completely. When the rice is fully boiled with exact amount of water there should not be any water in the inner surface of the cooking pot. In this situation the temperature of the inside bottom surface of the cooking potexceeds 100°C and increases rapidly. As a result the temperature of the thermostat surface increases rapidly, hence the temperature of the magnet increases thereby. When the temperature of the inside bottom surface of the cooking pot is around 105-107°C, the magnetic temperature controller assume the outside bottom surface temperature of the cooking pot is about 140-145°C. In this temperature the inner spring pressure becomes stronger than the magnetic pull and the metal and magnet will pop apart [4]. This phenomena cause the bimetal to separate and thus a signal goes to the relay circuit to turn 'OFF' which stops the power supply to the solenoid valve and thus the solenoid valve automatically turned 'OFF'. Hence, there is no gas supply through the solenoid valve and the burner is put off. Though the regulating switch is not turned 'OFF' but the gas supply stops. Experiments were conducted with 100 gm rice with 300 ml water for several times and after completion of cooking photographic view of cooked rice was taken and is shown in Figure 6.

Fig.4: Photographic view of gas rice cooker in cooking condition

Fig.5: Photographic view of gas rice cooker when the solenoid valve is switched 'OFF'

Fig.6: Photographic view of the inner surface of cooking pot when rice is cooked

From the photographic viewas shown in Figure 6,it is seen that a negligible amount of rice has been burned out. The inside surface of the cooking pot is coated with a black color non-stick layer, that's why it looks black. Similar experience is also observed with an electric rice cooker. So, a small portion of rice burning is common to all rice cookers.

5. EXPERIMENTAL DATA

The performance test of the domestic gas rice cooker was conducted with rice at different times. Some of the data found while cooking rice is shown in Table 1 below.

Table1: Data for the performance test of domestic gas rice cooker

No. of Obs.	Date of Experiment	Cooking started at	Cooking stopped at	Time required to cook (min)
01	04-07-2013	01.27pm	01.55pm	28
02	05-07-2013	10.07am	10.37am	30
03	19-08-2013	11.23am	11.50am	27

As mentioned earlier, in the experiment 300gm rice hasbeen used each time. From the Table it is seen that the time required to cook rice varies slightly. This is because of the amount of water varies slightly and the different quality of rice. The experiment was conducted keeping the gas flow at nearly similar rate.

6. CONCLUSION

In this project the objective was todesign, construct and testing of a gas rice cooker whichwould reduce the wastage of gas and human work. According to design of this project to turn 'ON' the gas supply it requires load to apply on the magnetic temperature controller. The experiments confirmed this phenomenon that when cooking pot was put on the gas burner the gas supply starts and the gas supply is cut off when the cooking is over. So, it reduces the gas wastage and accidental hazards.

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DOCINFO IT'S ALL ABOUT HEALTH

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ABSTRACT: Getting proper health services are inadequate only because there is a big information gap between patients and providers. Our plan was to cover up the gap. We developed an information management system where all the information of health service providers will be enlisted. Anyone can get any information regarding doctors, hospitals, diagnostic centers, disease, and blood banksin a single portal. Visitors can get the location of a health service; can get a vast idea about a doctor and his specialty, chamber visiting hours. We structured the system in such way that it can be merged with telecommunication value added services. From urban to rural people, everyone can use it through internet, through a smartphone app, through text service. Our target was to cover up the gap, and furthermore developed an ideal system as a solution.

Keywords: Health; Patients; Doctor; Visitors; Smartphone.

1. INTRODUCTION

1.1 Background

Technologies started evolving rapidly around Internet for the last few ten to twenty years. Many software solutions are available in web platform rather than desktop based. It became possible only because Internet is becoming more convenient, and the uniqueness of being mobile. The mobility and robustness of Internet has motivated us so much that we planned to put our efforts into action and do something very useful for the mass people with this technology. Thinking about the mass people, we planned to design a web application that can provide the information of health service all over the country.

The main purpose of this project is to develop an information management system for the health service providers. It will store all the information of doctors, hospitals, blood banks, diagnostic centers, health tips. The user of this web application will be the Local people, employers of the system, super admins and the health service providers. This project will serve information with an online solution. User will have access to the site from anywhere in the world, all they need is a device connected with Internet. Using this application employer will be able to add, delete, edit, and update information of health service providers with the admin panel interface. Doctors can post their current information.

1.2 Software or Technology Product Proposed

Listed below technology will be used in this project proposed

▪	ASP Net 4	▪	M VC 4.0	▪	H RML	▪	SS

1.3 Business Process Impacted

This application will have a huge impact in health service.

- We can use Google AdSense in this website.
- We can post different advertisements of private health service providers.
- We can feature doctors with their private practice information.
- Many revenue providing options will be opened.

1.4 Purpose

The purpose of this document is to present a detailed description of the project "DOCINFO, It's all about health". It will explain the purpose and features of the system, the interfaces of the system, what the system will do, the constraints under which it must operate and how the system will react to

external stimuli. This document is intended for both the stakeholders and the developers of the system and will be proposed to the AIUB-Department of Computer Science for its approval.

1.5. Project Scope

- This web application will be developed to satisfy the user with proper and enough information.
- This application will maximize the doctor identification process at its best.
- This application will facilitate communication between employer, admin, doctors and owner of the different health service provider.
- This system will contain a relational database containing a list of doctors, hospitals, diagnostic centers, blood banks.
- Other facilities are notice ticker, notice board, health tips.

1.6 Product Perspective

This product is intended for the admins, data entry officers, doctors and the visitors. This site will be maintained by the SUPER ADMIN who wants to use this product. Super Admin can grant admin privileges to other registered users like data entry officer and doctors.

2. PROJECT FEATURES

Website:

- Information about doctors including certificates.
- Information about diagnostic centers and tests.
- Information about doctors' chamber and visiting time with fees.
- Information about blood bank and blood groups
- News box.
- Information about hospitals.
- . Search engine.
- Notice board.
- Contact information.
- Notice ticker.

Admin:

- Add Edit, Delete, Update, Approve, Disapprove functionality with solo module.
- Approval of the data entry officer and doctor's validation.
- Account Modification
- Certificate validation

Data Entry Officer:

- Add doctor, hospital, diagnostic center, blood bank information.
- Add news.
- Add photo.
- Add notice.

Doctors:

- Add degree information.
- Add chamber, fees, time schedule.
- Update profile picture

Visitors:

- Search and view doctors, diagnostic center, blood bank information.
- Add review about any doctor, diagnostic center, blood bank.
- View notice, news.

3. USER CLASSES AND CHARACTERISTICS

There will be four kinds of user. They are Admin, Data Entry Officer, Doctors and Visitors.

Admin:

- Add Edit, Delete, Update, Approve, Disapprove functionality with solo module
- Approval of the data entry officer and doctor's validation.
- Certificate validation
- Account Modification

Data Entry Officer:

- Add doctor, hospital, diagnostic center, blood bank information.
- Add photo , certificates.
- Add news.
- Add notice.

Doctors:

- Add degree information.
- Add chamber, fees, time schedule.
- Update profile picture

Visitors:

- Search and view doctors, diagnostic center, blood bank information.
- View notice, news.
- Add review about any doctor, diagnostic center, blood bank.

4. OPERATING ENVIRONMENT

This product is developed using ASP .Net4, and MVC 4. This application runs well on almost all available web browsers including the ones in mobile phones. Namely

▪ Internet Explorer	▪ pera	▪ irefox	▪ axton	▪ olphin	▪ hrome	▪ et Front	▪ et scape

5. DESIGN AND IMPLEMENTATION CONSTRAINTS

Product is developed using ASP.NET 4. The product is accomplished with login option so the specific function is available to the specific user. Also additional security is provided by ASP.NET 4 during development

5.1. Hardware Constraints

Development of the software was carried on an Intel Core 2 Duo 3.1 GHz processor with 2 GB Ram running on windows 7 ultimate (64 bit). .Net server was used and it ran smoothly. Analysis says that once it is deployed on a real server with recommended configuration, it will run much better than that of the test phase.

5.2 Recommended Configuration:

The system requires a database in order to store persistent data. The database should have backup capabilities.

• Intel Quad Core Xeon Processor	• 4 GB RAM	• 1 TB HDD	• Other necessary accessories/ devices.

5.3 Software Constraints

As mentioned earlier, development of the software was carried on an Intel Core 2 Duo 3.1 GHz processor with 2 GB Ram running on windows 7 ultimate (64 bit) which consumes 877 MB RAM out of 3GB at idle state. .NET server uses very efficiency at idle state. At a loader state of, let's say around 100 user loads, it was found consuming 35% of the 3GB RAM and 42% CPU Processing. The development of the system will be constrained by the availability of required software such as web servers, database and development tools. Much better results are expected when it will be deployed on the real environment.

5.4 Design Constraints

The system must be designed to allow web usability. That is, the system must be designed in such a way that will be easy to use and visible on most of the browsers even in the mobile devices. The designing was done with long term service and ease of maintainability in mind.

5.5 Assumption and Dependencies

This product needs the following third party libraries and software:

- ASP.NET 4
- MVC 4
- OS

5.6 Stimulus / Response Sequences

Responses for User: Users (Super admin, admin, data entry officer, doctor) can log in and out or stay signed in to their account (if they are registered). The login and signup go through verification and validation in the server and if the request succeeds the user is redirected to their account. Also, while posting any information, database will require verification and validation of the information takes place. This is to ensure the consistency of the data and information.

6. FUNCTIONAL REQUIREMENTS

6.1 User Interface

Different screenshots will show the user interface flow in the Fig.1

Every possible interface required for this project has been implemented. Future updates for more features and ease of access can be added.

Priority to user roles and access control restricts general visitors from utilizing features that are only accessible by authorized personnel.

Fig.1: Different screenshots will show the user interface

6.2 Hardware Interface

Server Side:

- Quad Core Intel Xeon Processor 2.66 GHz or higher
- 4 GB RAM
- Smart Cooling System
- Power Backup System (Recommended)
- 500 GB HDD
- LCD Monitor

Client Side:

- Windows XP or higher, Mac OS 10.6+ or Any Linux Distribution with Silver light 5.0 Runtime
- Any Web browser (e.g. Internet Explorer, Google Chrome, Mozilla Firefox etc.)
- Monitor
- 512 MB RAM (minimum)
- Intel Pentium 4 or higher

Software Interface:

A. Web browsers (example. Internet Explorer, Google Chrome) ***B.*** MVC 4.0 C. Visual Studio 2012
D. Photoshop ***E.*** Illustrator

References:

- *SRS*
- *SOW*

7. DEPLOPMENT AND ACTIVITY DIAGRAM

Development and activity diagram of the software is shown in Fig.2

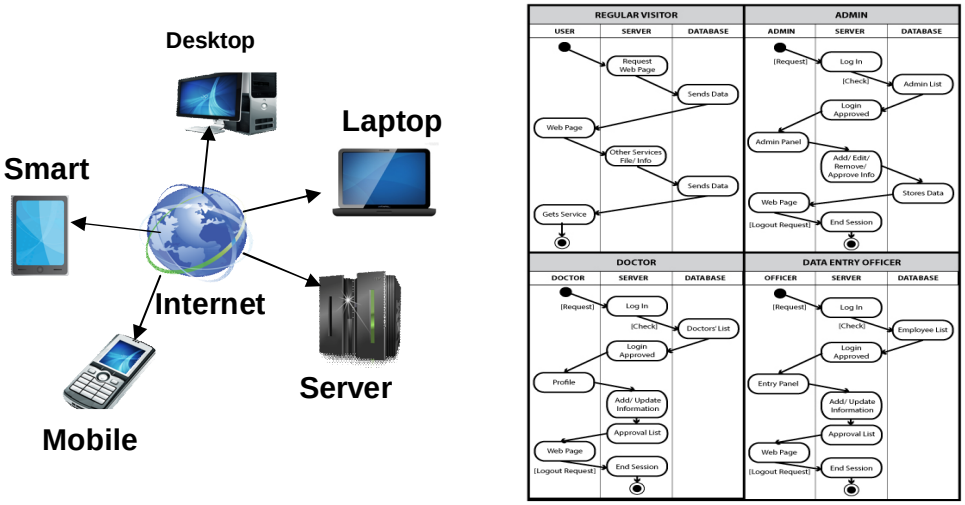

Fig.2: Development diagram and Activity diagram

8. CONCLUSION

"DOCINFO, it's all about health" is a complete health service management information system. It can be as ideal as a central health service database system. Visitors and the managers both will be satisfied with proper and vast information.

It has a great business opportunity too. Featuring and promoting doctors and health service provider organization will make a big cash flow which will help to support the maintenance costs. This software architecture can be extended to a new level like SMS based query, disease detection with smartphones, and emergency services in the long run.

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FIRE SAFETY IN BNBC '93: A CRITICAL REVIEW

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ABSTRACT: Every independent nation prefers to have their own National Building Code to streamline their construction practices with a view to establishing minimum standards for maintaining quality and safety in design, construction, operation, maintenance and demolition, use and occupancy, location of buildings within their respective geographical boundary. Bangladesh is also proud of having a National Building Code, which has been published first in 1993. This code contains a dedicated chapter on fire safety and related guidelines are furnished in other chapters where necessary.

As a first endeavour of this kind the fire safety related guidelines are found to be quite comprehensive. Nevertheless there are few important guidelines found missing and some guidelines could be formulated in a much acceptable manner. In this paper all the guidelines related to fire safety in buildings are critically reviewed and the major shortfalls are discussed for further improvement in future. The important guides to be practiced in making a building safe from fire, which are found missing in the code are suggested here in for inclusion and some guides are amended as suggestion for modification in the subsequent updating process.

Keywords: Building, fire, Safety, fire fighting.

1. INTRODUCTION

Building of various occupancies constitutes the major part of infrastructural development in the country where huge resource is invested for its development. In order to ensure optimum return of these investments and to achieve satisfactory performance of those buildings in terms of safety, serviceability, health, environment and general welfare of its users, the process of building development needs to follow an uniform standard of practice covering all aspects of planning, design, construction, maintenance and demolition. These standard practices are generally provided comprehensively in the building code appropriate to the need of the country. Prompted by such necessity a national building code naming as Bangladesh National Building Code (BNBC) has been published in 1993.

To ensure total safety in a building the importance of arrangement for making building safe from fire is very important. Fire becomes a great hazard when its protection system is not well addressed in the whole building development processes. Fire may be caused by wrong doing of a human being but it is mostly managed by the coordinated and collective efforts of organized people with the help of fire detecting, communicating and fighting elements installed inside the building. So various guidelines are to be formulated to practice while planning, design, construction, maintenance and even in demolition of any building to save lives and property, within and around, from fire. In BNBC '93 a dedicated part is attributed to include almost all the relevant guidelines to ensure safety, in building and during its development process, from fire hazard. This paper is the description of pros and cons of some of the important guidelines, which are mentioned herein, after critically reviewing the relevant portions addressing the fire safety issues in the code.

Introduction of Chapters on Fire in BNBC '93:
Bangladesh National Building Code 1993 has been furnished comprising of 10 parts. Among those part 4 fully specifies the requirements for fire prevention and protection measures in buildings in five chapters. All the measures furnished herein are grouped into three categories and furnished in three chapters. In chapter 2 precautionary measure to prevent or arrest propagation of fire in the buildings are furnished. In chapter 3 provision of life saving means of escape from the building in the event of considerable fire are furnished and in chapter 4 provision of various in-built fire fighting arrangements within the building are specified. Requirements for each of these in built arrangements are elaborated in this chapter. In addition to these requirements specific requirements for fire

protection for various occupancy classes of low rise buildings are specified in chapter 5. Buildings lower than 20 meter height is termed as low rise building in the code. In the first chapter some general requirements for fire protection have been furnished. The fire protection requirements of the code are based on the principle of providing reasonable protection within achievable means. With a view to supplementing the provisions furnished in all the chapters four annexure are included. The annexure are as follows.

Appendix A: Guidelines for Fire Drill and Evacuation Procedure for High Rise Building.
Appendix B: Fire Protection Considerations for Venting for Industrial and Storage Building.
Appendix C: Detailed Guidelines for Selection of and Sitting of fire Detection System.
Appendix D: Special Requirements of Buildings more than 20 meter High.

Besides the provisions provided in the part 4 a few relevant provisions addressing the requirements of fire protection have been furnished in chapter 1 and chapter 2 of part 3 which furnishes guidelines on general requirements, control and regulation. Chapter 3 of part 3 is exclusively for classification of building construction types based on fire resistance.

Critical Review of Some Provisions

Chapter 1: In section 1.5 the fire resistant rating of various structural elements, in buildings, of various materials and various dimension have been furnished in Table 4.1.1. It is found that a solid wall made of clay bricks of thickness 75mm has fire resistant rating of 0.75 hours; 125 mm thickness has 1.5 hours where as 250 mm thickness has 5 hours. Here fire resistant rating of 75mm brick wall seems to be considerably low. According to International Code Council (ICC) fire resistant rating of 69 mm (2.7 inch) brick is 1 hour; 97 mm (3.7inch) brick is 2 hours; 124 mm (4.9 inch) brick is 3 hours and 152 mm (6 inch) brick is 4 hours.

Chapter 4: In section 4.2 water requirements for fire hydrant system has been furnished in Table 4.4.1 where it is seen that in sprinkler system water flow requirement for various hazard condition is varied and it is incremental with the severity of hazard conditions. But in stand pipe and hose system only for light hazard I the flow requirement is 1000 liter / minute which is 1900 liter/ minute for light hazard II and maintained the same flow rate for other severe hazards even for ordinary hazard III, which seems to be irrational. In sub-section 4.2.2 various water sources are prescribed for fire plumbing. There is a provision for direct connection of hydrant system with water main when there is continuous supply of water in the main. But there is no mention of pressure to be available in the main. If there is no sufficient pressure in the main there will be insufficient pressure at the outlet of the nozzle for which the arrangement will become ineffective. The other source of water is prescribed as roof gravity tank when water is inadequate in the main or pressure during peak demand period but with sufficient pressure to feed the roof tank. Here there is ambiguity regarding availability of pressure in the main. Virtually the condition shall be for inadequate water but sufficient pressure to feed the roof gravity tank. The other problem is that the pressure maintained in the water supply main can serve feeding the roof tank on low to medium rise buildings depending upon the pressure but in high rise building this option cannot be applicable which is not mentioned. Another problem related to this system is ensuring sufficient nozzle outlet pressure at the upper level floors. Generally on roof of buildings tanks are placed on the roof of stair or lift well. The water pressure developed for making tank at this height can never satisfy the pressure requirement at the nozzle outlet. In such case provision for installation of pressure boosting system with the hydrant is required to be specified.

In sub-section 4.2.3 design considerations for standpipe and hose system has been specified. It is mentioned that all standpipes shall have to provide minimum flow specified in Table 4.4.1 where the minimum flow is 1000 and 1900 liter per minute. Again the determination of size of standpipe is related to height of building where for six to ten storey building of up to 33 meter height, the stand pipe shall be 100mm and for ten to twenty storey building or 33 meter to 63 meter high building the stand pipe shall be 150 mm. So confusion arises for a 10 storey building of height 33 meter for which both 100mm and 150 mm riser pipe is applicable. Again basing on the principles of hydraulics by a 100 mm stand pipe about 1200 liter per minute can be flown at a velocity of about 2.4 meter per second where pressure drop is dependent on building height only. So by a 100 mm stand pipe

virtually more than eleven storeys can also be served if minimum flow is the only criteria to be fulfilled which would be more economical.

In Figures 4.4.3, 4.4.4 and 4.4.5 the Siamese connection has been shown within the building which is not very effective for use by the fire brigade. It shall be outside the building as shown in Figure 4.4.1 and 4.4.2. In sub-section 4.2.5 provisions for water supply for fire protection in tall buildings have been furnished. In terminologies of chapter one, tall building is not defined.

In sub-section 4.2.6 guidelines regarding fire pump have been furnished. For the design of fire pump flow rate shall be determined for requirement of the highest and farthest firefighting equipment during peak demand hour which is very irrelevant. Flow rate shall be determined considering the number and size of hose to be used simultaneously for protecting specified premises inside the building.

In this chapter there is a figure of pressure tank system which is not mentioned in any provisions. This system is an old technology used to meet the fluctuation in water demand which is not applicable in fire fighting.

In section 4.3 provisions for fire protective signaling and fire alarm system have been furnished. Here it is mentioned that there shall be plan for location and number of alarm initiating devices and alarm indicating appliances where required by the code. But in the code there are nowhere any exclusive guidelines for installation of specific number of and locations for alarm initiators or alarm indicators devices.

In section 4.4 provisions for fire and smoke detection system have been furnished. Here it is mentioned that when the size, arrangement and occupancy of a building become such that a fire cannot provide adequate warning to the occupants then automatic fire detection system has to be installed. This is not a clear guideline which shall be more specified.

In section 4.5 provisions of foam extinguishing system have been furnished. Here it is specified to install this system in accordance with the provision of this code. But nowhere in the code there is any guideline for selecting foam extinguishing system for particular situation and cause of fire.

In section 4.6 provisions for Carbon-di-Oxide extinguishing system have been furnished. The supply of CO_2 is mentioned to be from pressurized vessel through fixed pipes and nozzles. It would not be possible to follow the guide unless sufficient instruction is furnished in this regard.

In section 4.7 provisions for Halogenated extinguishing system have been furnished. The supply of Halogen is mentioned to be from pressurized vessel through fixed pipes and nozzles. It would not also be possible to follow the guide unless sufficient instruction is furnished in this regard.

Chapter 5: This chapter is for specific requirements for various occupancies of low rise building lower than 20 meter height. In buildings of many various occupancies portable fire fighting extinguishers and other fire fighting extinguishing systems are suggested to be installed as per instruction of the concerned authority. But who would be the concerned authority there is no specific guidelines. It is to be noted that in part 2, chapter 2 of this code, authority is defined as a new or a designated existing agency made responsible by the government for the purpose of administering and enforcing the code, which is yet to be established. So, in the code, referring any authority, which does not exists, is meaningless.

This chapter should be for all types of buildings including high rise also. Some special requirements for high rise building could be furnished in this chapter.

Some Suggested Provisions

Bangladesh National Building Code 1993 is found to be quite comprehensive in furnishing all the guidelines to develop a building safe and sound in all respect considering social, economy, culture, religion and environment of Bangladesh. Similarly the fire related provisions furnished in the code are also found to be quite comprehensive. Nevertheless as a first initiative there are some guidelines

found to be missing, inclusion of those would make the code more appreciable in this regard. The missing provisions those are considered to be more relevant and important as well to be included are mentioned below.

1. In chapter 1 of part 3 inclusion of lightning arrestor arrangement in buildings could be included and relevant chapter elsewhere in the code could be referred for detail in this regard.
2. In chapter 3 of part 3 inclusion of fire spreading rate of various building material and finish materials could be included.
3. In chapter 1 of part 4 inclusion of provisions regarding fire doors could be incorporated.
4. In chapter 2 of part 4 inclusion of some precautionary measures in electrical installations could be furnished.
5. In chapter 3 of part 4 various provisions for refuge areas could be included.
6. In chapter 4 of part 4 following provisions could be included.

6.1 In section 4.2 the dry riser type hydrant system could be included for limited conditions.

6.2 Provisions of various arrangements of fire fighting system and equipments, considering the types of construction based on fire resistance, could be furnished elaborately.

6.3 Use of Jockey pump (Duffy, 2013), could be included along with fire pumping system.

6.4 Use of various pipes considering the allowable pressure range could be furnished.

6.5 Necessary provisions regarding outdoor Siamese connection could be included.

6.6 Additional provisions of housekeeping and maintenance of fire fighting equipments and other related items could be included in exclusive sections.

A new chapter on fire detection and communication could be written to cover all aspects of fire safety in buildings in a very comprehensive way.

2. CONCLUDING REMARKS

After 22 years of independence the National Building Code has been published. As an emerging new nation preparation of such a comprehensive document on building development is praise worthy. Nevertheless there might be ample chance of having mistakes, misunderstandings, ambiguity and some missing provisions in the document. This document is no longer a book of guide for good practice in building development sector rather it is now a document under the auspices of law. So every sentence, word, symbol, figure and even punctuation carries importance and value in the eye of law**.** So the code shall be a very precise document having almost no flaws. With a view to making the code more or less full proof and comprehensive, the observations pointed in the critical review and the provisions suggested herein, could be addressed properly in the upcoming updated version of BNBC in near future.

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A FUZZY APPROACH TO CONTROL INVENTORY FOR VARIABLE DEMAND AND SUPPLY

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ABSTRACT: The inventory problem is a buzz topic in manufacturing industries and its every subsequent stage of supply chain to keep the inventory level to the optimum level while meeting the customer demand turns to the key challenge. This problem adds a dimension due to the uncertain nature of demand and supply. To minimize the extent of this problem, a fuzzy logic approach has been proposed using information available on current demand and supply. This approach is used to deal with both variable demand and supply using fuzzy control system. In this proposed Fuzzy Inventory Control (FIC) system, both demand and supply are described by linguistic terms. Then the developed fuzzy rules are used to extract the order quantity and the reorder point continuously. The continuous review model of the inventory control problem with fuzzy input data has been focused in and a new solution method has been presented. The approach is more flexible than the conventional approach due to adjustment of both order quantity and reorder point.

Keywords: Uncertain demand and supply, Fuzzy Inventory Control

1. INTRODUCTION

Inventory represents an important asset to any business organization. After the pioneering work known as the classical economic order quantity (EOQ) model with known constant demand, a great deal of researches on inventory modeling have been conducted to capture many interesting and realistic situations. However, in real world inventory systems, there exists parameters and variables which are almost uncertain. When these uncertainties are significant, they are usually treated by probability theory. Of course, to address such an uncertainty, we need to prescribe an appropriate probability distribution. In some cases, uncertainties can be defined as fuzziness or vagueness, which are characterized by fuzzy numbers of the fuzzy set theory. An introduced fuzzy set theory was made to deal with quality-related problems with imprecise demand. Then the difference between randomness and fuzziness by showing that the former deals with uncertainty regarding membership or non-membership of an element in a set while later is concerned with the degree of uncertainty by which an element belongs to a set was distinguished. In real world, many decisions are made under uncertainty since there are many important parameters that affect the decisions have unknown probability of occurrence. There have been many kinds of mathematical programming models developed to solve decision-making problems under uncertain conditions. Inventory control is one of the main issues in logistic and supply chain management in which various types of uncertain and imprecise parameters exist. In most of the earlier literature dealing with inventory problems in deterministic, probabilistic or fuzzy environment, researchers have considered lead-time as constant, stochastic or fuzzy [1].

Inventory control is treated as both highly risked and benefitted decisions throughout these supply chain. A shortage or not enough supply can disrupt manufacturing plan or inventory management. On the other hand, overstock on inventory level may also be barrier to management. The most importance task of inventory management is making trade-off between the minimization of the total cost and maximization of the customer satisfaction. The inventory control defines how often the stock level is reviewed to determine when and how much to order. It is performed on either a continuous or periodic basic types. In a continuous inventory control system, an order is placed for the same constant amount whenever the inventory on hand decreased to a certain level, whereas in a periodic system, an order is placed for a variable amount after the specific regular time interval. Conventional inventory models assume certain or variable demand and supply. Fuzzy set theory, originally introduced by Zadeh, provides a framework for considering parameters that are vaguely or unclearly defined or whose values are imprecise or determined based on subjective beliefs of

individuals. Some researches applied fuzzy set and fuzzy number to determined uncertainties in demand, order quantity and lead time [2].

Another approach to simplify complicated system is to use Fuzzy Logic Control (FLC). FLC has been applied in many applications in industry such as machine control, scheduling and system controls including inventory control. There are few researches consider both uncertainty quantities of demand and supply. Most of them determine uncertain supply by considering time to reorder with the same quantity of economic order. But varying of amount of reorder point has not been in concern. In case of unavailability of supply, increasing of reorder point can be used to protect shortage [3-5].

2. METHODOLOGY

The purpose of the EOQ model is to find the optimal order quantity of inventory items at each time such that the combination of the order cost and the stock cost is minimal. In the classical EOQ model without backordering, an instantaneous replenishment is assumed to take place when the inventory level drops to zero and the stock items are exhausted with a fixed demand rate. In most cases, these parameters are described as "approximately equal to some certain amounts" or "located in some intervals with a membership degree". It is more reasonable, therefore, to characterize these parameters as fuzzy variables. The purpose of this section is to discuss the EOQ model in the fuzzy sense.

2.1 FUZZY INFERENCE SYSTEM

Fuzzy inference systems (FISs) are also known as fuzzy rule-based systems, fuzzy model, fuzzy expert system, and fuzzy associative memory. This is a major unit of a fuzzy logic system [6]. The system formulates the mapping from a given input to an output using fuzzy logic. The most important type of fuzzy inference method is Mamdani's fuzzy inference method, which is the most commonly seen inference method. This method was introduced by Mamdani and Assilian [7]. Another well-known inference method is the so-called Sugeno or Takagi–Sugeno–Kang method of fuzzy inference process. It was introduced by Sugeno [8] and is also called as TS method. The main difference between the two methods lies in the consequent of fuzzy rules. Mamdani fuzzy systems use fuzzy sets as rule consequent whereas TS fuzzy systems employ linear functions of input variables as rule consequent [9]. In this research, it has been assumed that rules are being laid down by experts and the fact that expert opinions are being used in the framework of different procedures of weighting to determine the weight of rules. Thus, these researches have not taken into account in the learning process [10]. The fuzzy inference system is shown in Fig. 1.

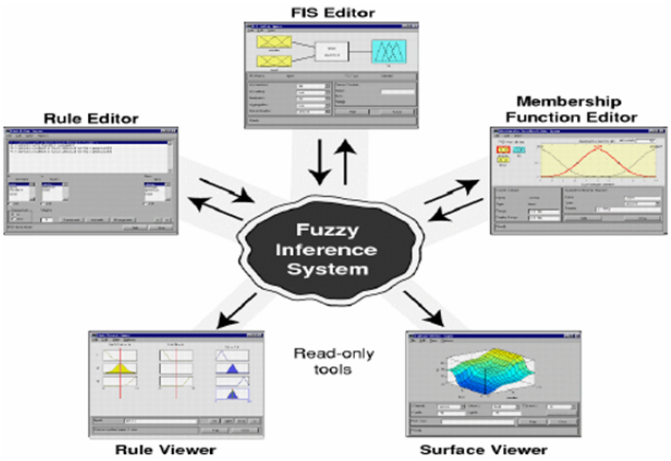


Fig.1: Fuzzy Inference system

3. FUZZY INVENTORY CONTROL MODEL

In the proposed Fuzzy Inventory Control (FIC) model, there are three components: fuzzy inputs, fuzzy outputs and fuzzy rules. Fuzzy logic toolbox of MATLAB is used to construct the FIC model for calculating order quantities and reorder points in any time period. Each element of FIC is shown in fuzzy inference system editor (FIS editor) as shown in Fig. 2.

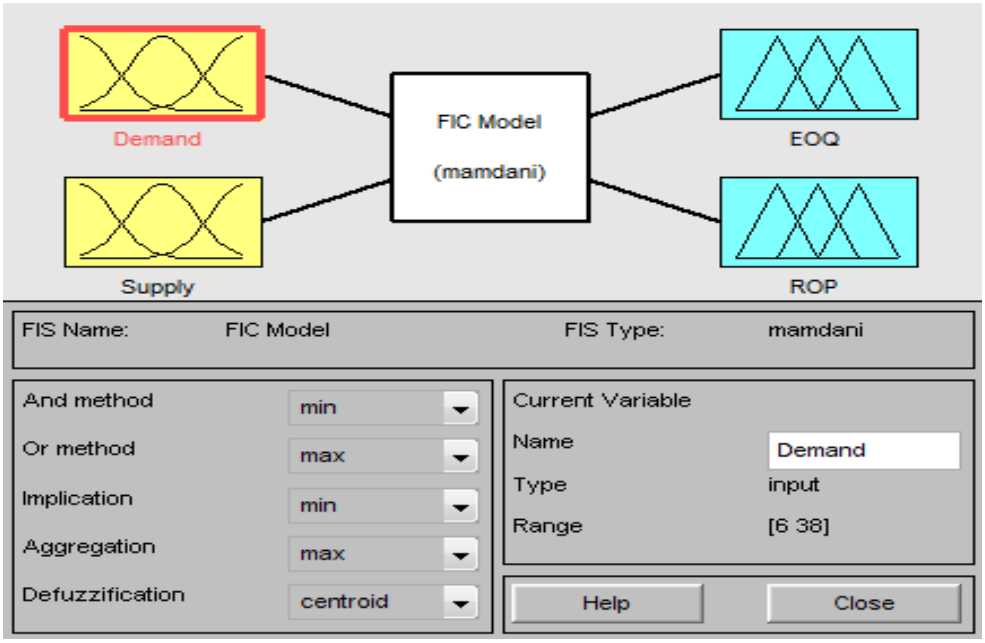


Fig.2: Fuzzy inventory control model

Two fuzzy input variables are demand and availability of supply and two output variables are economic order quantity and reorder point. These variables are represented by linguistic variables. The gaussmf membership function is used to represent the input and output variables. The gaussian membership functions have two parameters: kurtosis and mean. Kurtosis is a statistical measure used to describe the distribution of observed data around the mean. It is represented by β_2 and measured by the following equation:

$$\beta_2 = \frac{\sum[(x-\mu)^4]}{\{\sum[(x-\mu)^2]\}^2} = \frac{\mu_4}{\sigma^4}$$

Where,

μ_4 is the fourth moment about the mean and σ is the standard deviation.

Kurtosis is more commonly defined as the fourth cumulant divided by the square of the second cumulant, which is equal to the fourth moment around the mean divided by the square of the variance [11].

3.1 FUZZY INPUTS

Fuzzy inputs in the fuzzy model are demand and availability of supply which are described by membership functions μ_D and μ_S, respectively. Fuzzy demand and fuzzy availability of supply were determined based on observation and test using normal distributions of historical data. Demand is assumed to be represented by 5 linguistic values: very low, low, medium, high and very high as shown in figure 3. On the other hand supply is assumed to be represented by 3 linguistic values: low, average and high as shown in figure 4.

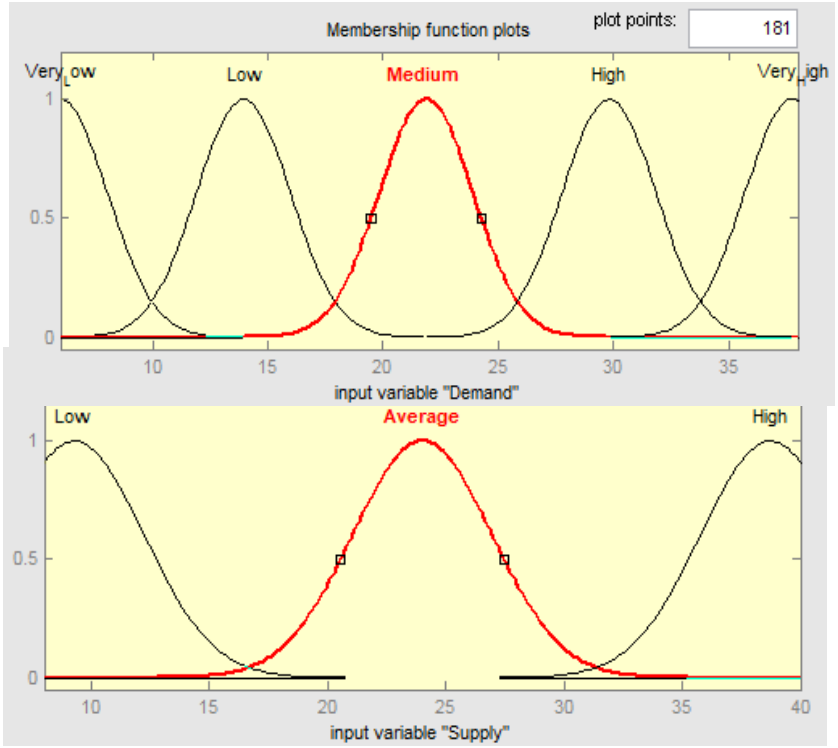
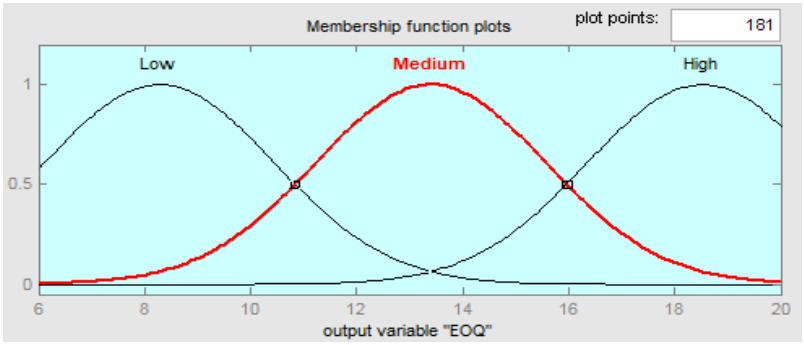


Fig.4: Supply Membership Function

The universe of discourse of the demand input space is designed from the real data within the interval μ-3σ, μ-1.5σ, μ, μ+1.5σ and μ+3σ. The parameters are designed according to characteristics of normal distribution and actual situation of uncertain demand.
Availability of supply is designed based on real data within the interval μ-3σ, μ and μ+3σ. These are used for supply linguistic values according to normal distribution.

3.2 FUZZY OUTPUTS

In this case two fuzzy outputs, fuzzy order quantity and fuzzy reorder point are constructed and described by membership functions μ_Q and μ_R, respectively. Fuzzy order quantity is represented by 3 linguistic values: low, medium, high as shown in Fig. 5. Reorder point is represented by 5 linguistic values: very low, low, medium, high, very high as shown in Fig. 6. Linguistic values of order quantity is designed from available of supply because in real situation of variable supply order quantity should be in the possible range of supply so the universe of discourse for fuzzy order quantity (FOQ) output is in the interval μ-3σ, μ and μ+3σ. The universe of discourse of the reorder point space is the set of real numbers within the interval μ-3σ, μ-2σ, μ, μ+2σ and μ+3σ.



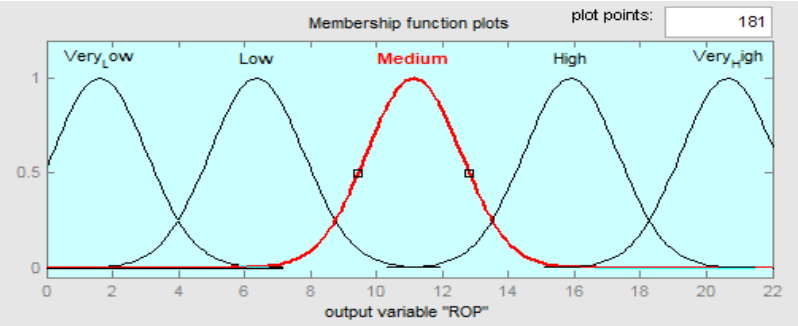


Fig. 6: ROP Membership Function

3.3 FUZZY RULES

Fuzzy inference type of the proposed system is Mandani. The relationship between demand (x1), availability of supply (x2) and order quantity (y1), reorder point (y2) are described by the following rules:

R1: IF (x1 is 'Very Low') AND (x2 is 'Low') THEN (y1 is 'Medium') AND (y2 is 'High')
R2: IF (x1 is 'Low') AND (x2 is 'Low') THEN (y1 is 'Medium') AND (y2 is 'High') ELSE
R3: IF (x1 is 'Low') AND (x2 is 'Average') THEN (y1 is 'Low') AND (y2 is 'Medium') ELSE
R4: IF (x1 is 'Low') AND (x2 is 'High') THEN (y1 is 'Medium') AND (y2 is 'Low') ELSE
R5: IF (x1 is 'Medium') AND (x2 is 'Low') THEN (y1 is 'Low') AND (y2 is 'Very High') ELSE
R6: IF (x1 is 'Medium') AND (x2 is 'Average') THEN (y1 is 'Medium') AND (y2 is 'High') ELSE
R7: IF (x1 is 'Medium') AND (x2 is 'Average') THEN (y1 is 'Medium') AND (y2 is 'High') ELSE
R8: IF (x1 is 'Medium') AND (x2 is 'High') THEN (y1 is 'High') AND (y2 is 'High') ELSE
R9: IF (x1 is 'Medium') AND (x2 is 'High') THEN (y1 is 'Medium') AND (y2 is 'Very High') ELSE
R10: IF (x1 is 'High') AND (x2 is 'Low') THEN (y1 is 'Medium') AND (y2 is 'Very High') ELSE
R11: IF (x1 is 'High') AND (x2 is 'Medium) THEN (y1 is 'High') AND (y2 is 'High') ELSE
R12: IF (x1 is 'High') AND (x2 is 'High') THEN (y1 is 'High') AND (y2 is 'High')
R13: IF (x1 is 'High') AND (x2 is 'High') THEN (y1 is 'High') AND (y2 is 'Very High')
R14: IF (x1 is 'Very High') AND (x2 is 'High') THEN (y1 is 'High') AND (y2 is 'Very High')
R15: IF (x1 is 'Very High') AND (x2 is 'High') THEN (y1 is 'High') AND (y2 is 'High'

4. DATA ANALYSIS

Fifteen weeks data for demand and supply have been considered. The demand and supply are assumed as variable. The carrying cost and ordering cost is assumed as constant due to consideration of the items to be ordered from a specific supplier. Lead time is taken 2 days and safety stock is calculated for 95% service level. The economic order quantity and reorder point are calculated by traditional formula. And for each input and output variable the mean(μ), standard deviation (SD) and Kurtosis(β_2) are calculated and shown in the following table.

Table 1: Sample dataset for demand, supply, EOQ and ROP

Week	Demand (Units)	Supply (Units)	Ordering Cost (BDT)	Holding Cost (BDT)	EOQ	Lead Time (days)	Safety Stock	ROP
1	12	20	60	15	10	2	4.63	8
2	14	22			11			9
3	15	26			11			9
4	18	25			12			10
5	19	25			13			10

6	21	22			13			11
7	21	20			13			11
8	22	25			14			11
9	23	30			14			11
10	25	35			14			12
11	25	18			15			12
12	27	15			15			13
13	28	22			15			13
14	28	30			15			13
15	30	25			16			14
Mean(μ)	21.87	24			13.4			11.13
SD(σ)	5.29	4.91			1.70			4.76
Kurtosis(β_2)	2.04	2.94			2.18			1.43

5. RESULT

The output of five weeks' calculted data of EOQ vs FOQ are given in the following table. Every dataset is taken from previous data table and FOQ is calculated from rule viewer where the FIS model generates a new output response for each input.

Table 2: Comparison of outputs for Traditional Vs FIS

Week	Demand (Items)	Supply (Items)	Traditional		FIS	
			EOQ	ROP	FOQ	ROP
1	12	20	9.79	8.05	9.46	6.37
2	14	22	10.58	8.63	8.9	6.39
3	15	26	10.95	8.91	8.93	6.47
4	30	25	15.49	13.20	17.6	11.1
5	28	30	14.96	12.63	16.1	11.8

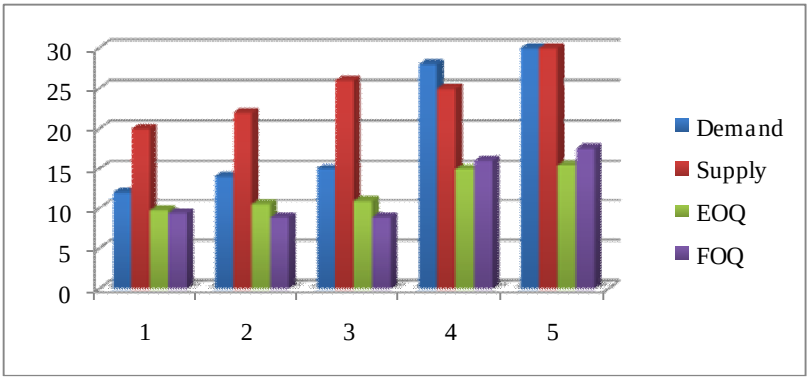


Fig. 7: Comparison of demand and supply of 5 data sets between traditional EOQ models at service level 95% and the FIC model.

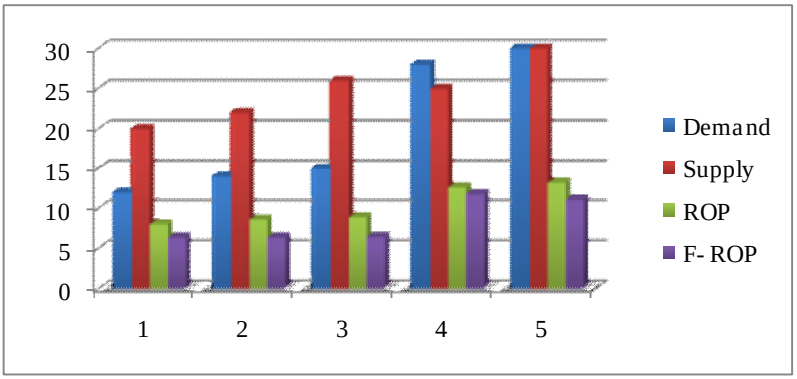


Fig. 8: Comparison of demand and supply of 5 data sets between stochastic ROP models at service level 95% and the FIC model.

Fig. 7 shows that EOQ of traditional models at service level 95% have higher value than the FIC model for first three weeks. But for the last two weeks traditional models at service level 95% have lower value than the FIC model. For further weeks the FOQ is higher than EOQ which means that the FIC model has higher average inventory level than traditional EOQ models. Fig. 8 shows that ROP of FIC models have always lower than the traditional model. As a result, in FIC model the total number of yearly orders are decreased. So the ordering costs are saved for this model and total inventory costs are decreesed.

6. CONCLUSION

Inventory management has become highly developed to meet the rising challenges in most corporate entities and this is in response to the fact that inventory is an asset of distinct feature. The fuzzy knowledge-based approach proposed is relatively simple and efficient both analytically and computationally. In this work a Fuzzy Inventory Control (FIC) model based on continuous inventory control system was developed. Both variable demand and supply were considered in the model. Fuzzy Logic Tool Box of MATLAB was used to implement the model. Demand and availability of supply are inputs and order quantity and reorder point are outputs of the system. Linguistic values were used for both inputs and outputs. Fuzzy Rules were constructed. Five sets of data of inputs are used to evaluate the FIC model.

The developed model provides substantial improvement compared to traditional statistical models and improves the prediction accuracy and is capable of integrating fuzzy knowledge into quantitative data. This can also be applied in areas of system analysis and decision making when a complex input output function is to be predicted in the presence of fuzzy knowledge and fuzzy variables. Computer implementation of this methodology is suggested for future research, so that stakeholders can easily implement this methodology for their necessary purposes.

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GENERIC COMPETENCY AND ACCREDITATION OF ENGINEERING PROGRAMS: IMPACT ON GLOBAL MOBILITY

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ABSTRACT: The quality delivery of engineering programs is paramount for global professional recognition especially by the professional engineering bodies of Washington Accord signatory nations. Today professional bodies of 15 nations (Australia, Canada, Hong Kong, Ireland, Japan, South Korea, Malaysia, New Zealand, Russia, Singapore, South Africa, Taiwan, Turkey, U.K. and USA) are the signatory of Washington Accord. The accord allows engineering qualifications accredited or recognised by other signatories are recognised by each signatory as being substantially equivalent to accredited or recognised qualifications within its own jurisdiction. Despite inheriting western engineering education system, the engineering and technological qualifications obtained in Bangladesh are not readily recognized globally mainly due to the absence of appropriate accreditation and quality assurance processes. This paper discusses the generic competencies developed by the Institution of Engineers Australia for bachelor of engineering programs offered by Australian universities and examples of attainment of such competencies.

Keywords: Engineering education, accreditation, Washington accord, generic competency

1. INTRODUCTION

Engineering and technology education plays an important role in the advancement of global economic prosperity and technological know-how. The mobility of engineering graduates across the nations has necessitated educational institutions to enhance the program quality and standard by adopting various quality assurance practices including professional recognition/accreditation. Educational institutions, employers, and professional bodies have a common interest in graduate professional competency so that graduate can be work effective anywhere in the world regardless of their location of education. The high standard and professionally recognised (accredited) engineering education is more important and necessary for countries like Bangladesh that heavily rely on human resources export and [1-3, 6]. One of the key external quality assurance mechanisms for engineering education is professional accreditation of educational programs (degrees). The accreditation methods used by the Washington Accord signatory countries (details are given later) are considered to be the best developed, well structured and increasingly world wide recognised [3]. As a low middle income nation, Bangladesh with over 150 million people has set a target to become a middle income county by 2020 [2]. However, to achieve this goal, it needs to accelerate the growth of its current Gross Domestic Product (GDP) to a double digit figure for which Bangladesh needs to invest heavily in skills development. Without quality engineering and technologically skilled human resources, it would be extremely hard for Bangladesh to attract large scale foreign and local investments in manufacturing and technology intensive industrial sectors. As a result, with 'low skills and low pay' workforce, the country will not be able to achieve its double digit annual GDP growth target. Although places for undergraduate engineering programs have slightly increased over the time both in public and private sector institutions, still the yearly intake numbers are one of the lowest in the world [1-2]. A comprehensive overview of current engineering education in Bangladesh can be found in Chowdhury and Alam [2]. The primary objective of this paper is to discuss the importance of quality assurance in engineering education and accreditation process. The paper also describes some practices undertaken by the universities of the developed world for the enhancement of quality of engineering education. The Board of Accreditation for Engineering and Technical Education (BAETE) under the Institution of Engineers Bangladesh (IEB) has become a provisional member of Washington Accord along with five other countries' representatives (China, India, Pakistan, Philippines and Sri Lanka). A complete list of full member and provisional member signatory countries is shown in Tables 1 & 2.

Table 1: Full members of Washington Accord as on 27 October, 2013, adapted from [7]

	Full Members (Washington Accord)	Joining Year	Represented by
1	Australia	1989	Engineers Australia (formerly IEA)
2	Canada	1989	Engineers Canada
3	Ireland	1989	Engineers Ireland
4	New Zealand	1989	Institution of Professional Engineers NZ
5	United Kingdom	1989	Engineering Council UK
6	United States	1989	Accreditation Board for Engineering and Technology (ABET)
7	Hong Kong	1995	The Hong Kong Institution of Engineers
8	South Africa	1999	Engineering Council of South Africa (EASA)
9	Japan	2005	Japan Accreditation Board for Engineering Education (JABEE)
10	Singapore	2006	Institution of Engineers Singapore (IES)
11	South Korea	2007	Accreditation Board for Engineering Education of Korea (ABEEK)
12	Taiwan	2007	Institute of Engineering Education Taiwan (IEET)
13	Malaysia	2009	Board of Engineers Malaysia (BEM)
14	Turkey	2011	MUDEK
15	Russia	2012	Association for Engineering Education of Russia

Table 2: Provisional members of Washington Accord as on 27 October, 2013, adapted from [7]

	Provisional Members (Washington Accord)	Joining Year	Represented by
1	Bangladesh	2006?	Board of Accreditation for Engineering and Technical Education (BAETE)
2	India	-	National Board of Accreditation of All India Council for Technical Education
3	Pakistan	-	Pakistan Engineering Council
4	Sri Lanka	-	Institution of Engineers Sri Lanka
5	China	2013	China Association for Science and Technology
6	Philippines	2013	Philippines Technological Council

These provisional signatory nations have been identified as having qualification accreditation or recognition procedures that are potentially suitable for the purposes of the Accord and they need to develop procedures with the goal of achieving signatory status in the future (see Table 3). It may be noted that qualifications accredited or recognised by organisations holding provisional status are not recognised by the full signatory nations at this time.

Table 3: Tasks/Steps to become full signatory from provisional signatory, adapted from [8]

Washington Accord: Provisional Status	**Washington Accord: Becoming a Signatory**
▪ Application for Signatory Status will be preceded by a prescribed period of Provisional Status; ▪ Applicants for provisional status must be nominated by two signatories, (who have usually mentored the applicant); ▪ Acceptance as provisional by a two-thirds majority of signatories; ▪ Admission requires that the body has an accreditation system: o Substantial equivalence is not required for provisional status; o Provisional may need to develop criteria, policies and procedures; ▪ Mentoring continues during provisional status.	▪ Normal minimum period as provisional is two years; ▪ A provisional that is ready to apply for signatory status requests a verification visit; ▪ Application must be supported by two signatories; ▪ Visit takes place; ▪ Visit must demonstrate substantial equivalence of: o Accreditation standard to the Graduate Attributes; o Policies and processes to be substantially equivalent; ▪ Visit report is considered at a general meeting; ▪ Admission of a new signatory requires unanimous approval.

The full life cycle of engineering eduction is shown in Figure 1. The figure clearly shows the importance of graduates attributes (competencies) and achieving such attributes (verified through the professional accreditation) lead to achieving the stage 2 competencies at professional practice level.

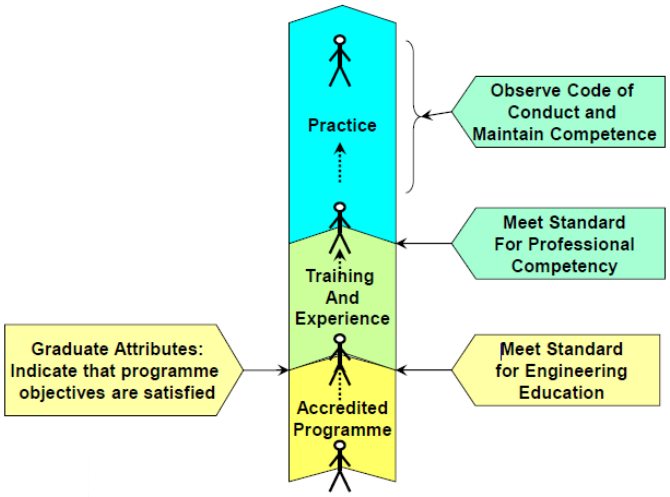

Fig.1: Engineering program life cycle, adapted from [8]

Despite Bangladesh produces over 10,000 graduates in various engineering programs each year from its public and private universities/institutions, most of these engineering programs and qualifications are not professionally accredited by the BAETE. Only a small number of programs are accredited. It may be noted that not a single engineering program from the country's five engineering universities (Bangladesh University of Engineering and Technology, Chittagong University of Engineering and Technology, Khulna University of Engineering and Technology, Rajshahi University of Engineering and Technology, and Dhaka University of Engineering and Technology) is professionally accredited by the BAETE. In contrast, all Bachelor of Engineering programs offered by universities in Australia without any exception must be accredited by the Institution of Engineers in five years cycle. It is worthwhile to mention that at least 20 out of 40 Australian universities have been ranked within top 500 universities in the world.

One of the biggest hindrances in professional accreditation in Bangladesh is the lack standard stage 1 competencies and the implementation standard. The curriculum renewal process is lengthy and bureaucratic process. There is no data available for curriculum relevance as scant information is available in the public domain. This paper gives an over view of Stage 1 Competencies and how these competencies can be developed in engineering programs. The paper also provides an example of Mechanical Engineering program offered by an Australian university that meets competencies of 3 organisations (Stage 1 Competencies by the Institution of Engineers Australia, Australian Qualifications Framework-AQF by TEQSA, and internally developed (by a university) graduate attributes.

1.1 International Agreements on Mutual Recognition of Engineering Qualifications

Currently there are 6 international agreements governing mutual recognition of engineering qualifications and professional competence. In each of these agreements countries/economies who wish to participate may apply for membership, and if accepted become members or signatories to the agreement [7]. There are three agreements covering mutual recognition in respect of tertiary-level qualifications in engineering. The Washington Accord signed in 1989 was the first - it recognises substantial equivalence in the accreditation of qualifications in professional engineering, normally of four years duration (Bachelor of Engineering, Bachelor of Science in Engineering, etc.) [7]. The Sydney Accord commenced in 2001 and recognises substantial equivalence in the accreditation of qualifications in engineering technology, normally of three years duration (Diploma in Engineering, Associated Degree in Engineering) [7]. The Dublin Accord is an agreement for substantial equivalence in the accreditation of tertiary qualifications in technician engineering, normally of two years duration (Certificate/diploma in Engineering). It commenced in 2002 [7].

1.2 Agreements covering competence standards for practising engineers

The other three agreements cover recognition of equivalence at the practising engineer level (individual people), not qualifications that are seen to meet the benchmark standard. The concept of these agreements is that a person recognised in one country as reaching the agreed international standard of competence should only be minimally assessed (primarily for local knowledge) prior to obtaining registration in another country that is party to the agreement [7]. The first such agreement is the Asia Pacific Economic Community (APEC) Engineer agreement which commenced in 1999. This has Government support in the participating APEC economies. The representative organisation in each economy creates a "register" of those engineers wishing to be recognised as meeting the generic international standard [7]. Other economies should give credit when such an engineer seeks to have his or her competence recognised. The Agreement is largely administered between engineering bodies, but there can be Government representation and substantive changes need to be signed off at governmental APEC Agreement level [7].

The 2nd agreement is the International Professional Engineers Agreement (IPEA) effective from 2001. It operates the same competence standard as the APEC Engineer agreement but any country can join it. The parties to the agreement are largely engineering bodies. There are intentions to draw IPEA and APEC closer together [7]. The 3rd agreement is the International Engineering Technologist Agreement (IETA) which was signed by participating countries in 2003. The parties to the Agreement have agreed to commence establishing a mutual recognition scheme for engineering technologists [7].

2. Stage 1 Competency for B. Eng Programs Offered in Australia

All 15 full member signatories of Washington Accord have adopted standard Stage 1 generic competencies for bachelor of engineering programs. The stage 1 competencies adopted by the Institution of Australia are the benchmark for B. Eng programs in Australia. All engineering programs must develop these competencies in an engineering program. Each individual subject/course must address one or more competencies to address all competencies of the program.
The Engineers Australia (EA) formerly the Institution of Engineers Australia has adopted the following key Stage 1 Engineering Graduate Competencies and Elements of Competency. The main competencies are sub grouped into 3 main categories. They are 1) Knowledge and Skill Base, 2) Engineering Application Ability, and 3) Professional and Personal Attributes. Each of these sub groups contains some elements of competency. Such elements are 16 since 2011 in EA's Stage 1 Competencies [4].

Stage 1 Competencies and Elements of Competency

1. KNOWLEDGE AND SKILL BASE
1.1. Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline.
1.2. Conceptual understanding of the, mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline.
1.3. In-depth understanding of specialist bodies of knowledge within the engineering discipline.
1.4. Discernment of knowledge development and research directions within the engineering discipline.
1.5. Knowledge of contextual factors impacting the engineering discipline.
1.6. Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline.

2. ENGINEERING APPLICATION ABILITY

2.1. Application of established engineering methods to complex engineering problem solving.
2.2. Fluent application of engineering techniques, tools and resources.
2.3. Application of systematic engineering synthesis and design processes.
2.4. Application of systematic approaches to the conduct and management of engineering projects.

3. PROFESSIONAL AND PERSONAL ATTRIBUTES

3.1. Ethical conduct and professional accountability
3.2. Effective oral and written communication in professional and lay domains.
3.3. Creative, innovative and pro-active demeanour.
3.4. Professional use and management of information.
3.5. Orderly management of self, and professional conduct.
3.6. Effective team membership and team leadership.

The Stage 1 Competencies are covered by 16 mandatory Elements of Competency. The Competencies and Elements of Competency represent the profession's expression of the knowledge and skill base, engineering application abilities, and professional skills, values and attitudes that must be demonstrated at the point of entry to practice [7]. Some indicators of attainment in Tables 4, 5 and 6 provide insight to the breadth and depth of ability expected for each element of competency. Therefore, the indicators guide the competency demonstration and assessment processes as well as curriculum design.

Recently the Australian government has developed Australian Qualifications Framework (AQF) which is the national policy for regulated qualifications in Australian education and training. It incorporates the qualifications from each education and training sector into a single comprehensive national qualifications framework [9]. The AQF was first introduced in 1995 to underpin the national system of qualifications in Australia encompassing higher education, vocational education and training and schools. The AQF has also developed its own generic competencies which are comparable and close the EA competencies. Every Australian university has its own graduate attributes/generic competencies as well. These competencies are generally comparable to professional engineering competencies. A bachelor degree with honours (3 years + 1 year) comparable to a 4 years bachelor degree in engineering with significant emphasis on research competency satisfies the AQF learning outcome descriptors (AQF LODs) at level 8. Such descriptors of Level 8 are:

Knowledge:
K1 Coherent and advanced knowledge of the underlying principles and concepts in one or more disciplines
K2 Knowledge of research principles and methods

Skills:
S1 Cognitive skills to review, analyse, consolidate and synthesise knowledge to identify and provide solutions to complex problems with intellectual independence
S2 Cognitive and technical skills to demonstrate a broad understanding of a body of knowledge and theoretical concepts with advanced understanding in some areas
S3 Cognitive skills to exercise critical thinking and judgement in developing new understanding
S4 Technical skills to design and use research in a project
S5 Communication skills to present a clear and coherent exposition of knowledge and ideas to a variety of audiences

Application of Knowledge and Skills:
A1 Demonstrate application of knowledge and skills with initiative and judgement in professional practice and/or scholarship
A2 Adapt knowledge and skills in diverse contexts
A3 Demonstrate application of knowledge and skills with responsibility and accountability for own learning and practice in collaboration with others within broad parameters
A4 Demonstrate application of knowledge and skills to plan and execute project work and/or a piece of research and scholarship with some independence

The RMIT university developed generic graduate attributes (GAs) are:

GA1 Work ready

GA2 Global in outlook and competence
GA3 Environmentally aware and responsive
GA4 Culturally and socially aware
GA5 Active and lifelong learners
GA6 Innovative

Table 7 lists individual subjects/courses of bachelor of mechanical engineering program offered by RMIT University. The table also shows how each individual subject/course in all 4 years addresses each of 16 EA competencies, AQF LODs and RMIT Graduate Attributes. The attainment of each of these competencies is also shown under individual subject/course guide, which is not illustrated here due space constraint.

Table 4: Knowledge and skill base: Elements and Indicator

ELEMENT OF COMPETENCY	INDICATORS OF ATTAINMENT
1.1 Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline.	a) **Engages** with the engineering discipline at a phenomenological level, applying sciences and engineering fundamentals to systematic investigation, interpretation, analysis and innovative solution of *complex* problems and broader aspects of engineering practice.
1.2 Conceptual understanding of the, mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline.	a) **Develops and fluently applies** relevant investigation analysis, interpretation, assessment, characterisation, prediction, evaluation, modelling, decision making, measurement, evaluation, knowledge management and communication tools and techniques pertinent to the engineering discipline.
1.3 In depth understanding of specialist bodies of knowledge within the engineering discipline.	a) **Proficiently applies** advanced technical knowledge and skills in at least one specialist practice domain of the engineering discipline.
1.4 Discernment of knowledge development and research directions within the engineering discipline.	a) **Identifies and critically appraises** current developments, advanced technologies, emerging issues and interdisciplinary linkages in at least one specialist practice domain of the engineering discipline. b) **Interprets and applies** selected research literature to inform engineering application in at least one specialist domain of the engineering discipline.
1.5 Knowledge of contextual factors impacting the engineering discipline.	a) **Identifies and understands** the interactions between engineering systems and people in the social, cultural, environmental, commercial, legal and political contexts in which they operate, including both the positive role of engineering in sustainable development and the potentially adverse impacts of engineering activity in the engineering discipline. b) **Is aware of** the founding principles of human factors relevant to the engineering discipline. c) **Is aware of** the fundamentals of business and enterprise management. d) **Identifies** the structure, roles and capabilities of the engineering workforce. e) **Appreciates** the issues associated with international engineering practice and global operating contexts.
1.6 Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the engineering discipline.	a) **Applies** systematic principles of engineering design relevant to the engineering discipline. b) **Appreciates** the basis and relevance of standards and codes of practice, as well as legislative and statutory requirements applicable to the engineering discipline. c) **Appreciates** the principles of safety engineering, risk management and the health and safety responsibilities of the professional engineer, including legislative requirements applicable to the engineering discipline. d) **Appreciates** the social, environmental and economic principles of sustainable engineering practice. e) **Understands** the fundamental principles of engineering project management as a basis for planning, organising and managing resources. f) **Appreciates** the formal structures and methodologies of systems engineering as a holistic basis for managing complexity and sustainability in engineering practice.

Table 5: Engineering application ability: Elements and Indicators

ELEMENT OF COMPETENCY	INDICATORS OF ATTAINMENT
2.1 Application of established engineering methods to *complex* engineering problem solving.	a) **Identifies, discerns and characterises** salient issues, **determines and analyses** causes and effects, **justifies and applies** appropriate simplifying assumptions, **predicts** performance and behaviour, **synthesises** solution strategies and **develops** substantiated conclusions. b) **Ensures** that all aspects of an engineering activity are soundly based on fundamental principles - by diagnosing, and taking appropriate action with data, calculations, results, proposals, processes, practices, and documented information that may be ill-founded, illogical, erroneous, unreliable or unrealistic. c) **Competently addresses** engineering problems involving uncertainty, ambiguity, imprecise information and wide-ranging and sometimes conflicting technical and non-technical factors. d) **Partitions** problems, processes or systems into manageable elements for the purposes of analysis, modelling or design and then **re-combines** to form a whole, with the integrity and performance of the overall system as the paramount consideration. e) **Conceptualises** alternative engineering approaches and **evaluates** potential outcomes against appropriate criteria to justify an optimal solution choice. f) **Critically reviews and applies** relevant standards and codes of practice underpinning the engineering discipline and nominated specialisations. g) **Identifies, quantifies, mitigates and manages** technical, health, environmental, safety and other contextual risks associated with engineering application in the designated engineering discipline. h) **Interprets and ensures** compliance with relevant legislative and statutory requirements applicable to the engineering discipline. i) **Investigates** complex problems using research-based knowledge and research methods.
2.2 Fluent application of engineering techniques, tools and resources.	a) **Proficiently identifies, selects and applies** the materials, components, devices, systems, processes, resources, plant and equipment relevant to the engineering discipline. b) **Constructs or selects and applies** from a qualitative description of a phenomenon, process, system, component or device a mathematical, physical or computational model based on fundamental scientific principles and justifiable simplifying assumptions. c) **Determines** properties, performance, safe working limits, failure modes, and other inherent parameters of materials, components and systems relevant to the engineering discipline. d) **Applies** a wide range of engineering tools for analysis, simulation, visualisation, synthesis and design, including assessing the accuracy and limitations of such tools, and validation of their results. e) **Applies** formal systems engineering methods to address the planning and execution of complex, problem solving and engineering projects. f) **Designs and conducts** experiments, **analyses and interprets** result data and **formulates** reliable conclusions. g) **Analyses** sources of error in applied models and experiments; eliminates, **minimises or compensates** for such errors; **quantifies** significance of errors to any conclusions drawn. h) **Safely applies** laboratory, test and experimental procedures appropriate to the engineering discipline. i) **Understands** the need for systematic management of the acquisition, commissioning, operation, upgrade, monitoring and maintenance of engineering plant, facilities, equipment and systems. j) **Understands** the role of quality management systems, tools and processes within a culture of continuous improvement.
2.3 Application of systematic engineering synthesis and design processes.	a) **Proficiently applies** technical knowledge and open ended problem solving skills as well as appropriate tools and resources to design components, elements, systems, plant, facilities and/or processes to satisfy user requirements. b) **Addresses** broad contextual constraints such as social, cultural, environmental, commercial, legal political and human factors, as well as health, safety and sustainability imperatives as an integral part of the design process. c) **Executes and leads** a whole systems design cycle approach including tasks such as: - determining client requirements and identifying the impact of relevant contextual factors, including business planning and costing targets; - systematically addressing sustainability criteria; - working within projected development, production and implementation constraints; - eliciting, scoping and documenting the required outcomes of the design task and defining acceptance criteria; - identifying assessing and managing technical, health and safety risks integral to the design process; - writing engineering specifications, that fully satisfy the formal requirements; - ensuring compliance with essential engineering standards and codes of practice; - partitioning the design task into appropriate modular, functional elements; that can be separately addressed and subsequently integrated through defined interfaces; - identifying and analysing possible design approaches and justifying an optimal approach; - developing and completing the design using appropriate engineering principles, tools, and processes; - integrating functional elements to form a coherent design solution; - quantifying the materials, components, systems, equipment, facilities, engineering resources and operating arrangements needed for implementation of the solution; - checking the design solution for each element and the integrated system against the engineering specifications; - devising and documenting tests that will verify performance of the elements and the integrated realisation; - prototyping/implementing the design solution and verifying performance against specification; - documenting, commissioning and reporting the design outcome. d) **Is aware of** the accountabilities of the professional engineer in relation to the 'design authority' role.
2.4 Application of systematic approaches to the conduct and management of engineering projects.	a) **Contributes to and/or manages** *complex* engineering project activity, as a member and/or as leader of an engineering team. b) **Seeks out** the requirements and associated resources and **realistically assesses** the scope, dimensions, scale of effort and indicative costs of a *complex* engineering project. c) **Accommodates** relevant contextual issues into all phases of engineering project work, including the fundamentals of business planning and financial management d) **Proficiently applies** basic systems engineering and/or project management tools and processes to the planning and execution of project work, targeting the delivery of a significant outcome to a professional standard. e) **Is aware of** the need to plan and quantify performance over the full life-cycle of a project, managing engineering performance within the overall implementation context. f) **Demonstrates** commitment to sustainable engineering practices and the achievement of sustainable outcomes in all facets of engineering project work.

Table 7: Complete program mapping against EA Stage 1 competencies, RMIT Graduate Attributes and AQF LODs

Program Learning Outcomes ***Bachelor of Engineering***	**AQF LODs**	**RMIT's GAs**	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Knowledge and Skill Base						
1.1. Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline.	K1	GA1, GA5	MIET2419, MANU2095, MIET2422	MIET2370 MIET2115 MIET2134	MIET1071 MIET1076 MIET1081	
1.2. Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline.	K1	GA1, GA5	MATH2117 MATH2118 MANU2095	MATH2124 MIET2370	MIET1081 MIET1084	
1.3. In-depth understanding of specialist bodies of knowledge within the engineering discipline.	S2	GA1	MANU2095	MIET2134, MIET2420	MIET1076 MIET1081 MIET1068 MIET1077 MIET1084	OENG1074 OENG1075 OENG1076 MIET2032
1.4. Discernment of knowledge development and research directions within the engineering discipline.	K2, S4	GA1			MIET1081 MIET1084	OENG1074 OENG1075 OENG1076
1.5. Knowledge of contextual factors impacting the engineering discipline.	S1	GA1	AERO2248 MIET2421 MIET2422		MIET1199 MIET1068 MIET2116	OENG1074 OENG1075 OENG1076 MIET2032
1.6. Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline.	A1	GA1	AERO2248		MIET1199 MIET1068 MIET2116	OENG1074 OENG1075 OENG1076
Engineering Application Ability						
2.1. Application of established engineering methods to complex engineering solving.	S1	GA1	MIET2422	MIET2370 MIET2115 MIET2134	MIET1071 MIET1081 MIET1068 MIET1077 MIET1084 MIET2116	OENG1074 OENG1075 OENG1076 MIET2032
2.2. Fluent application of engineering techniques, tools and resources.	S2	GA1	MIET2093 MIET2419 MIET2421 MIET2422 MANU2095	MATH2124 MIET2370 MIET2115 MIET2420	MIET1199 MIET1076 MIET1081 MIET1068 MIET1077 MIET1084	OENG1074 OENG1075 OENG1076 MIET2032
2.3. Application of systematic engineering synthesis and design processes.	S3	GA1, GA6	AERO2248	MIET2370 MIET2134 MIET2420	MIET1199 MIET1068 MIET1077 MIET2116	OENG1074 OENG1075 OENG1076
2.4. Application of systematic approaches to the conduct and management of engineering projects.	A4			MIET2370	MIET2116	OENG1074 OENG1075 OENG1076
Professional and Personal Attributes						
3.1. Ethical conduct and professional accountability.	A1	GA1	AERO2248		MIET1199 MIET1068 MIET2116	OENG1074 OENG1075 OENG1076
3.2. Effective oral and written communication in professional and lay domains.	S5	GA1	AERO2248 MIET2093 MIET2419 MIET2421 MIET2422	MIET2370 MIET2115	MIET2116	OENG1074 OENG1075 OENG1076
3.3. Creative, innovative and pro-active demeanour.	A2	GA2, GA3, GA4		MIET2370, MIET2420	MIET1068	OENG1074 OENG1075 OENG1076
3.4. Professional use and management of information.	A4	GA1	AERO2248	MIET2370 MIET2115	MIET1199 MIET1068 MIET2116	OENG1074 OENG1075 OENG1076 MIET2032
3.5.Orderly management of self, and professional conduct.	A3	GA1 GA5	AERO2248	MIET2420	MIET1199 MIET2116	OENG1074 OENG1075 OENG1076
3.6.Effective team membership and team leadership.	A3	GA1, GA5	AERO2248	MIET2370	MIET1199	OENG1074 OENG1075 OENG1076

3. Concluding Remarks

A generic national competency standard/benchmark is mandatory for enhancing quality of engineering education and student program learning outcomes. All accredited bachelor of engineering programs in Australia must attain the 16 EA Stage 1 competencies. Additionally, to qualify the generic program title "honours", the program needs to comply with the AQF LODs at level 8.

The Bangladesh Board of Accreditation for Engineering and Technical Education (BAETE) should develop its national generic competency standard for engineering programs offered by all institutions/universities across the country. The BAETE should follow the example of EA Stage 1 competency, accreditation standard and procedure in order to develop a comparable national competency standard and accreditation mechanism. The attainment of such systems will assist BAETE to become a full signatory of Washington Accord and its accredited engineering programs in Bangladesh to be automatically recognised in Washington Accord signatory countries.

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COMPARISON OF CHIP-TOOL INTERFACE TEMPERATURE AND TOOL WEAR IN TURNING STEELS UNDER HIGH-PRESSURE COOLANT ENVIRONMENTS

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ABSTRACT: Tool wear is a natural phenomenon during machining processes, which leads to tool failure, loss of production and weakens the product quality. The growing demands for high productivity of machining need use of high cutting velocity, feed rate and depth of cut. High heat and cutting temperature generation is inherent under such machining condition, which not only reduces dimensional accuracy and tool life but also impairs the product quality particularly when the work piece is strong, tough, hard and heat resistant. The cutting fluids are believed to reduce cutting temperature either by removing heat as a coolant or reducing the heat generation as a lubricant. But conventional cutting fluids are not that effective in high speed machining particularly in continuous cutting of materials as they can't enter into the chip tool interface at such situation and also deteriorate the working environment by producing harmful gasses and smokes. High pressure coolant may be the possible solution in such cases. This paper deals with the experimental investigation on the role of high pressure coolant on cutting temperature and tool wear in turning of C-60 steel, 17CrNiMo6 steel and 42CrMo4 steel at industrial speed-feed combinations by uncoated carbide inserts (SNMG and SNMM, Sandvik). The results include significant reduction in tool wear rate by employing high pressure coolant mainly through reduction in the cutting zone temperature and favorable change in the chip-tool and work-tool interaction.

***Key Words*:** High pressure coolant, steel, cutting temperature and tool wear.

1. INTRODUCTION

Machining is the process in which a tool removes material from the surface of a less resistant body, through relative movement and application of force. The material removed, called chip, slides on the face of tool, known as tool rake face, submitting it to high normal and shear stresses and, moreover, to a high coefficient of friction during chip formation [1, 2]. Most of the mechanical energy used to form the chip is converted into heat, which causes high temperatures in the cutting region. Due to the fact that the higher the tool temperature, the faster it wears, the use of cutting fluids in machining processes has, as its main goal, the reduction of the cutting zone temperature, either through lubrication reducing friction wear, or through cooling by conduction, or through a combination thereof.

However, the advantages caused by the cutting fluids have been questioned lately, due to the several negative effects they cause. The conventional cutting fluids utilized in machining are considered a problem for manufacturers, since these substances can seriously damage human health and environment [3, 4]. In line with growing environmental concerns involved in the use of cutting fluids in machining processes, as reported by several researchers and manufacturers of machine tools [5, 6], strong emphasis is being placed on the development of environmentally friendly technology, i.e., on environmental preservation and the search for conformity with the ISO 14000 standard. On the other hand, despite persistent attempts to eliminate cutting fluids, in many cases cooling is still essential to the economically feasible service life of tools and the required surface qualities. This is particularly true when tight tolerances and high dimensional and shape exactness are required, or when the machining of critical and difficult to cut materials is involved [2, 7].

Cryogenic cooling by liquid nitrogen jet provides environment friendly, clean technology for suitable control of cutting temperature but it is not cost effective due to high cost of cryogen [8, 9]. In normal cutting condition minimum quantity lubricant (MQL) provides better performance but at higher speed-feed condition performance is not good [10, 11]. Some recent techniques of dry cutting have enabled partial control of the machining temperature by using heat and wear resistant tools like coated carbides, diamond, CBN etc. However, diamond and CBN tools are very expensive and the practices in the industry are still not wide spread [12].

High pressure assisted cooling is one of the preferred technologies, currently, under exploitation especially in the aerospace and power plant industries for machining exotic materials. The credibility of high-pressure coolant assisted machining had been investigated over the years [13–16]. This system not only provides adequate cooling at the tool–work piece interface but also provides an effective flushing of chips from the cutting area. The coolant jet under such high pressure is capable of creating a hydraulic wedge between the tool and the work piece, penetrating the interface deeply with a speed exceeding that necessary even for very high-speed machining. This phenomenon also changes the chip flow conditions [17]. The penetration of the high-energy jet at the tool–chip interface reduces the temperature gradient and minimizes the seizure effect, offering an adequate lubrication at the tool–chip interface with a significant reduction in friction. Excellent chip breakability has been reported when machining difficult-to-cut materials with high pressure coolant supply [18, 19]. This is attributed to a coolant wedge, which forms between the chip and the tool forcing the chip to bend upwards giving it a desirable up curl required for segmentation. Coolant supply at high-pressure tends to lift up the chip after passing through the deformation zone resulting to a reduction in the tool–chip contact length/area. This tends to enhance chip segmentation as the chip curl radius is reduced significantly; hence, maximum coolant pressure is restricted only to a smaller area on the chip. Similar observation with chip segmentation was made while machining steel. It was observed that the power of the coolant jet and the lateral position of the point where the jet hits the line where the chip exits the tool rake face has significant influence on the chip segmentation process with high pressure coolant supplies [20].

The main objectives of this paper is to experimentally investigate the role of high pressure coolant jet by water insoluble mineral oil VG 68 on cutting temperature and tool wear in turning C-60 steel, 17CrNiMo6 steel and 42CrMo4 steel by uncoated SNMG and SNMM carbide inserts.

2. EXPERIMENTAL CONDITIONS

The machining tests have been carried out by straight turning of different steels (C-60 steel, 17CrNiMo6 steel and 42CrMo4 steel) in a rigid and reasonably powerful lathe (10 hp, China) by standard carbide insert (SNMG and SNMM, Sandvik) at different cutting speed (V) and feeds (f) under both dry and high pressure coolant (HPC) conditions. The machinability characteristics of that work materials mainly in respect of cutting temperature and tool wear have been investigated to study the role of high pressure coolant. The experimental conditions are given in Table 1. The ranges of the cutting speed (V) and feed rate (f) were selected based on the tool manufacturer's recommendation and industrial practices.

The experimental set-up used for the present purpose has been shown in Fig.1. High pressure coolant jet was impinged from a specially designed nozzle to cool the tool and the work material at the hot cutting zone. The thin but high velocity stream of coolant was projected along the auxiliary cutting edge of the insert, so that the coolant reaches as close to the chip-tool and the work-tool interfaces as possible.

Table 1 Experimental conditions

Machine tool	:	Centre lathe 10 hp (China)
Work materials	:	C-60 steel, 17CrNiMo6 steel and 42CrMo4 steel
Cutting tool insert	:	SNMG and SNMM (Sandvik)
Tool holder	:	PSBNR 2525 M12 (Sandvik)
Working tool geometry	:	-6^0, -6^0, 6^0, 6^0,5^0, 75^0, 0.8 (mm)
Process parameters		
Cutting speed (V)	:	93, 133, 186, 266and 193 m/min
Feed (f)	:	0.10, 0.14, 0.18 and 0.22 mm/rev

Depth of cut (d)	:	1.00 mm and 1.50 mm
HPC supply	:	80 bar
Machining Environment	:	Dry and High pressure coolant (HPC)

Nozzle, an important part of the HPC system, is connected to the direction control valve by a long high-pressure hydraulic pipe. It is located at the top of the cutting tool along the auxiliary cutting edge making an angle 15^0 with true horizontal. The nozzle has been designed so that the nozzle spray pattern and covering area can be controlled easily. In the present work, cutting temperature and tool wear are considered for studying the role of high pressure coolant.

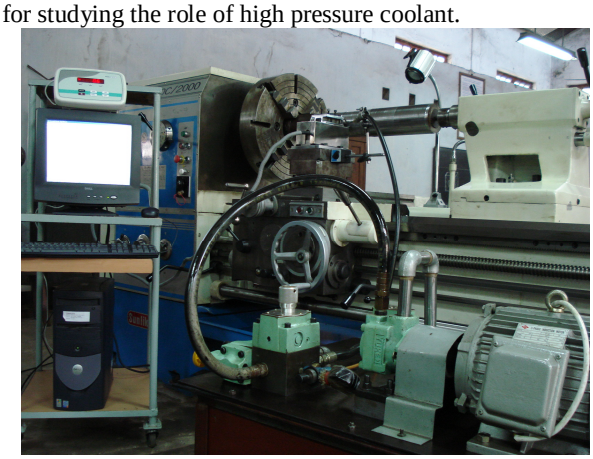


Fig.1: Photographic view of the experimental set-up

The average cutting temperature was measured under all the machining conditions undertaken by simple but reliable tool-work thermocouple technique with proper calibration. In the present case, almost linear relationships between the temperature and emf have been obtained with multiple correlation coefficients around 0.994. Tool-work thermocouple calibration curves have been shown in Fig.2.

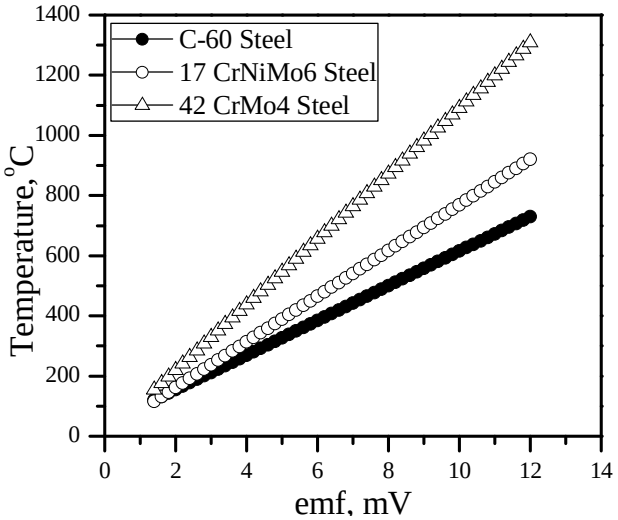


Fig.2: Tool-work thermocouple calibration curve

The cutting tools in conventional machining, particularly in continuous chip formation processes like turning, generally fails by gradual wear by abrasion, adhesion, diffusion, chemical erosion, galvanic action etc. depending upon the tool-work materials and machining condition. Tool wear initially starts with a relatively faster rate due to what is called break-in wear caused by attrition and micro-chipping at the sharp cutting edges.

Cutting tools may also often fail prematurely, randomly and catastrophically by mechanical breakage and plastic deformation under adverse machining conditions caused by intensive pressure and temperature and/or dynamic loading at the tool tips particularly if the tool material lacks strength, hot-hardness and fracture toughness. However, in the present investigations with the tools and work materials and the machining conditions undertaken, the tool failure mode has been mostly gradual wear. The geometrical pattern of tool wear that is generally observed in turning by carbide inserts is schematically shown in Fig.3. The major features that characterize flank wear and crater wear are also indicated in that figure.

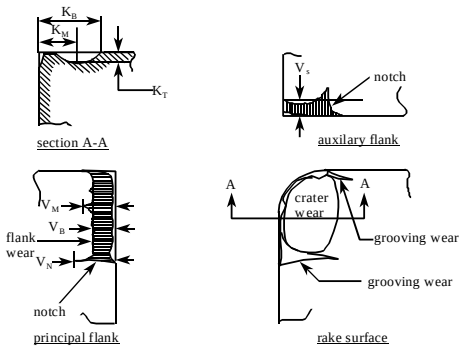
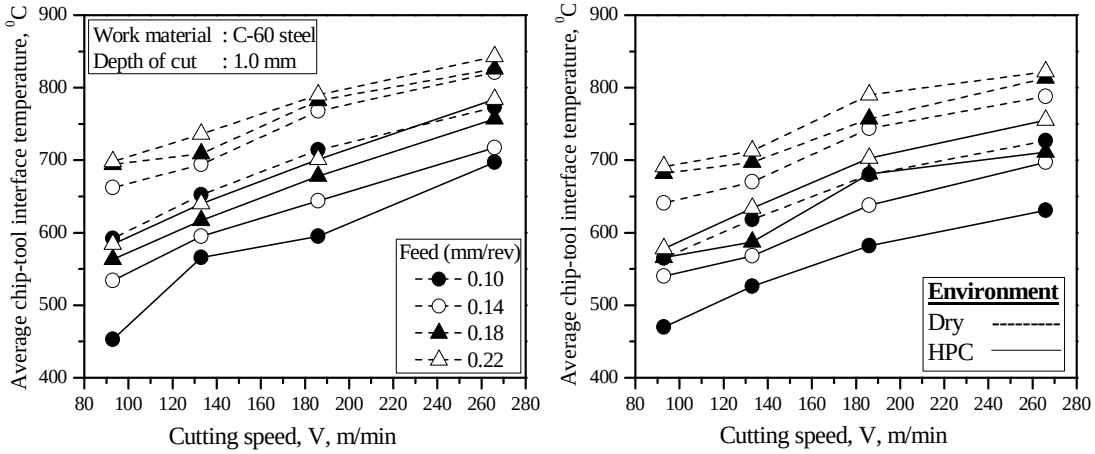


Fig. 3: Schematic view of general pattern of wear [Dhar 2001]

The cutting insert was withdrawn at regular intervals to study the pattern and magnitude of wear on main and auxiliary flanks for all the trials. The average width of the principal flank wear, VB and auxiliary flank wear, VS were measured using in inverted metallurgical microscope (Carl Zeiss, Germany) fitted with micrometer of least count 1 μm. At the end of full cut, the cutting insert was inspected under scanning electron microscope (Philips XL-30, Japan).

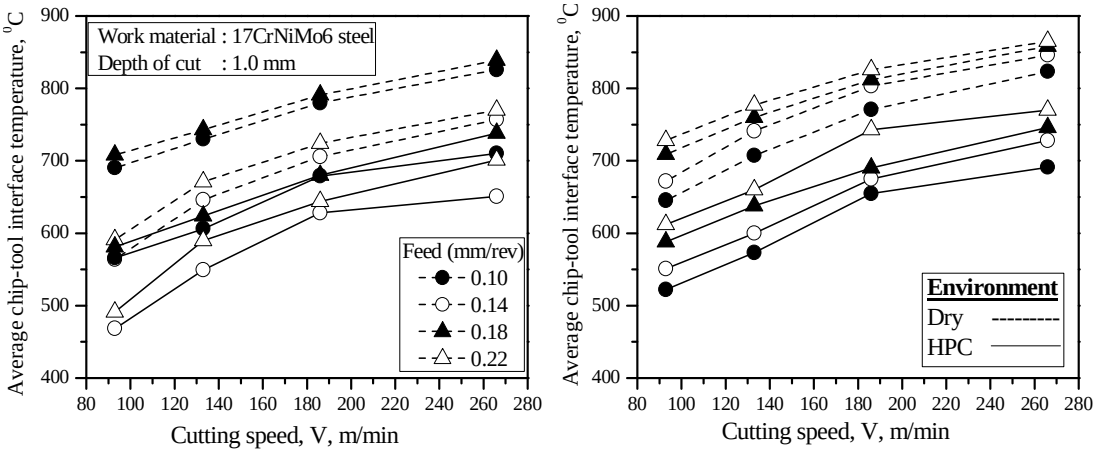
3. EXPERIMENTAL RESULTS AND DISCUSSION

To achieve an effective cutting condition the machining temperature at the cutting zone needs to be controlled as far as possible as it is an important index of machinability. High pressure coolant (HPC) system reduces the cutting temperature and provides a very favorable effect. The effect of HPC on average chip-tool interface temperature (θ) at different V and f under both dry and high pressure coolant (HPC) conditions has been shown in Fig.4, Fig.5 and Fig.6. It is clear from the figures that during machining at lower V and f the effective cooling is more as the chip-tool contact there is partially elastic and when the chip leaves the tool, High pressure coolant is dragged in that elastic contact zone in small quantity by capillary effect. With an increase in V the chip makes fully plastic or bulk contact with the tool rake surface which prevents from entering of any fluid into the hot chip-tool interface. HPC cooling effect also improved to some extent with the decrease in feed particularly at lower cutting speed. At lower chip velocity, the thinner chips are slightly pushed up by the high pressure jet coming from opposite direction and enable it come closer to the hot chip-tool contact zone to remove heat more effectively. But at high speed the coolant might not get enough time to remove the heat accumulated at the cutting zone resulting in less reduction in temperature under high pressure coolant condition at high cutting speed. The SNMM insert having wide and deep slope parallel to its cutting edges seemed to provide better cooling effect particularly when the work material is 17CrNiMo6 steel. It is also evident from the figures that HPC effect slightly decreases with the increase in V and f. This may be attributed to the fact that with the increase in V and f, V in particular, the chip–tool contact tends to become fully plastic obstructing penetration of the HPC jet into the hot chip–tool interface.



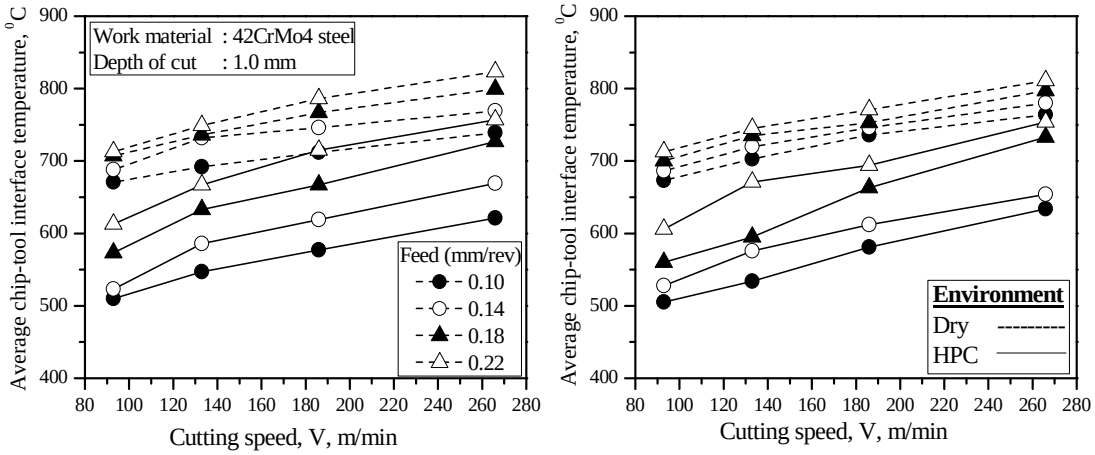
(a) SNMG insert **(b) SNMM insert**

Fig.4 Variation in **temperature(θ)** with that of V and f in turning **C-60 Steel** by (a) **SNMG** and (b) **SNMM** inserts under **Dry** and **HPC** conditions



(a) SNMG insert **(b) SNMM insert**

Fig.5 Variation in **temperature (θ)** with that of V and f in turning **17CrNiMo6 steel** by (a) **SNMG** and (b) **SNMM** inserts under **Dry** and **HPC** conditions



(a) SNMG insert **(b) SNMM insert**

Fig.6 Variation in **temperature (θ)** with that of V and f in turning **42CrMo4 Steel** by (a) **SNMG** and (b) **SNMM** inserts under **Dry** and **HPC** conditions

Productivity and economy of manufacturing by machining are significantly influenced by life of the cutting tools. Cutting tools may fail by brittle fracturing, plastic deformation or gradual wear. Turning carbide inserts having enough strength; toughness and hot hardness generally fail by gradual wear. With the progress of machining the tools attain crater wear at the rake surface and flank wear at the clearance surfaces due to continuous interaction and rubbing with the chips and the work surfaces, respectively. Among the aforesaid wears, the principal flank wear is the most important because it raises the cutting forces and the related problems. The life of carbide tools, which mostly fail by wearing, is assessed by the actual machining time after which according to ISO the average value (VB) of its principal flank wear reaches a limiting value, like 0.3 mm. Therefore, attempts should be made to reduce the rate of growth of flank wear (VB) in all possible ways without sacrifice in MRR.

The growth of principal flank wear, VB with progress of machining recorded while turning the steels, undertaken, by the SNMG and SNMM type inserts at the same cutting speed, feed and depth of cut under dry and HPC conditions have been shown in Fig.7, Fig.8 and Fig.9. Pattern and magnitude of tool wear under conventional coolant condition was observed in case of machining C-60 steel. Fig.7 shows that the tool wear aggravates under flood cooling. This indicate that coolant under flood condition can not get access into the hot chip-tool interface due to plastic contact and experiences a dry mode of cutting. Due to the fact and scarcity of costly alloy steel conventional coolant was not tried for 17CrNiMo6 steel and 42CrMo4 steel. Premature and catastrophic type of tool failure by plastic deformation or macro fracture were not found to occur expectedly within the present experimental domain excepting in only one case where insert broke after 14 minutes while machining 42CrMo4 steel with SNMG insert at moderately high speed, feed and depth of cut under dry condition.

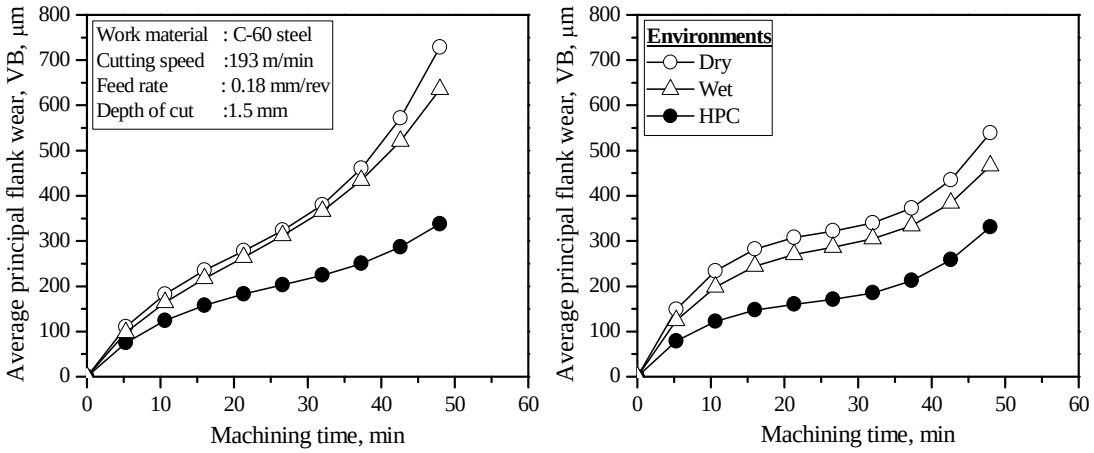
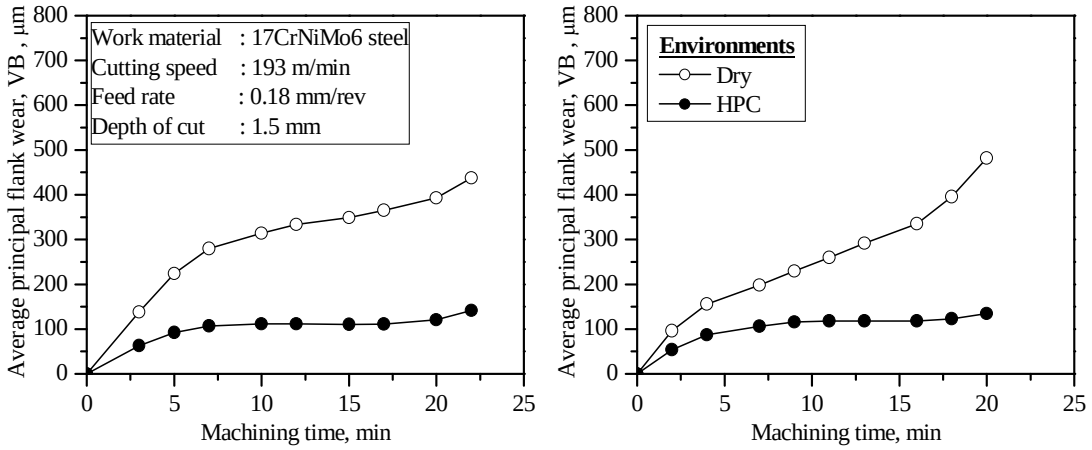
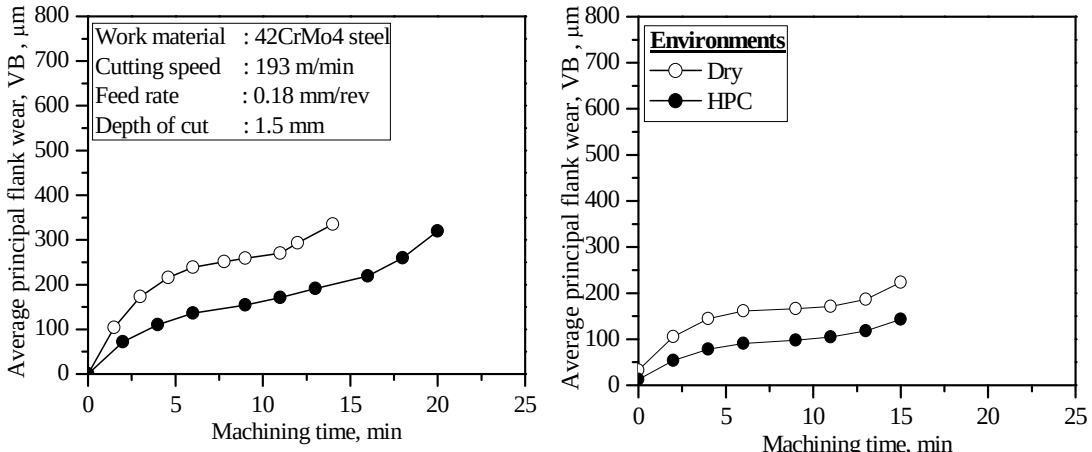


Fig. 7 Growth of **average principal flank wear (VB)** with machining time in turning **C-60 Steel** by (a) **SNMG** and (b) **SNMM** inserts under **Dry, Wet** and **HPC** conditions



(a) SNMG insert **(b) SNMM insert**

Fig. 8 Growth of **average principal flank wear (VB)** with machining time in turning **17CrNiMo6 Steel** by (a) **SNMG** and (b) **SNMM** inserts under **Dry** and **HPC** conditions



(a) SNMG insert **(b) SNMM insert**

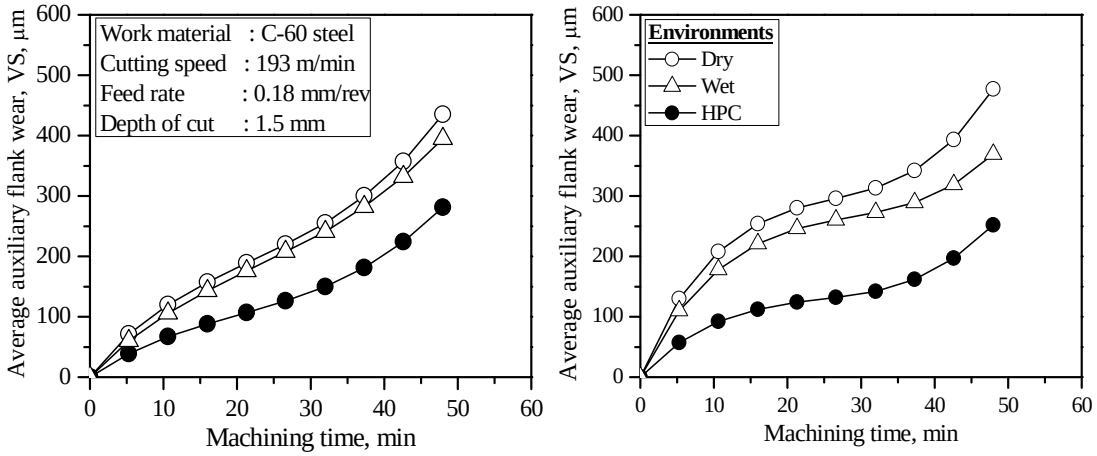
Fig. 9 Growth of **average principal flank wear (VB)** with machining time in turning **42CrMo4 steel** by (a) **SNMG** and (b) **SNMM** inserts under **Dry** and **HPC** conditions

Cutting tools generally attain, particularly in turning of steels by carbides, large notch and grooving wear at the outer ends of their principal flank and crater wear at the rake face respectively as are indicated in Fig.3. Such deeper wear, particularly notch wear, weakens the cutting edges and may lead to premature failure of the tool tips by fracture. Machining environment substantially influences the growth of such wear which is susceptible to oxidation and corrosion.

Fig.9 reveals that during machining 42CrMo4 steel with both type of inserts, VB grew slowly and uniformly, but after about 14 min of machining of 42CrMo4 steel under dry condition, the insert failed by large fracturing as can be seen in Fig.17. Fig.13, Fig.14, Fig.15, Fig.16, Fig.17 and Fig.18 also depicts how flank notch wear, VN remarkably decreased due to high pressure coolant. Deep notching, if forms, not only raises cutting forces but also may cause catastrophic tool failure prematurely and randomly, which is extremely harmful and undesirable for the present days' sophisticated and expensive manufacturing systems. So, proper high pressure coolant system is expected also to enhance reliability and safely of machining processes and systems. Fig.7, Fig.8 and Fig.9 clearly shows that flank wear, VB particularly its rate of growth decreased substantially by the application of high pressure coolant. Crater wears of carbide tools in machining steels particularly at higher V and f occur by adhesion and diffusion as well as post abrasion. Whereas, flank wear occurs

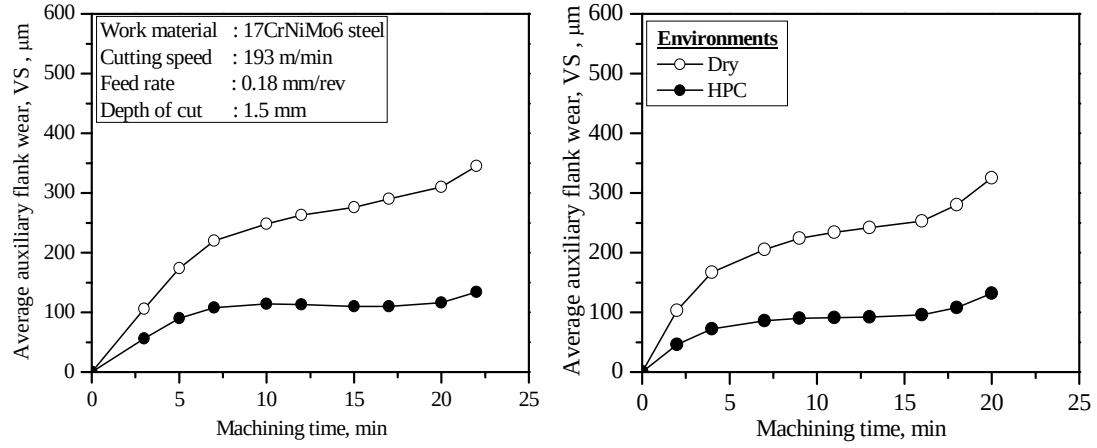
mainly by micro-chipping and abrasion and with increase in V and f adhesion and diffusion also come into picture due to intimate contact with the work surface at elevated temperature.

The cause behind reduction in VB observed may reasonably be attributed to substantial reduction in the flank temperature by the application of high pressure coolant particularly the jet impinged along the auxiliary cutting edge, which helped in reducing abrasion wear by retaining tool hardness and also adhesion and diffusion types of wear which are highly sensitive to temperature. Because of such reduction in rate of growth of flank wear the tool life would be much higher if high pressure coolant is properly applied. . Fig.10, Fig.11 and Fig.12 show the beneficial role of high pressure coolant on the auxiliary flank wear, VS the nature and extent of which affects dimensional accuracy and surface finish of the turned job. Auxiliary flank wear (VS), though occurs less intensively, also plays significant role in machining by aggravating dimensional inaccuracy and roughness of the finished surface. It appears from Fig.10, Fig.11 and Fig.12 that auxiliary flank wear (VS) has also decreased sizeably due to application of high pressure coolant.



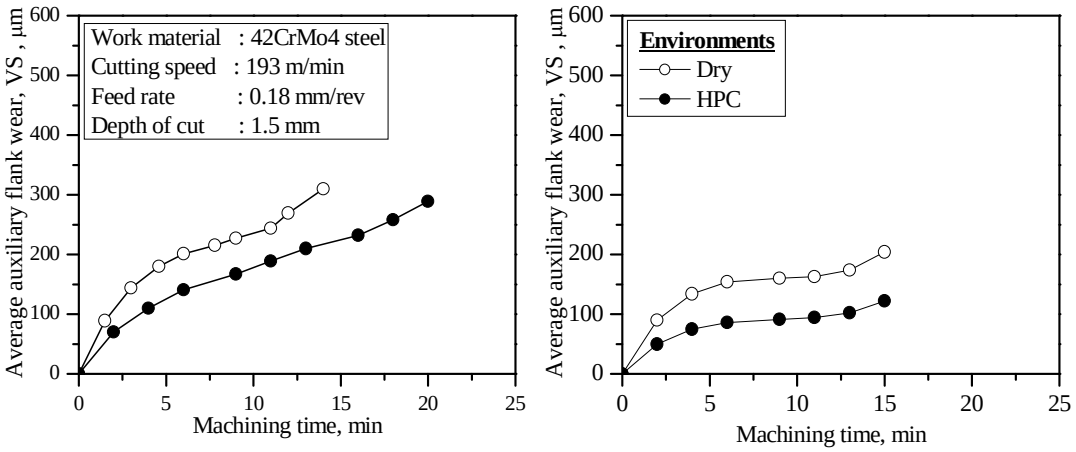
(a) SNMG insert **(b) SNMM insert**

Fig. 10 Growth of **average auxiliary flank wear (VS)** with machining time in turning **C-60 Steel** by (a) **SNMG** and (b) **SNMM** inserts under **Dry, Wet a**nd **HPC** conditions



(a) SNMG insert **(b) SNMM insert**

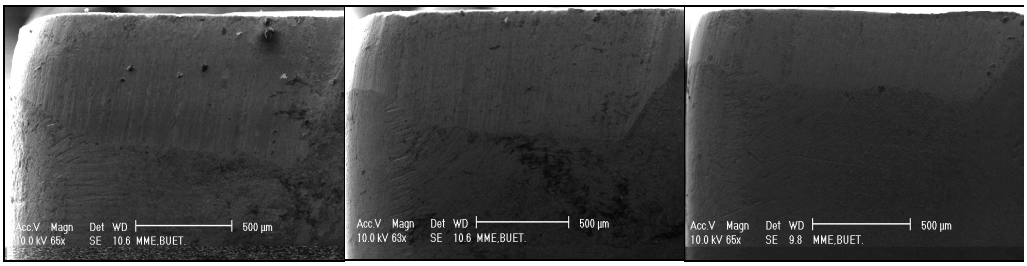
Fig. 11 Growth of **average auxiliary flank wear (VS)** with machining time in turning **17CrNiMo6 Steel** by (a) **SNMG** and (b) **SNMM** inserts under **Dry** and **HPC** conditions



(a) SNMG insert **(b) SNMM insert**

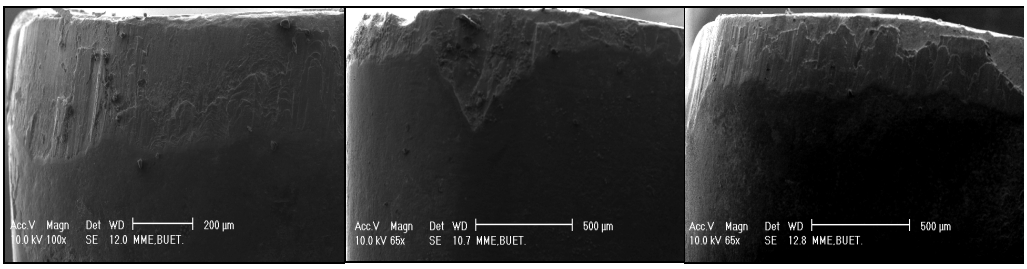
Fig. 12 Growth of **average auxiliary flank wear (VS)** with machining time in turning **42CrMo4 steel** by (a) **SNMG** and (b) **SNMM** inserts under **Dry** and **HPC** conditions

Fig.13, Fig.14, Fig.15, Fig.16, Fig.17 and Fig.18 show the SEM photographs of worn out principal flank of SNMG and SNMM inserts used for machining C-60 steel, 17CrNiMo6 steel and 42CrMo4 steel bars under dry and HPC environments. No notch and groove wear were observed under all the environments. The main cutting edge has suffered minor micro-fracturing under dry machining. HPC cooling expectedly reduced main flank and auxiliary flank wear. The SEM photographs of worn out auxiliary flank of SNMG and SNMM inserts used are shown in Fig.19, Fig.20, Fig.21, Fig.22, Fig.23 and Fig.24.



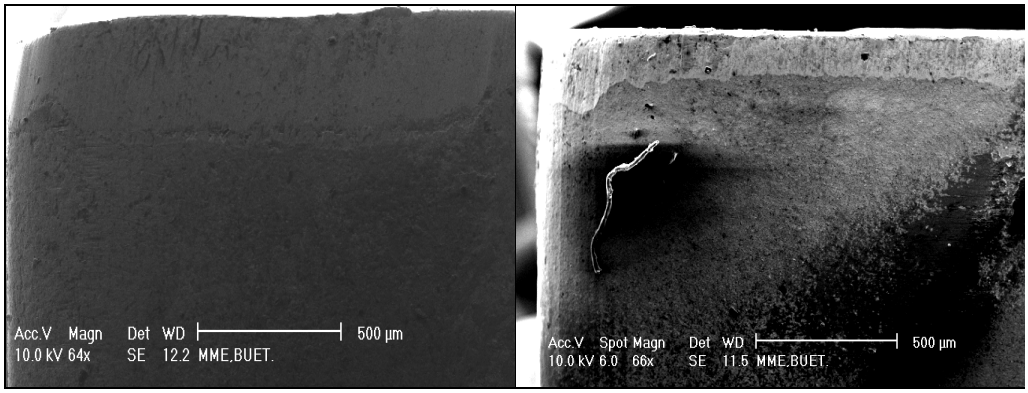
(a) Dry condition, 48 min (b) Wet condition, 48 min (c) HPC condition, 48 min

Fig. 13 SEM views of **principal flank** of worn out tip of **SNMG** insert after machining **C-60 steel** under (a) **Dry,** (b) **Wet** and (c) **HPC** conditions



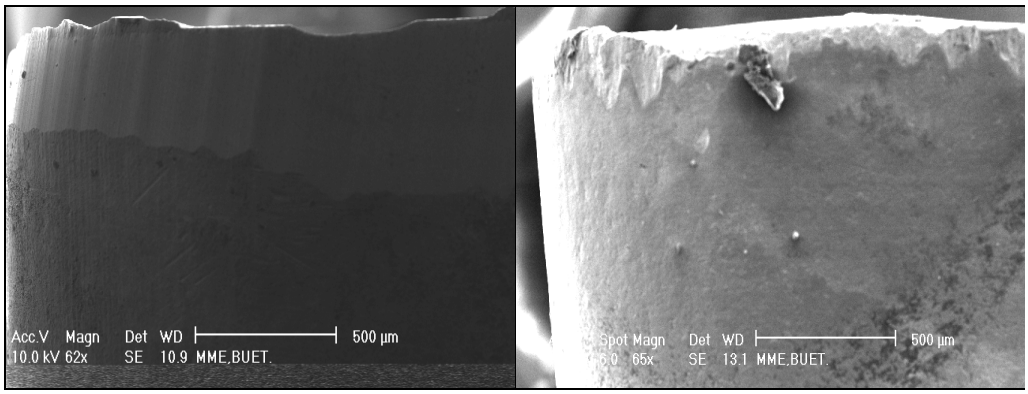
(a) Dry condition, 48 min (b) Wet condition, 48 min (c) HPC condition, 48 min

Fig. 14 SEM views of **principal flank** of worn out tip of **SNMM** insert after machining **C-60 steel** under (a) **Dry,** (b) **Wet** and (c) **HPC** conditions



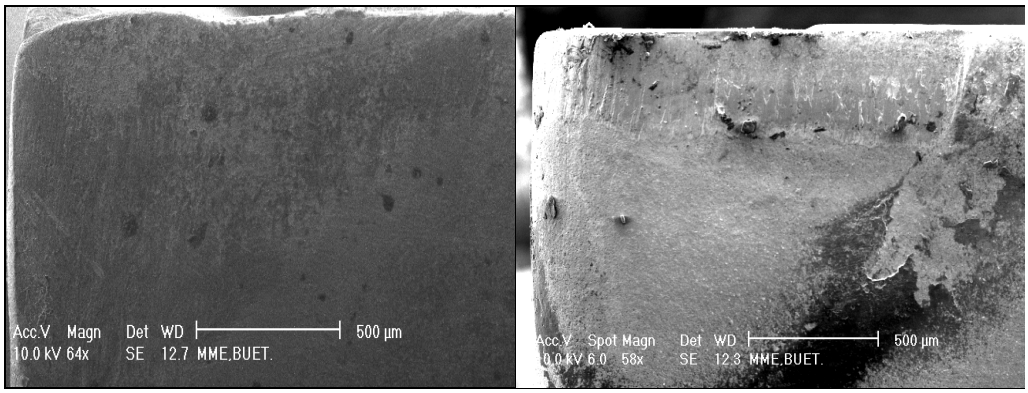
(a) Dry condition, 22 min (b) HPC condition, 22 min

Fig. 15 SEM views of **principal flank** of worn out tip of **SNMG** insert after machining **17CrNiMo6 steel** under (a) **Dry** and (b) **HPC** conditions



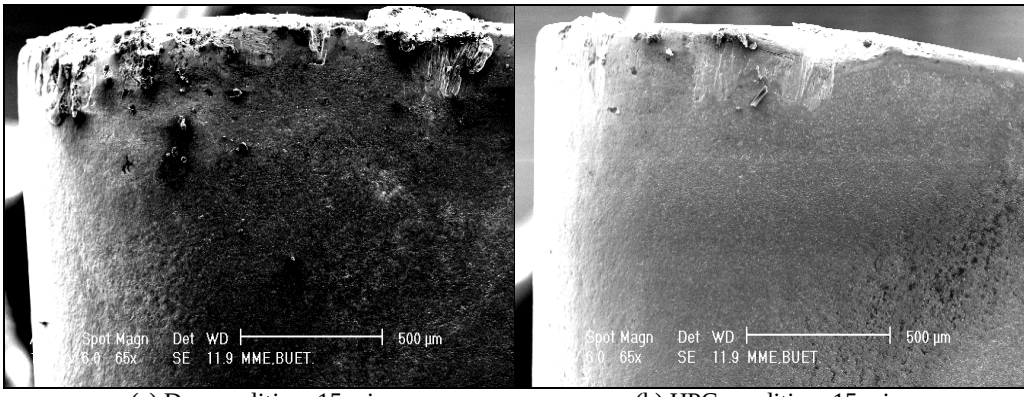
(a) Dry condition, 20 min (b) HPC condition, 20 min

Fig. 16 SEM views of **principal flank** of worn out tip of **SNMM** insert after machining **17CrNiMo6 steel** under (a) **Dry** and (b) **HPC** conditions



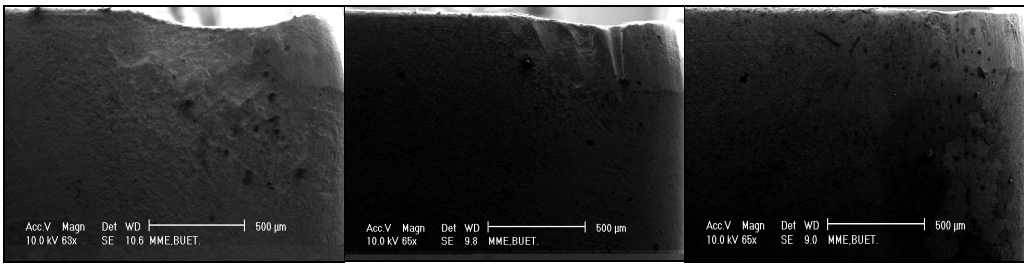
(a) Dry condition, 14 min (b) HPC condition, 20 min

Fig. 17 SEM views of **principal flank** of worn out tip of **SNMG** insert after machining **42CrMo4 steel** under (a) **Dry and** (b) **HPC** conditions



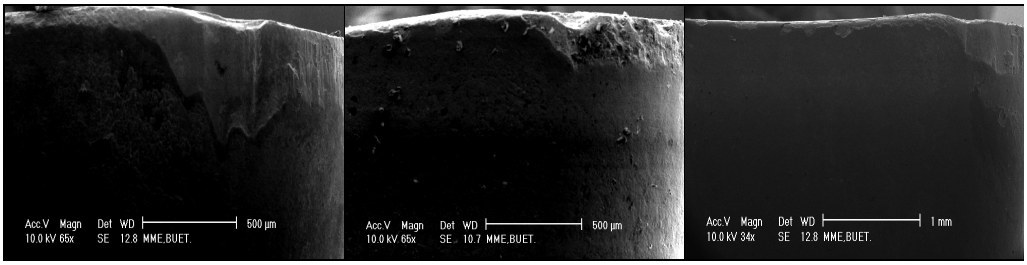
(a) Dry condition, 15 min (b) HPC condition, 15 min

Fig. 18 SEM views of **principal flank** of worn out tip of **SNMM** insert after machining **42CrMo4 steel** under (a) **Dry** and (b) **HPC** conditions



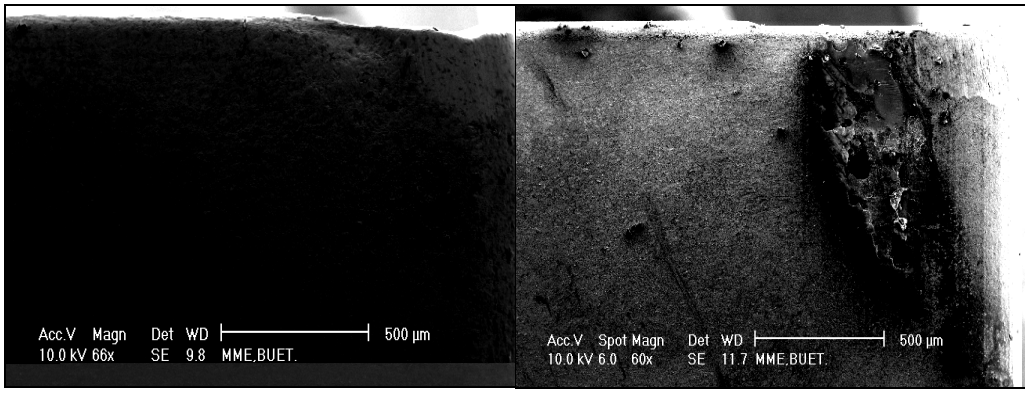
(a) Dry condition, 48 min (b) Wet condition, 48 min (c) HPC condition, 48 min

Fig. 19 SEM views of **auxiliary flank** of worn out tip of **SNMG** insert after machining **C-60 steel** under (a) **Dry,** (b) **Wet** and (c) **HPC** conditions



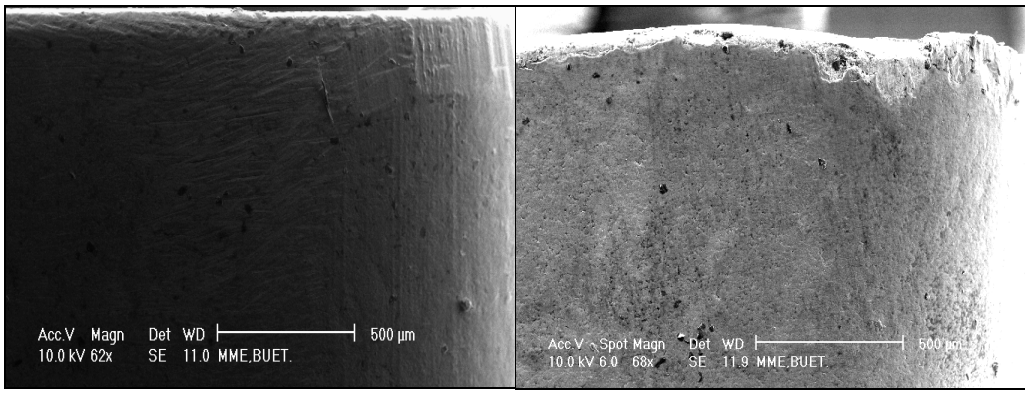
(a) Dry condition, 48 min (b) Wet condition, 48 min (c) HPC condition, 48 min

Fig. 20 SEM views of **auxiliary** worn out tip of **SNMM** insert after machining **C-60 steel** under (a) **Dry,** (b) **Wet** and (c) **HPC** conditions



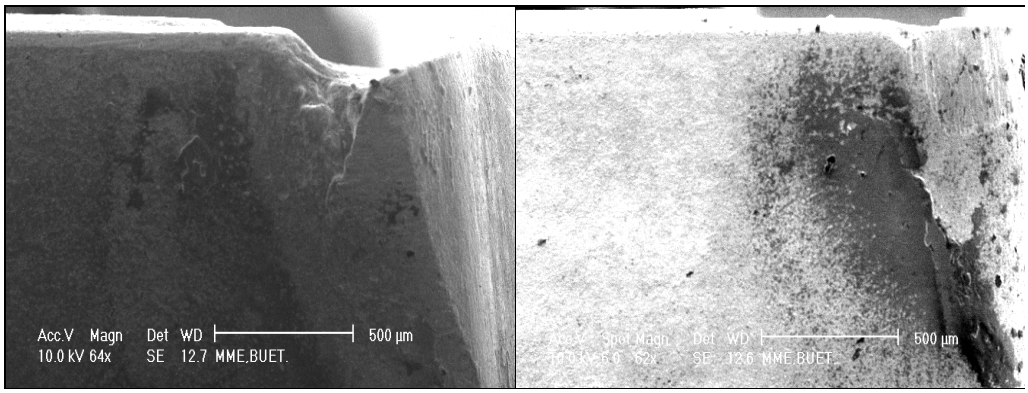
(a) Dry condition, 22 min (b) HPC condition, 22 min

Fig. 21 SEM views of **auxiliary flank** of worn out tip of **SNMG** insert after machining **17CrNiMo6 steel** under (a) **Dry** and (b) **HPC** conditions



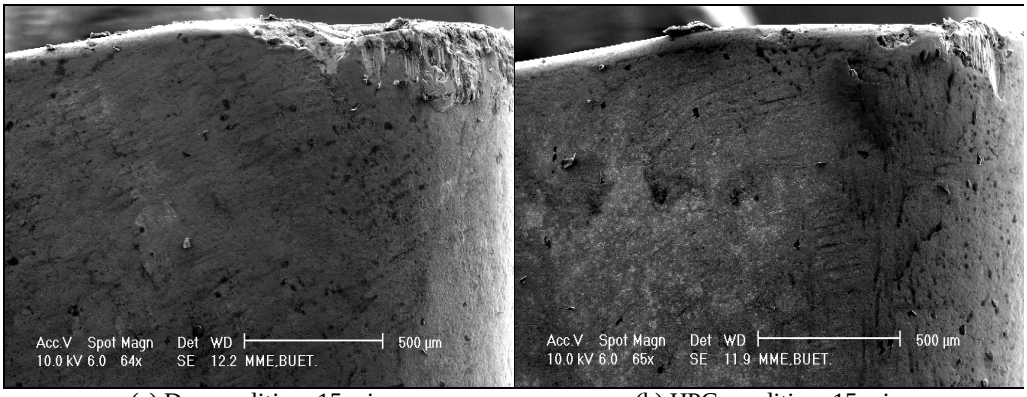
(a) Dry condition, 20 min (b) HPC condition, 20 min

Fig. 22 SEM views of **auxiliary flank** of worn out tip of **SNMM** insert after machining **17CrNiMo6 steel** under (a) **Dry** and (b) **HPC** conditions



(a) Dry condition, 14 min (b) HPC condition, 20 min

Fig. 23 SEM views of **auxiliary flank** of worn out tip of **SNMG** insert after machining **42CrMo4 steel** under (a) **Dry** and (b) **HPC** conditions



(a) Dry condition, 15 min (b) HPC condition, 15 min

Fig. 24 SEM views of **auxiliary flank** of worn out tip of **SNMM** insert after machining **42CrMo4 steel** under (a) **Dry** and (b) **HPC** conditions

4. CONCLUSION

Based on the results of the present experimental investigation the following conclusions can be drawn:

1. Application of high pressure coolant (HPC) jet can provide substantial technological benefits as has been observed in machining some steels by carbide tool.
2. The present HPC system enabled reduction in average chip-tool interface temperature upto 25% depending upon the work materials, cutting conditions and even such small reduction enabled significant improvement in the major machinability index like tool wear.
3. The most significant contribution of application of HPC jet in machining the steels by the carbide insert undertaken has been the high reduction in flank wear, which would enable remarkable improvement in tool life. Such reduction in tool wear might have been possible for retardation of abrasion and notching, decrease or prevention of adhesion and diffusion type thermal sensitive wear at the flanks and reduction of built-up edge formation which accelerates wear at the cutting edges by chipping and flaking. Deep notching and grooving, which are very detrimental and may cause premature and catastrophic failure of the cutting tools, are remarkably reduced by high pressure coolant.

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PERFORMANCE EVALUATION OF HPC IN TURNING AISI 4320 STEEL AND AISI 4140 STEEL

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ABSTRACT: High heat generation is inherent in machining steel and other hard materials and instant heat transfer is required from the cutting interface of the tool and the work material where the intensity of cutting temperature is the maximum to avoid surface distortion and to improve tool life. Conventional cooling fails to control the cutting temperature and to maintain the product quality. Moreover it creates hazardous environment for human being and a major source of pollution in the industries. High pressure and high velocity coolant may provide the best control to reduce cutting temperature and tool wear as well as to increase tool life. This paper deals with an experimental investigation of the effect of high-pressure coolant on temperature, tool wear and surface roughness in machining of AISI 4320 and AISI 4140 steels using uncoated carbide tools and comparing them under dry cut condition as well as the materials themselves. The inspiring experimental results include the reduction of cutting temperature and tool wear and improvement of surface finish with the use of high-pressure coolant. But increasing hardness increases cutting temperature and tool wear rate.

Keywords: High- pressure coolant, Cutting temperature, Tool wear and Surface finish.

1. INTRODUCTION

During machining, a tool penetrates into the work piece because of the relative motion between the tool and the work piece and deforms the work material plastically and removes the material in the form of chips. Plastic deformation of the work material, rubbing of the tool flank with the finished surface and friction between tool rake face and flowing chips produces huge amount of heat and intense temperature at the chip tool interface. A major portion of the energy is consumed in the formation and removal of chips. Energy consumption increases with the increase in cutting velocity, feed and depth of cut as well as strength and hardness of work material. The greater the energy consumption, the greater are the temperature and frictional forces at the tool-chip interface and consequently the higher is the tool wear and lower the tool life.

In industries, a flood of conventional coolant is usually applied from the over head position to remove the heat generated at the cutting zone. During machining [1], especially of hard materials, much heat is generated by the friction of the cutter against the work piece, which is one of the major causes of reduction in tool hardness and rapid tool wear. For this reason, conventional coolant is often used on the cutting tool for bulk cooling and to prevent overheating. However, the main problem [2] with conventional coolant is that it does not reach the real cutting area i.e chip tool interface where the maximum temperature attains. The extensive heat generated evaporates the coolant before it can reach the cutting area and makes a semi conductive vapor barrier and consequently prevents heat conduction. The high cutting forces generated during machining will induce intensive pressure at the cutting edge between the tool tip and the work piece. Conventional coolant might not be able to overcome this pressure and flow into the cutting zone to cool the cutting tool. Hence, heat generated during machining is not removed and is one of the main causes of the reduction in tool life. More- over conventional coolant is one of the major sources of pollution in the industries.

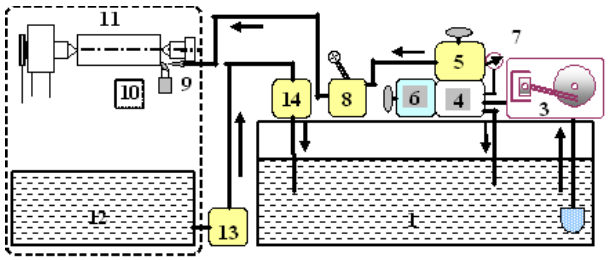
Controlling of high cutting temperature in high production machining some alternative methods have already been experimented in the different part of the world. Cutting forces and temperature were found to reduce while machining steel with tribologically modified carbide inserts [3]. Application of CO2 in the form of liquid jet at high pressure also enabled [4] some reduction in cutting forces. Cryogenic machining with liquid nitrogen [5, 6] and machining with minimum quantity lubrication (MQL) [7, 8] have improved machinability of steel to a certain extent under normal cutting conditions. It has also been reported that the machining of steel with liquid nitrogen improves the machinability index [5, 6] but cryogenic machining is costly due to high cost of liquid nitrogen. Also accelerated notch wear on the principal flank of the carbide insert was observed at nitrogen rich atmosphere of cryogenic machining.

The concept of high-pressure coolant may be a possible solution for high speed machining in achieving intimate chip-tool interaction, low cutting temperature and slow tool wear while maintaining cutting forces/power at reasonable levels if the high pressure cooling parameters can be strategically tuned. With the use of high-pressure coolant during machining under normal cutting conditions, the tool life and surface finish are found to improve significantly [9, 10, 11], which has shown as the decrease in heat and cutting forces generated. Mazurkiewicz [11] reported that a coolant jet applied to the cutting zone at high-pressure through a nozzle could reduce the contact length and coefficient of friction at chip-tool interface and thus could reduce cutting forces and increase tool life to some extent. High-pressure coolant injection technique is not only provided a reduction in cutting forces and temperature but also reduced the consumption of cutting fluid by 50% [13, 14].

The review of the literature suggests that high-pressure coolant provides several benefits in machining. However, there is a need to improve machining conditions providing credible data for in depth understanding of high-pressure coolant supplies at the chip-tool interface and integrity of machined components, especially for hard materials. The main objective of this research is to evaluate the effectiveness of high-pressure coolant in improving the cutting parameters on harder work material. The performance of high-pressure coolant is investigated by focusing on cutting temperature, tool wear and surface roughness and compares the effectiveness of high-pressure coolant with that of dry machining.

2. EXPERIMENTAL INVESTIGATION

Plain turning of AISI 4320 steel (Φ200 X 520 mm) and AISI 4140 (Φ220 X 520 mm) steel rod of common use were carried out in a lathe (10 hp, China) at different cutting velocities (V_c) and feeds (S_o) under both dry and high- pressure coolant conditions. The schematic view of the experimental set-up used for the present purpose has been shown in Fig.1. The machinability indices of the work materials of different hardness have been investigated especially for cutting temperature, tool wear and surface roughness to study the role of high-pressure coolant on materials and on their hardness. The process parameters for this experiment are given in Table-1. Cutting velocity (V_c) and feed rate (S_o) ranges were selected as per the recommendation of tool manufacturer considering high material removal rate. Depth of cut is less significant as it only changes the magnitude of cutting forces, was kept constant to 1.5 mm all through the experimental domain of tool wear.



1. Coolant Tank
2. Foot Valve
3. High Pressure Pump
4. Block (BG-03)
5. Flow Control Valve
6. Relief Valve
7. Pressure Gauge
8. Direction Control Valve
9. Nozzle
10. Insert
11. Machine Tool
12. Coolant Tank
13. Supply Pump
14. Filter

Fig.1 Schematic view of the experimental set-up

Table 1 Experimental conditions

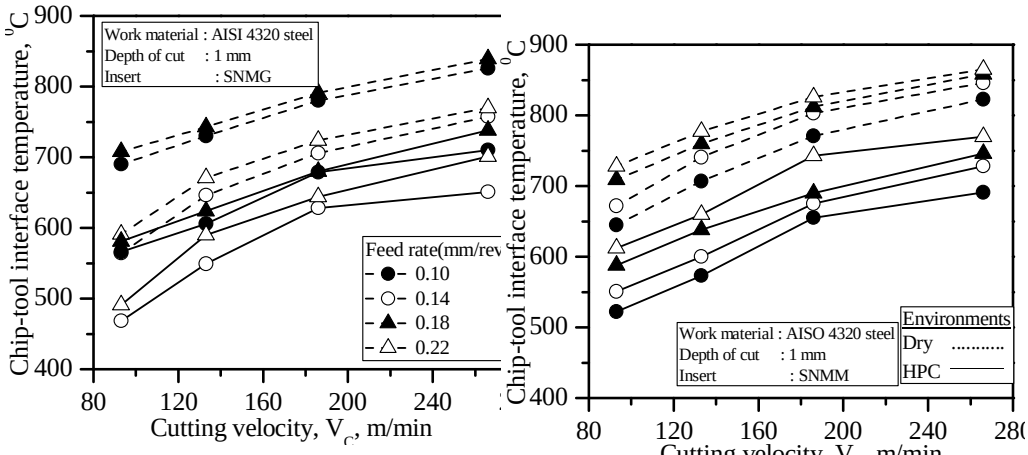
Machine tool	: Lathe (China), 10 hp
Work specimen	
Materials	: • AISI 4320 steel • AISI 4140 steel
BHN	• 201 for AISI 4320 steel • 252 for AISI 4140 steel
Cutting insert	: • SNMG insert, Sandvik • SNMM insert, Sandvik
Tool holder	: PSBNR 2525 M12, Sandvik
Tool geometry	: -6^o, -6^o, 6^o, 15^o, 75^o, 0.8 mm
Process parameters	
Cutting velocity	: 93,133, 186, 266 and 193 m/min
Feed rate	: 0.10, 0.14, 0.18 and 0.22 mm/rev
Depth of cut	: 1.0 mm and 1.50 mm
High pressure coolant	: 80 bar, Coolant: 6.0 l/h through external nozzle
Environments	: Dry and high-pressure coolant (HPC) condition

Considering the force exerted on the edge of cutting tool during machining a suitable cutting speed and feed (193 m/min, 0.18 mm/rev) was selected for tool wear monitoring. Pump pressurizes the coolant at a pressure of 80 bars with a flow rate 6 l/min. Taking into account the jet pattern and covering the entire cutting area by issuing jet, the nozzle diameter was selected as 0.5 mm. The high velocity stream of high-pressure coolant jet was impinged along the auxiliary cutting edge of the insert, so that the coolant reaches as close to the chip-tool and the work-tool interfaces as possible and effectively cools the tool and the work material at the hot cutting zone.

The average cutting temperature was measured by simple but reliable tool-work thermocouple technique with proper calibration [14]. Machining was interrupted at regular interval and the insert was unclamped to measure the width of wear land on the principal and auxiliary flank. Tool wear was monitored under optical microscope (Carl zeiss, Germany) fitted with micrometer of least count 10 µm. Surface roughness was measured at every interruption along the longitudinal direction of the turned job with the help of a Talysurf roughness checker (Surtronic 3^+, Tailor rank Hobson, UK). As per ISO standard tool rejection criteria was selected as the growth of wear V_B=300 µm on its principal flank. When the tool wear reaches to its limiting value or unexpectedly wear out rapidly, it was inspected under scanning electron microscope (Philips XL30) to study the wear mechanism.

3. EXPERIMENTAL RESULTS AND DISCUSSION

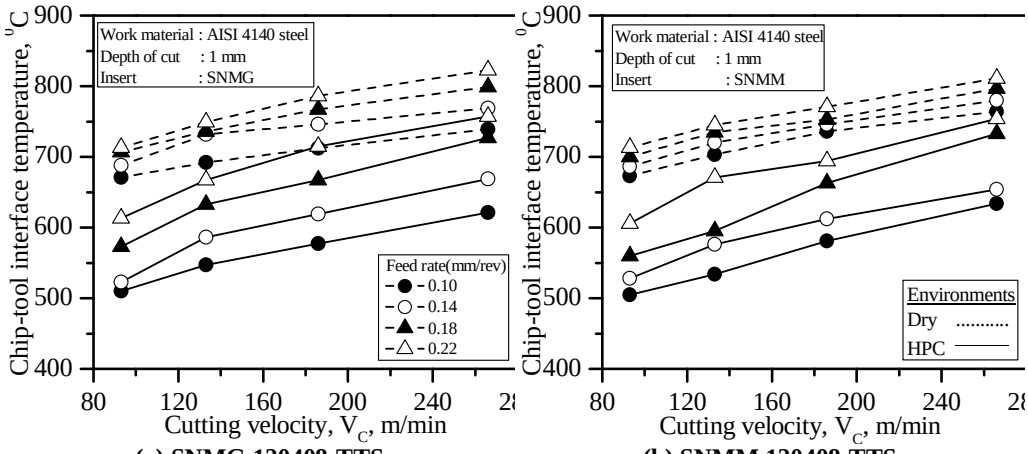
Reduction of friction between the chip-tool and work-tool interface is very important in cutting operation as reduction in kinetic coefficient of friction not only decreases frictional work, but also decreases the shear work. Usually cutting temperature increases with the increase in process parameters causing decrease in hardness of the contact layer of the work piece and also the tool material. The higher the cutting speed and feed, the higher the temperature is, due to high energy input. Machining high temperature has detrimental effect on cutting tool and product quality. So it is needed to control the cutting temperature to achieve an effective cutting condition and to improve machinability index. The high-pressure coolant system reduces the cutting temperature and provides a very favorable effect. The effect of high-pressure coolant on average chip-tool interface temperature (θ) at different V_c and S_o has been shown in Fig.2 and Fig.3. It is clear from Fig.2 and Fig.3 that during machining at lower V_c the cooling effect is more as the nature of chip-tool contact is plastic-elastic. Initially the chip-tool contact is plastic but when the chip leaves the tool the nature of contact is elastic. High velocity jet of high-pressure coolant is easily dragged in the elastic contact zone. With an increase in V_c the chip makes fully plastic or bulk contact with the tool rake surface which prevents from entering of jet into the hot chip-tool interface.



(a) SNMG 120408-TTS **(b) SNMM 120408-TTS**

Fig.2 Variation in temperature with that of V_c and S_o in turning AISI 4320 steel by (a) SNMG and (b) SNMM inserts under different environments

As a result under higher speed, rate of reduction is less in comparison with lower speed. High-pressure cooling effect also improved to some extent with the decrease in feed particularly at lower cutting velocity. At lower chip velocity, the thinner chips are pushed up by the high-pressure coolant jet coming from opposite direction of chip flow and enable it to come closer to the hot chip-tool contact zone to remove heat more effectively. Lifting up the chips with high-pressure coolant also facilitates chip breakability which indicate a decrease in shear angle. With an increase in feed curl radius of the thick chip is increased. For this, plastic contact length is increased and high-pressure coolant jet becomes less effective. At high velocity, little time is provided for the cutting fluid to penetrate, the coolant might not get enough time to remove the heat accumulated at the cutting zone resulting in less reduction in temperature under high-pressure cooling condition at high cutting velocity. The rate of frictional heat generation is reduced due to the lubrication of the chip as it passes over the tool and lubrication between work-tool interfaces.



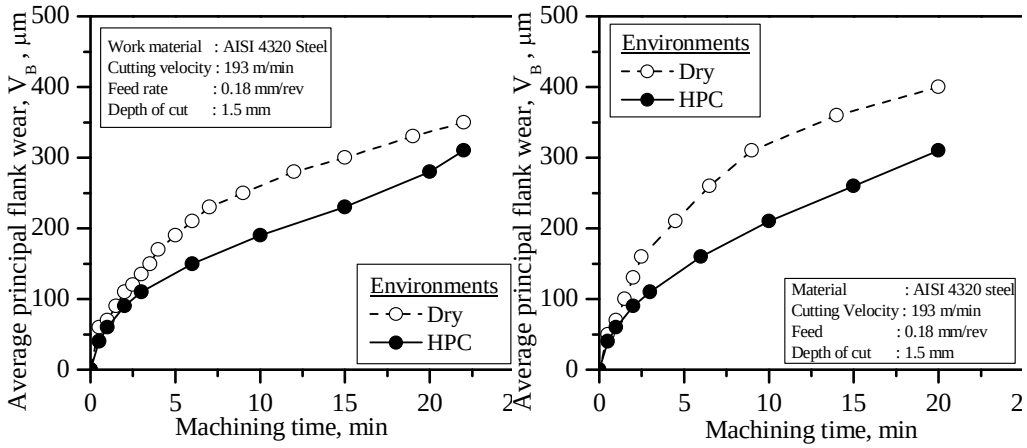
(a) SNMG 120408-TTS **(b) SNMM 120408-TTS**

Fig.3 Variation in temperature with that of V_c and S_o in turning AISI 4140 steel by (a) SNMG and (b) SNMM inserts under different environments

Table 2 Percent reduction of cutting temperature

Cutting velocity (m/min)	Feed (mm/rev)	Work material			
		AISI 4320 steel		AISI 4140 steel	
		Cutting insert		Cutting insert	
		SNMG	SNMM	SNMG	SNMM
93	0. 10	18	19	24	25
	0.14	17	18	24	23
	0.18	18	17	19	20
	0.22	17	16	14	15
133	0. 10	17	19	21	24
	0.14	15	19	20	20
	0.18	16	16	14	19
	0.22	12	15	11	10
186	0. 10	13	15	19	21
	0.14	11	16	17	18
	0.18	14	15	13	12
	0.22	11	10	9	10
266	0. 10	14	16	16	17
	0.14	14	14	13	16
	0.18	12	13	9	8
	0.22	9	11	8	7

Usually cutting temperature is increased with the increase in speed and feed. But some anomalies in temperature are observed during machining AISI 4320 with SNMG insert. Temperature is more at a feed rate of 0.10 and 0.18 mm/rev than feed rate 0.14 and 0.22 mm/rev under the range of cutting velocity undertaken and under both the condition. Higher temperature was recorded during cutting harder material with SNMG insert. It is evident from Fig.2 and Fig.3 that temperature is more as compared to AISI 4320 steel with AISI 4140 steel while machining with SNMG insert. But effect of hardness is not evident while machining the steels with SNMM insert. The percent reduction of cutting temperature for both the insert and materials is shown in Table 2. It is evident from the table that with the increase in feed the rate of reduction in temperature decreases.

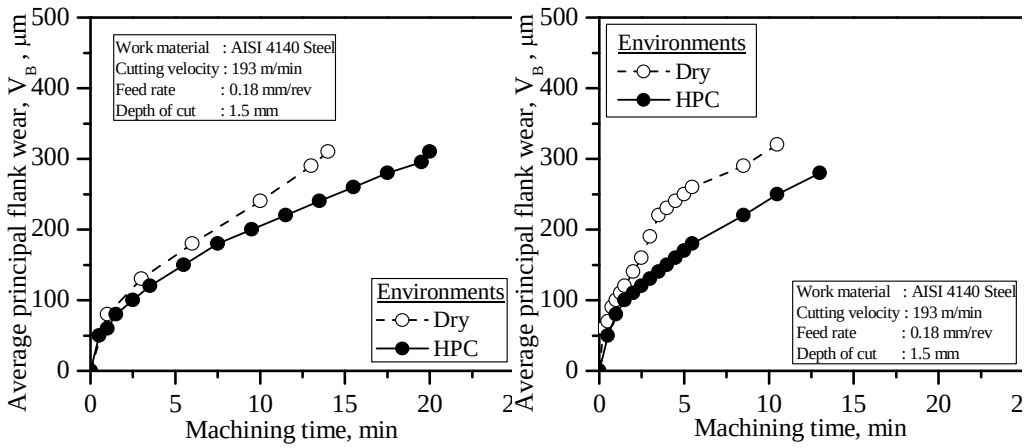


(a) SNMG 120408-TTS **(b) SNMM 120408-TTS**

Fig.4 Growth of V_B with machining time in turning AISI 4320 steel by (a) SNMG and (b) SNMM inserts under different environments

Under usual cutting conditions the cutting edge of a form stable cutting tool is worn out due to continuous interaction and rubbing between the chip and the tool and between the work and the tool. After the tool has been used for some times, wear land is appeared at the flank of the tool below the cutting edge extending approximately parallel to the cutting edge. The maximum or predominant wear is taken place in the zone where the energy input is greater. The nature of cutting tool wear under condition of mechanical wear depends on the distribution of frictional work on the contact surfaces. For high speed machining, diffusion wear is taken place both at the flank and face surfaces

and depending on the magnitude and nature of temperature distribution. Carbide inserts having enough strength, toughness and hot hardness generally fail by gradual wears. With the progress of machining the tools attain crater wear at the rake surface and flank wear at the clearance surfaces. The useful life of the tool is limited by tool wear. The principal concern of metal cutting research has been to investigate the basic mechanism of wear by which the life of the tool is governed. The life of carbide tools, which mostly fail by wearing, is assessed by the actual machining time after which the average value (V_B) of its principal flank wear reaches a limiting value, like 300 µm. Cost of manufacturing product are affected by life of the cutting tools. Therefore, attempts should be made to reduce the rate of growth of flank wear (V_B) without sacrificing metal removal rate.



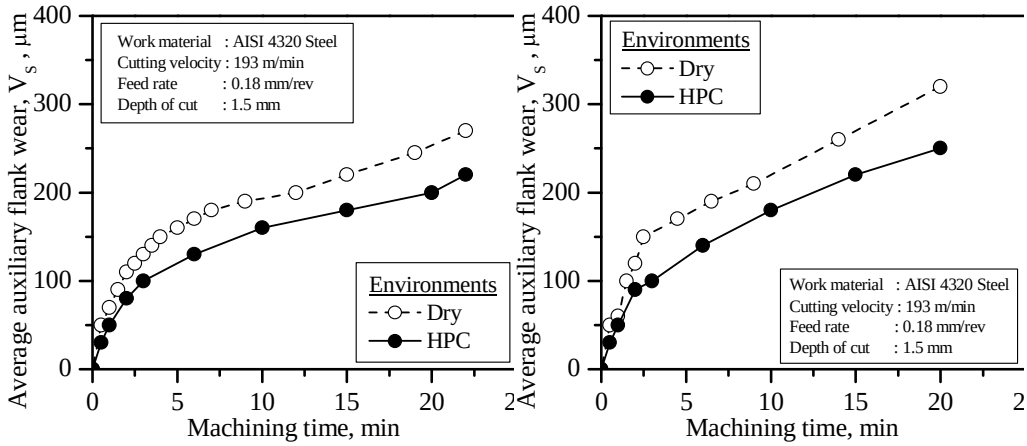
(a) SNMG 120408-TTS **(b) SNMM 120408-TTS**

Fig.5 Growth of V_B with machining time in turning AISI 4140 steel by (a) SNMG and (b) SNMM inserts under different environments

The growth of average principal flank wear (V_B) with machining time at high cutting velocity (193 m/min) and depth of cut (1.5 mm) by both the insert for both the material under dry and high-pressure coolant conditions have been shown in Fig.4 and Fig.5 respectively. It is observed that while dry cutting principal flank wear is more than that of high- pressure coolant condition. Tool wear reduces due to substantial reduction in cutting zone as well as flank temperature and lubrication in the interface by high-pressure coolant jet. Under both the condition initially the wear rate is more for both SNMG and SNMM insert because of sharp edge of the insert rapidly break down due to plastic deformation and consequential temperature rise. After some time the wear process is more or less uniform. While dry cutting AISI 4140 steel using SNMG insert, severe spark out is observed and the insert wear out rapidly in the last pass. Under high pressure coolant condition SNMG insert also wear out at its last cut. Before the appearance of spark, the wear data taken is plotted and shown in Fig.5.

Auxiliary flank wear (V_S), though occurs less intensively, also plays significant role in machining by aggravating dimensional inaccuracy and roughness of the finished surface. It appears from Fig.6 and Fig.7 that auxiliary flank wear (V_S) for both SNMG and SNMM insert have also decreased sizably due to high-pressure jet cooling. Oil film lubrication reduces the frictional heat generation as well as abrasion wear.

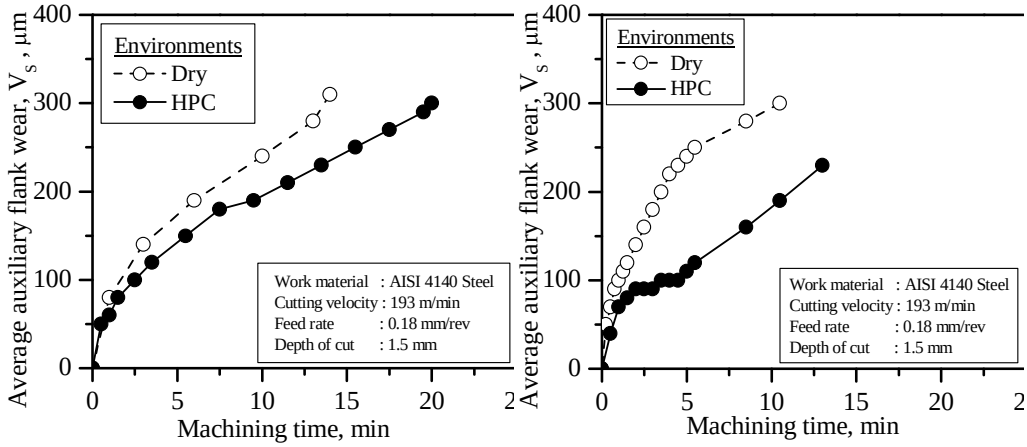
During metal cutting 33HRC is called transition hardness [15] because the effective zone under high pressure and dry cut for reducing flank wear is clearly mapped out from this hardness. Both the work materials with different hardness used in the experiment show the hardness below transition hardness. No significant improvement is found on hardness after employing high pressure coolant.



(a) SNMG 120408-TTS **(b) SNMM 120408-TTS**

Fig.6 Growth of V_S with machining time in turning AISI 4320 steel by (a) SNMG and (b) SNMM inserts under different environments

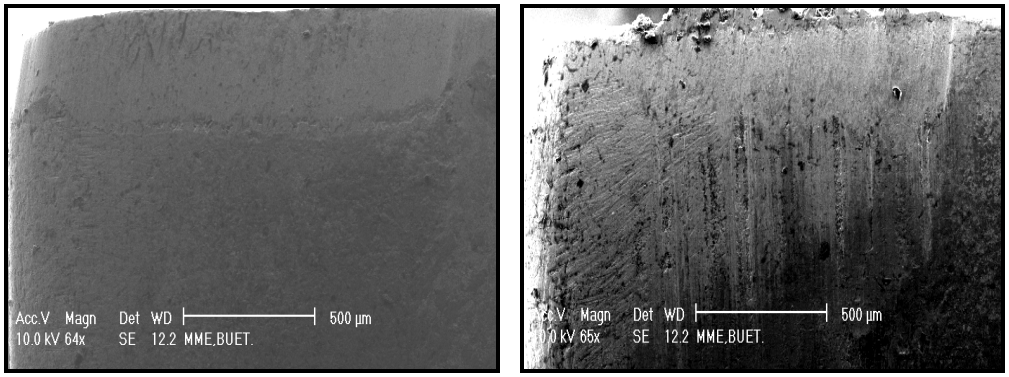
Principal and auxiliary flank surfaces of the tool tip have been observed under SEM to see the actual effects of different environments on wear of the carbide insert after being used for machining steel over reasonably long period. The SEM views of principal flank of the worn out SNMG and SNMM inserts after being machined AISI 4320 steel about 22 minutes and 20 minute respectively under dry and high- pressure coolant conditions have been shown in Fig.8 and Fig.9 respectively. Abrasive scratch marks appeared in the flanks in almost all the trials. No notch wears at the flank surfaces were found in insert under both dry and high-pressure coolant conditions. Effective temperature control and oil film lubrication by high-pressure coolant reduced oxidation completely. It has enabled the elimination in the principal and auxiliary notch wear.



(a) SNMG 120408-TTS **(b) SNMM 120408-TTS**

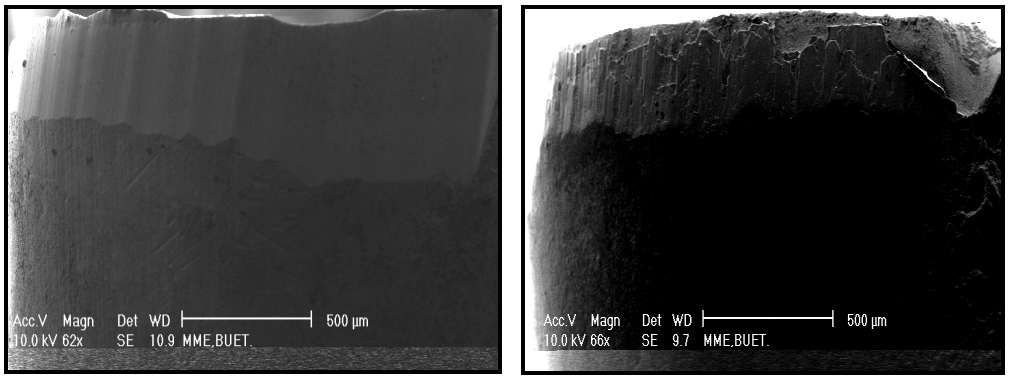
Fig.7 Growth of V_S with machining time in turning AISI 4140 steel by (a) SNMG and (b) SNMM inserts under different environments

The SEM views of principal flank of the worn out SNMG insert after being machined AISI 4140 steel about 14 minutes and 20 minute under dry and high- pressure coolant conditions have been shown in Fig.10. Tool edge wears out as soon as the last pass starts followed by severe sparking. Tool is withdrawn quickly and examined under SEM. Almost gradual wear was found before the appearance of spark and consequential blunting the cutting edge. Principal flank of the worn out SNMM inserts after 10.5 minutes and 13 minute under dry and high-pressure coolant conditions have been shown in Fig.11. Although cooling occurs by film boiling at the depth of cut area, the other heat sources increases the temperature, causing severe thermal shock, and hence micro chipping occurs on the flank of SNMM insert.



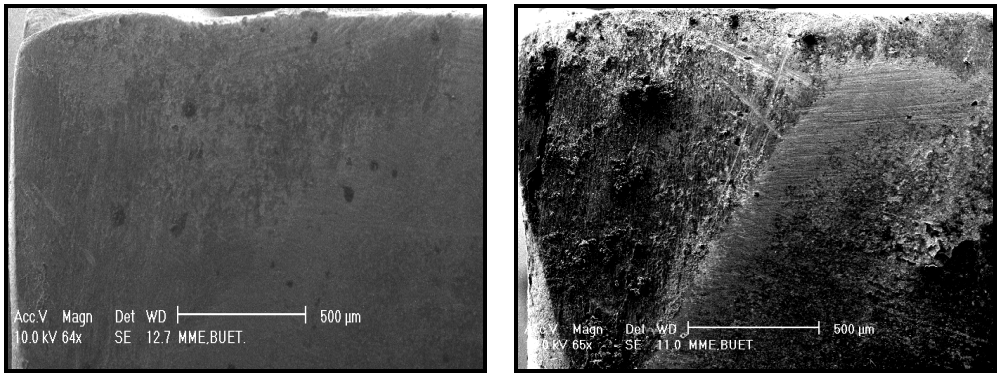
(a) **Dry condition, 22 min** (b) **High-pressure coolant condition, 22 min**

Fig.8 SEM views of principal flank of worn out tip of SNMG insert after machining AISI 4320 steel



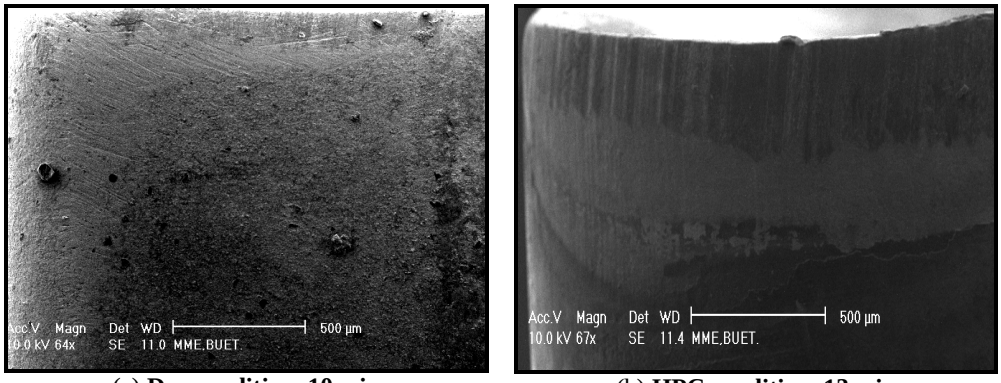
(a) **Dry condition, 20 min** (b)**HPC condition, 20 min**

Fig.9 SEM views of principal flank of worn out tip of SNMM insert after machining AISI 4320 steel



(a) **Dry condition, 14 min** (b) **High-pressure coolant condition, 20 min**

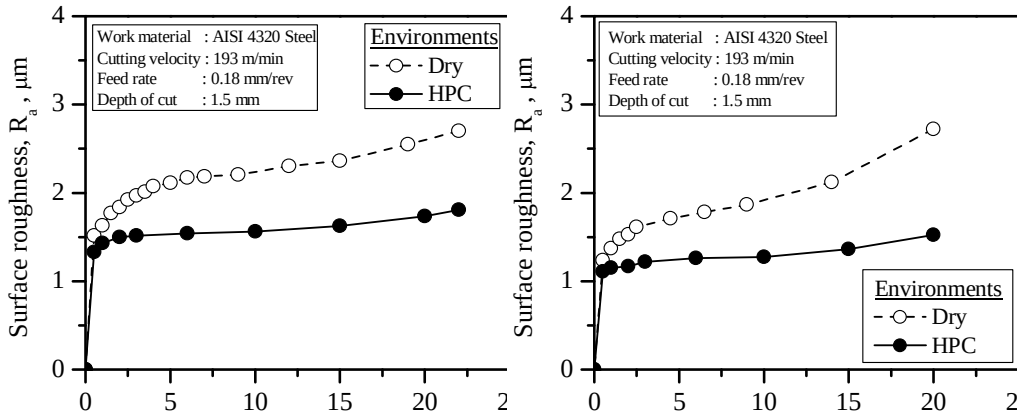
Fig.10 SEM views of principal flank of worn out tip of SNMG insert after machining AISI 4140 steel under different environments.



(a) **Dry condition, 10 min** (b) **HPC condition, 13 min**

Fig.11 SEM views of principal flank of worn out tip of SNMM insert after machining AISI 4140 steel under different environments.

Fig.12 and Fig 13 show the variation in surface roughness with progress of machining under dry and high- pressure coolant conditions. As high- pressure coolant reduced average auxiliary flank wear preventing the bulging of auxiliary flank, preventing the formation of built-up edge or removing instantaneously growing built-up edge, cooling the job effectively, surface roughness grew very slowly under high-pressure coolant conditions. It appears from the figures that surface roughness grows quite faster under dry condition. Softening of the metal in absence of coolant, increase surface roughness under dry condition. Increase in hardness of the work material also decreases surface roughness.



(a) SNMG 120408-TTS **(b) SNMM 120408-TTS**

Fig.1 2 Surface roughness (R_a) developed with progress of machining of AISI 4320 steel by (a) SNMG and (b) SNMM inserts under different environments

4. CONCLUSIONS

i. Application of high-pressure coolant along auxiliary cutting edge over the rake face of the tool forms a cushion layer by oil film that reduces friction at the tool-chip interface. Oil film prevents intimate contact between the tool and chip at the interface. Oil enters into the interface and significant reduction of temperature occurs while turning.

ii. The performance of high-pressure coolant machining is advantageous over dry machining because high-pressure cooling maintains the sharp cutting edge for prolonged time of machining. High-pressure coolant enables reduction of cutting temperature up to 25% depending upon process parameter.

iii. High-pressure coolant enables considerable reduction in the cutting zone temperature and favorable change in the chip-tool and work-tool interactions, which helps in reducing friction,

built-up edge formation, thermal distortion of the tool and the work. It reduces flank wear of the cutting tool and improves tool life.

iv. Surface finish is improved significantly by high-pressure coolant in turning alloy steels. Surface finish is improved mainly due to reduction of wear and damage at the tool tip by the application of high-pressure coolant.

ACKNOWLEDGEMENT

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THE EFFECT OF APPLYING HIGH-PRESSURE COOLANT (HPC) JET IN MACHINING OF 42CrMo4 STEEL BY UNCOATED CARBIDE INSERTS

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ABSTRACT: To avoid surface distortion and to improve tool life, machining of alloy steel and other hard materials under high speed-feed condition requires instant heat transfer from the work-tool interface where the intensity of cutting temperature is the maximum. Conventional cooling is completely unable and other special techniques like MQL and cryogenic cooling are not suitable in context of product quality and cost effectiveness. Supply of high-pressure coolant with high velocity may provide the best control to reduce cutting temperature and tool wear as well as increase tool life. This paper deals with an experimental investigation on the effect of high-pressure coolant on temperature, tool wear, surface roughness and dimensional deviation in turning 42CrMo4 steel by uncoated carbide inserts and comparing it with dry condition. It is observed that the cutting temperature and tool wear is reduced, tool life is increased, surface finish is improved, and dimensional deviation is decreased with the use of high-pressure coolant.

Keywords: High-pressure coolant, Alloy steel, Temperature, Wear and Product quality.

1. INTRODUCTION

During machining, a tool penetrates into the work piece because of the relative motion between the tool and the work piece, deforms the work material plastically and removes the material in the form of chips. Plastic deformation of the work material, rubbing of the tool flank with the finished surface and friction between tool rake face and flowing chips produces huge amount of heat and intense temperature at the chip-tool interface. A major portion of the energy is consumed in the formation and removal of chips. Energy consumption increases with the increase in cutting velocity, feed and depth of cut as well as strength and hardness of work material. The greater the energy consumption, the greater are the temperature and frictional forces at the tool-chip interface and consequently the higher is the tool wear and lower the tool life.

To remove the heat generated at the cutting zone, in industries, usually flood or conventional coolant is applied from the overhead position. During machining, especially of hard materials, much heat is generated by the friction of the cutter against the work piece, which is one of the major causes of reduction in tool hardness and rapid tool wear[1]. For this reason, conventional coolant is often used on the cutting tool for bulk cooling and to prevent overheating. However, the main problem with conventional coolant is that it does not reach the actual chip-tool interface where the maximum temperature attains[2]. The extensive heat generated evaporates the coolant before it can reach the cutting area, makes a semi conductive vapor barrier and consequently prevents heat conduction. The high cutting forces generated during machining induce intensive pressure at the cutting edge between the tool tip and the work piece. Conventional coolant might not be able to overcome this pressure and flow into the cutting zone to cool the cutting tool. Hence, heat generated during machining is not removed and is one of the main causes of the reduction in tool life. More over conventional coolant is one of the major sources of pollution in the industries.

Controlling of high cutting temperature in high production machining, some alternative methods have already been experimented in the different parts of the world. Cutting forces and temperature

have been found to reduce while machining steel with tribologically modified carbide inserts[3]. Application of CO_2 in the form of liquid jet at high pressure also enables some reduction in cutting forces[4]. Cryogenic machining with liquid nitrogen[5, 6] and machining with Minimum Quantity Lubrication (MQL) [7, 8] have improved machinability of steel to a certain extent under normal cutting conditions. It has also been reported that the machining of steel with liquid nitrogen improves the machinability index[5, 6] but cryogenic machining is costly due to high cost of liquid nitrogen[5, 6]. Also accelerated notch wear on the principal flank of the carbide insert has been observed at nitrogen rich atmosphere of cryogenic machining.

The concept of high-pressure coolant may be a possible solution for high speed machining in achieving intimate chip-tool interaction, low cutting temperature and slow tool wear while maintaining cutting forces/power at reasonable levels, if the high pressure cooling parameters can be strategically tuned. With the use of high-pressure coolant during machining under normal cutting conditions, the tool life and surface finish are found to improve significantly, which is due to the decrease in heat and cutting forces generated[9-11]. Mazurkiewicz[11] reported that a coolant applied at the cutting zone through a high-pressure jet nozzle can reduce the contact length and coefficient of friction at chip-tool interface and thus can reduce cutting forces and increases tool life to some extent. High-pressure coolant injection technique not only provides reduction in cutting forces and temperature but also reduces the consumption of cutting fluid by 50%[12, 13].

The review of the literature suggests that high-pressure cooling provides several benefits in machining. However, there is a need to improve machining conditions providing credible data for in depth understanding of high-pressure coolant supplies at the chip-tool interface and integrity of machined components, especially for hard materials. The main objective of this research is to evaluate the effectiveness of high-pressure coolant in improving the cutting parameters on harder work material. The performance of high-pressure coolant is investigated by focusing on cutting temperature, tool wear, tool life, surface finish, and dimensional deviation and compares the effectiveness of high-pressure coolant with that of dry machining.

2. EXPERIMENTAL INVESTIGATIONS

Experiments have been carried out by plain turning of 42CrMo4 steel rod (Ø 220x520 mm) in a powerful and rigid lathe at different cutting velocities (V) and feeds (f) under both dry and high-pressure coolant (HPC) conditions. The experimental set-up used for the present purpose has been shown in Figure 1. The machinability characteristics of that work material mainly in respect of cutting temperature, tool wear, tool life, surface roughness and dimensional deviation have been investigated to study the role of high-pressure coolant. The ranges of the cutting velocity (V) and feed (f) were selected based on the tool manufacturer's recommendation and industrial practices. Depth of cut (d), being less significant parameter, was kept fixed. The following cutting parameters have been chosen for the present experiment:

Cutting speed, V: 93,133,186,266 and 193 m/min
Feeds, f: 0.10, 0.14, 0.18 and 0.22 mm/rev
Depth of cut, d: 1.0 and 1.5 mm

Standard Sandvik PSBNR 2525M12 tool holder was used to hold indexable Sandvik cutting inserts SNMG and SNMM so that the geometry becomes (-6^o, -6^o, 6^o, 15^o, 75^o, 0. 8 mm). The high velocity stream of high-pressure coolant jet (80 bars) is impinged along the auxiliary cutting edge of the insert, so that the coolant reaches as close to the chip-tool and work-tool interfaces as possible and effectively cool the tool and the work material at the hot cutting zone.

The average cutting temperature was measured by simple but reliable tool-work thermocouple technique with proper calibration[14]. Figure 2 shows the photographic view of the calibration setup. Figure 3 shows the calibration curve obtained for the tool-work pair with tungsten carbide as the tool material and steel undertaken as the work material. Machining has been interrupted at regular interval and the tool has unclamped to measure width of wear land on the principal and auxiliary flank. Tool wear is monitored under optical microscope (Carl Zeiss, Germany) fitted with micrometer of least count 10 μm. As per ISO standard tool rejection criteria is selected as the growth of wear VB=300

µm on its principal flank. When the tool wear reaches to its limiting value, it is inspected under scanning electron microscope (Philips XL30) to study the wear mechanism. Surface roughness is measured along the longitudinal direction of the turned job with the help of a Talysurf roughness checker (Surtronic 3^{+}, Tailor rank Hobson, UK). A complete pass is performed with a fresh edge of the tool and deviation in dimension was measures with the help of a digital dial gauge of least count 10 µm.

Fig. 1 Photographic view of the experimental set-up

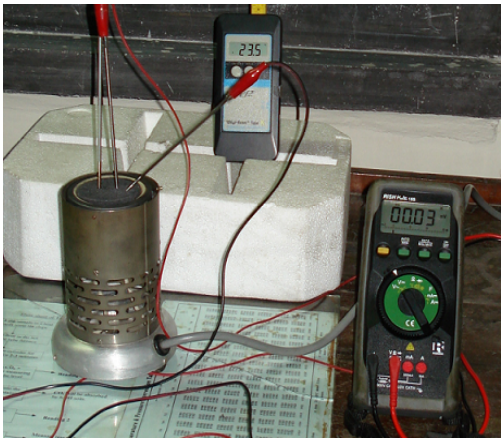

Fig. 2 Photographic view of the calibration set-up

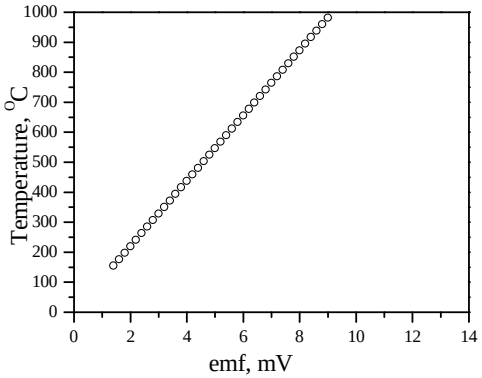

Fig. 3 Temperature calibration curve for carbide and 42CrMo4 steel

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

Reduction of friction between the chip-tool and work-tool interface is very important in cutting operation, as reduction in kinetic coefficient of friction not only decreases frictional work, but also decreases the shear work as well. Usually cutting temperature increases with the increase in process parameters causing decrease in hardness of the contact layer of the work piece and also the tool material. The higher the cutting speed and feed, the higher the temperature is, due to high energy input. Machining high temperature has detrimental effect on cutting tool and product quality. So it is needed to control the cutting temperature to achieve an effective cutting condition and to improve machinability index. The high-pressure coolant system reduces the cutting temperature and provides a very favorable effect. The effect of HPC on average chip-tool interface temperature at different cutting speed and feeds under both dry and HPC conditions has been shown in Figure 4.

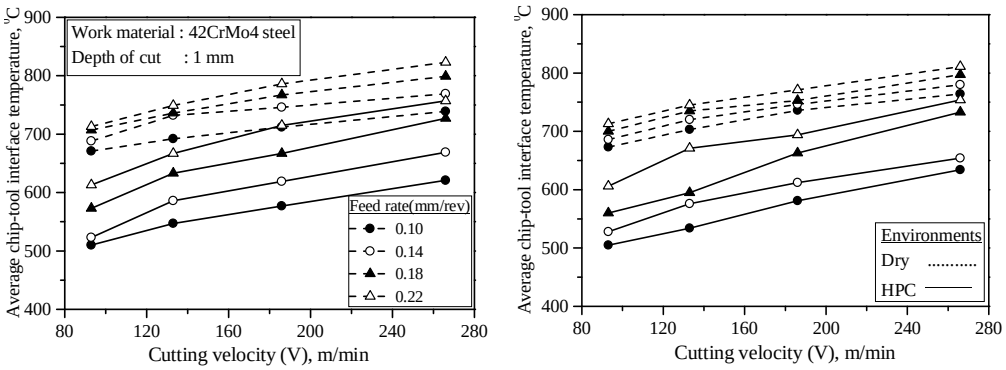

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Fig. 4 Variation in temperature with cutting speeds at different feeds under dry and high-pressure coolant conditions

It is clear from Figure 4 that during machining at lower cutting speed the cooling effect is more as the nature of chip-tool contact is plastic-elastic. Initially the chip tool contact is plastic but when the chip leaves the tool the nature of contact is elastic. High velocity jet of HPC is easily dragged in the elastic contact zone. With an increase in cutting speed the chip makes fully plastic or bulk contact with the tool rake surface which prevents from entering of jet into the hot chip-tool interface. As a result, under higher speed, rate of reduction of temperature is less in comparison with lower speed. HPC cooling effect also improved to some extent with the decrease in feed particularly at lower cutting speed. At lower chip velocity, the thinner chips are pushed up by the HPC jet coming from opposite direction of chip flow and enable it come closer to the hot chip-tool contact zone to remove heat more effectively. With an increase in feed curl radius of the thick chip is increased. For this plastic contact length is increased and HPC jet becomes less effective. At high speed, little time is provided for the cutting fluid to penetrate, the coolant might not get enough time to remove the heat accumulated at the cutting zone resulting in less reduction in temperature under HPC condition. The rate of frictional heat generation is reduced due to the lubrication of the chip as it passes over the tool and lubrication between work-tool interfaces.

Under usual cutting conditions the cutting edge of a form stable cutting tool is wear out due to continuous interaction and rubbing between the chip and the tool and between the work and the tool. After the tool has been used for some times, wear land is appeared at the flank of the tool below the cutting edge extending approximately parallel to the cutting edge. The maximum or predominant wear is taken place in the zone where the energy input is greater. The nature of cutting tool wear under condition of mechanical wear depends on the distribution of frictional work on the contact surfaces. For high speed machining, diffusion wear is taken place both at the flank and face surfaces and depending on the magnitude and nature of temperature distribution. Turning carbide inserts having enough strength; toughness and hot hardness generally fail by gradual wears. With the progress of machining the tools attain crater wear at the rake surface and flank wear at the clearance surfaces. The useful life of the tool is limited by tool wear. The principal concern of metal cutting research has been to investigate the basic mechanism of wear by which the life of the tool is

governed. The life of carbide tools, which mostly fail by wearing, is assessed by the actual machining time after which the average value (VB) of its principal flank wear reaches a limiting value, like 300 µm. Cost of manufacturing product are affected by life of the cutting tools. Therefore, attempts should be made to reduce the rate of growth of flank wear (VB) in all possible ways without much sacrifice in MRR.

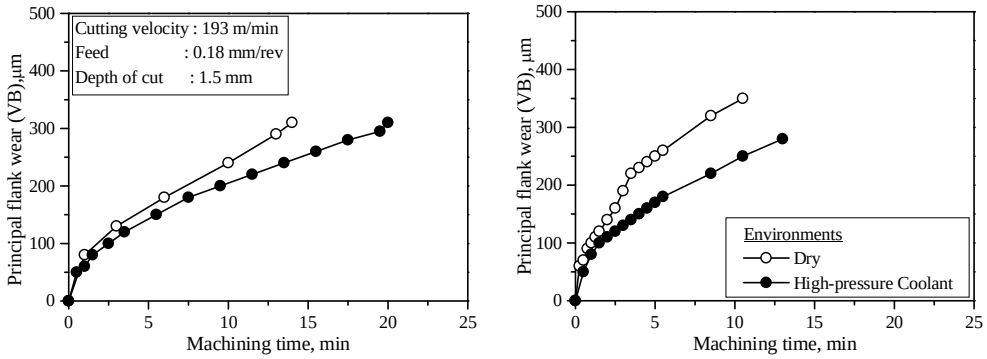

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Fig. 5 Growth of average principal flank wear (VB) with machining time under dry and high-pressure coolant conditions

The growth of average principal flank wear, VB and average auxiliary flank wear, VS with machining time at high cutting velocity (193 m/min) and depth of cut (1.5 mm) by both the inserts under dry and high-pressure coolant conditions have been shown in Figure 5 and Figure 6 respectively. It is observed that while dry cutting principal flank wear and auxiliary flank wear is more than that of HPC condition. Tool wear reduces due to substantial reduction in cutting zone as well as flank temperature and lubrication in the interface by HPC jet. Under both the condition initially the wear rate is more for both SNMG and SNMM insert because of sharp edge of the insert rapidly break down due to plastic deformation and consequential temperature rise. After some time the wear process is more or less uniform. For both the cases, severe sparking is observed and the insert wear out rapidly in the last pass. Before the appearance of spark, the wear data taken is plotted shown in Figure 5.

Auxiliary flank wear (VS), though occurs less intensively, also plays significant role in machining by aggravating dimensional inaccuracy and roughness of the finished surface. It appears from Figure 6 that auxiliary flank wear (VS) for both SNMG and SNMM insert have also decreased sizably due to high pressure jet cooling.

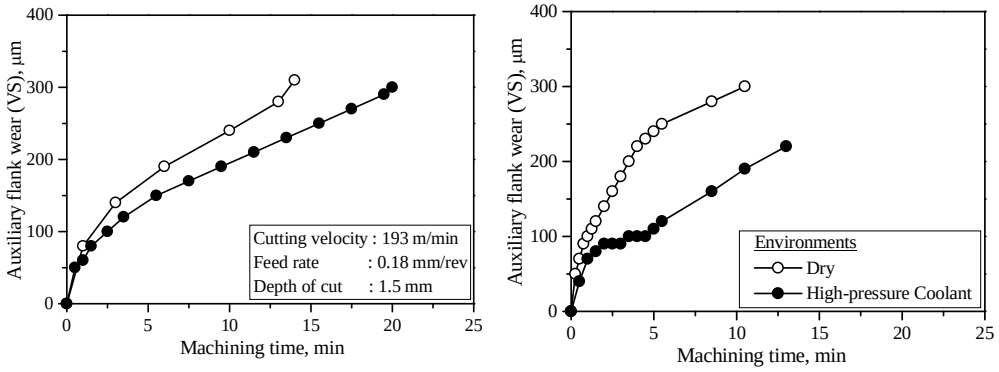

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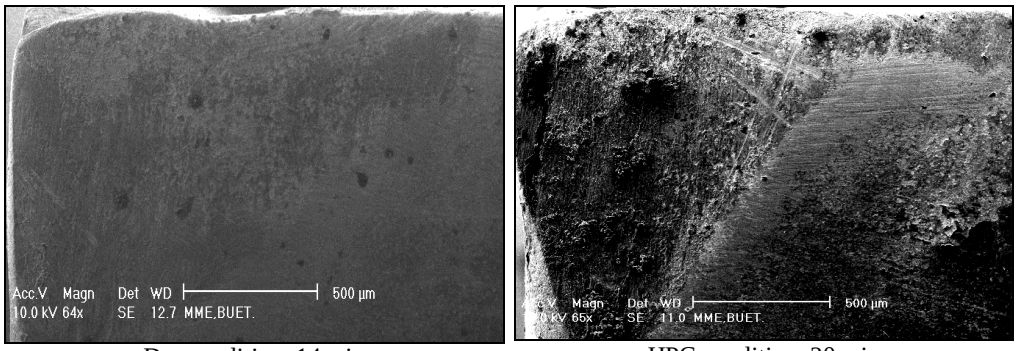
Fig. 6 Growth of average auxiliary flank wear (VS) with machining time under dry and high-pressure coolant conditions

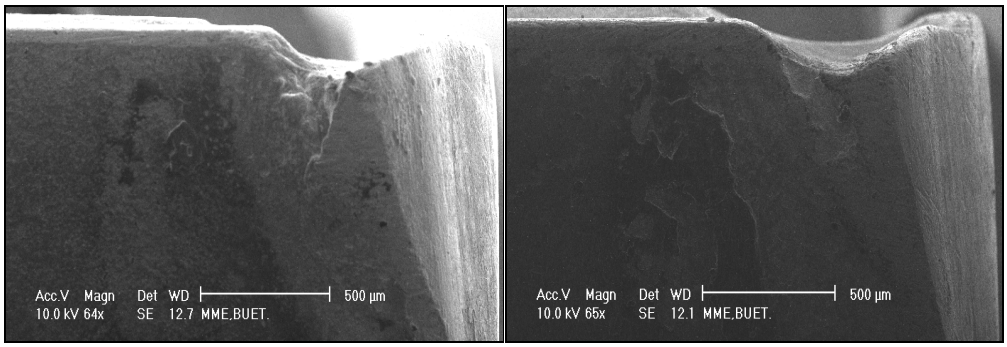
Principal and auxiliary flank surfaces of the tool tip have been observed under SEM to see the actual effects of different environments on wear of the carbide insert after being used for machining steel over reasonably long period. At the starting of last pass severe sparking is observed and the tool wears out rapidly. The SEM views principal and auxiliary flank of the worn out SNMG insert after about 14 minutes of dry machining and 20 minutes machining under HPC conditions have been shown in Figure 7 and Figure 8 respectively. Machining under dry condition with SNMM insert shown in Figure 9 and Figure 10, welding of work material over principal flank of the insert and scratching mark due to re-cutting of the chips is observed. No groove or notch wear is found under both the environments. Under all the environments, scratch marks appears in the flanks. There have also been some indications of adhesive wear in the insert. Some plastic deformation and micro chipping are found to occur under dry and HPC machining. Effective temperature control by HPC almost reduces the growth of notch and groove wear on the main cutting edge. It has also enabled the reduction in the auxiliary notch wear. Further the figure clearly shows reduced average flank wear, average auxiliary flank wear and crater wear under High Pressure Coolant condition.

The major causes behind development of surface roughness in continuous machining processes like turning, particularly of ductile metals are (i) regular feed marks left by the tool tip on the finished surface (ii) irregular deformation of the auxiliary cutting edge at the tool-tip due to chipping, fracturing and wear (iii) vibration in the machining system and (iv) built-up edge formation, if any. Figure 11 shows the variation in surface roughness with cutting velocity under dry and HPC conditions. As HPC reduces average auxiliary flank wear and notch wear on auxiliary cutting edge, surface roughness is observed comparatively lower under High Pressure Coolant conditions. However, it is evident that HPC improves surface finish depending upon the work-tool materials and mainly through controlling the deterioration of the auxiliary cutting edge by abrasion, chipping and built-up edge formation.



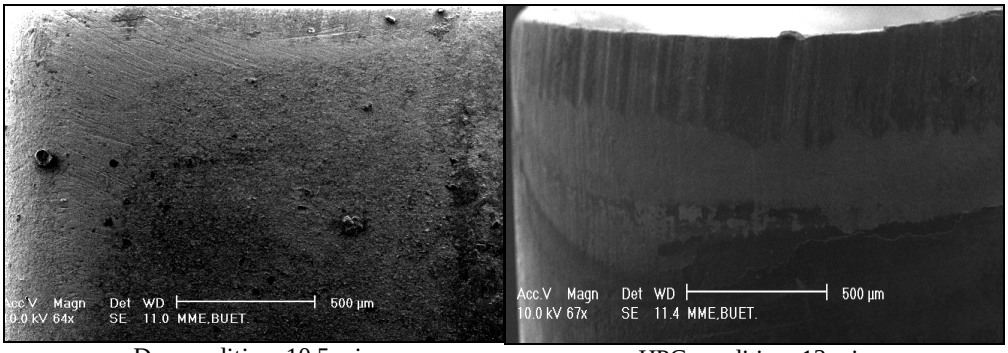
Dry condition, 14 min HPC condition, 20 min

Fig. 7 SEM views of principal flank of worn out tip of SNMG



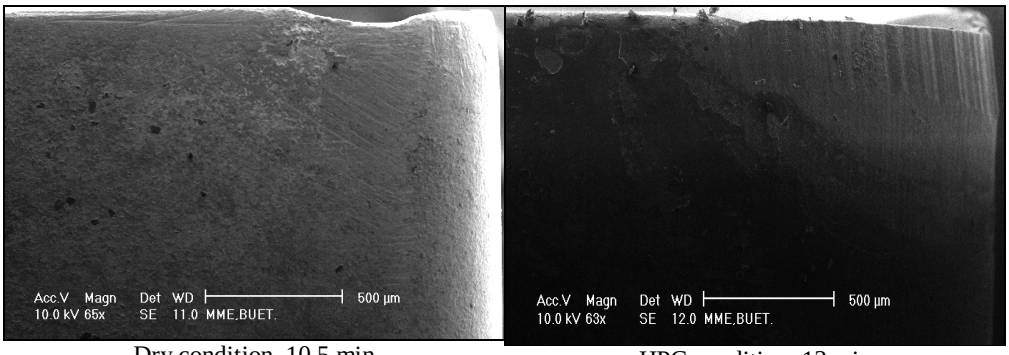
Dry condition, 14 min HPC condition, 20 min

Fig. 8 SEM views of auxiliary flank of worn out tip of SNMG insert



Dry condition, 10.5 min HPC condition, 13 min

Fig. 9 SEM views of principal flank of worn out tip of SNMM insert



Dry condition, 10.5 min HPC condition, 13 min

Fig. 10 SEM views of auxiliary flank of worn out tip of SNMM insert

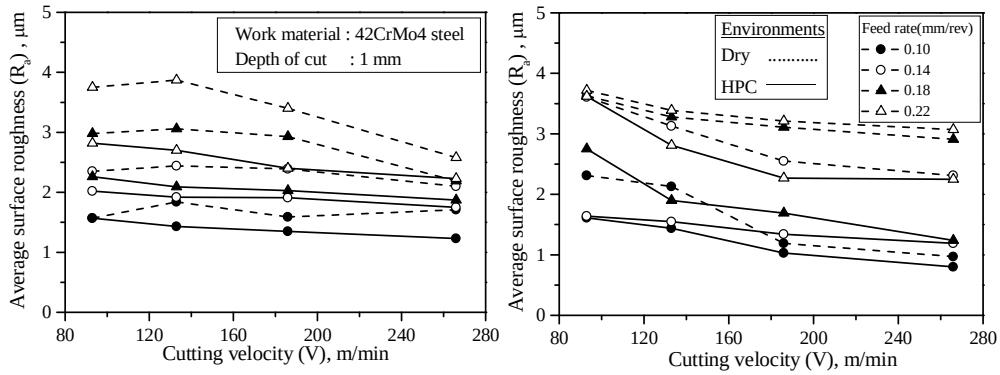


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Fig. 11 Variation in surface roughness with cutting speeds at different feeds under dry and high-pressure coolant conditions

Surface roughness gradually increases as usual with the machining time as can be seen in Figure 12, due to gradual increase in auxiliary flank wear (VS). Again it is observed that the rate of increase in surface roughness decreases to some extent when machining is done under HPC condition which not only reduces the auxiliary flank wear but also possibility of built-up edge formation due to reduction in temperature. It appears from Figure 12 that surface roughness grows quite fast under dry machining due to more intensive temperature and stresses at the tool-tips. High Pressure Coolant appeared to be effective in reducing surface roughness.

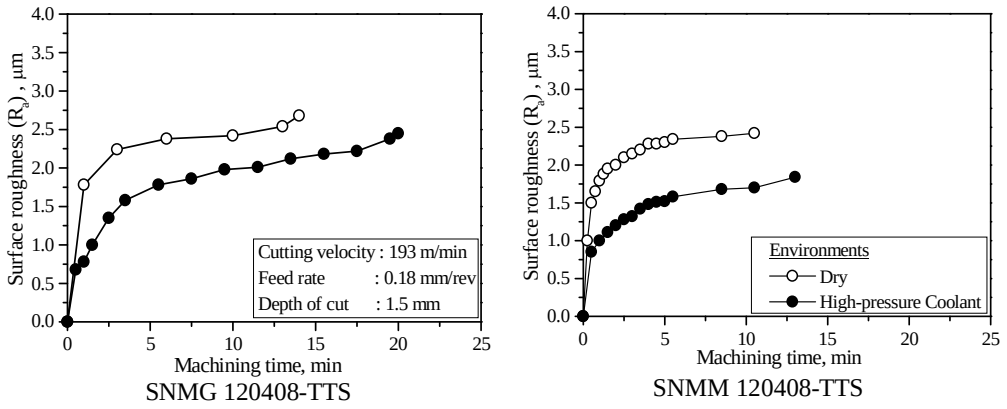

Fig. 12 Surface roughness developed with progress of machining under dry and high-pressure coolant conditions

High Pressure Coolant provides remarkable benefit in respect of controlling the increase in diameter of the finished job with machining time as can be seen in Figure 13. In plain turning the finished job diameter generally deviates from its desired value with the progress of machining i.e. along the job-length mainly for change in the effective depth of cut due to several reasons which include wear of the tool nose, over all compliance of the Machine-Fixture-Tool-Work (M-F-T-W) system and thermal expansion of the job during machining followed by cooling. Therefore, if the M-F-T-W system is rigid, variation in diameter would be governed mainly by the heat and cutting temperature. With the increase in temperature the rate of growth of auxiliary flank wear and thermal expansion of the job increases. High Pressure Coolant takes away the major portion of heat and reduces the temperature resulting decrease in dimensional deviation desirably.

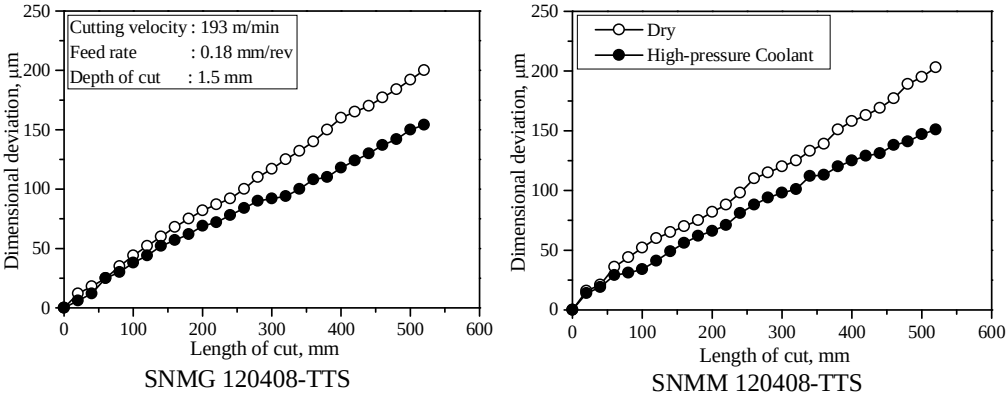

Fig. 13 Dimensional deviation observed after one full pass turning under dry and high-pressure coolant conditions

4. CONCLUSIONS

i. High-pressure coolant jet not only reduces chip-tool and work-tool interface temperature but also reduces the heat generation by its effective oil film lubrication under all the investigated speed-feed combinations.

ii. High-pressure coolant has significantly reduced flank wears as a result improved tool life. After machining 14 and 20 minutes with SNMG insert under dry and HPC condition respectively, severe spark is observed and cutting tools undergo severe plastic deformation as well as rapid tool wear.

iii. Surface finish improves under high-pressure coolant condition in turning 42CrMo4 steel.

Efficient chip removal, heat reduction and lower wear rates on the auxiliary flank helps in reduction of surface roughness. Also surface roughness grows slowly with machining time under HPC condition.

iv. HPC takes away the major portion of heat and provides remarkable benefit in respect of controlling the thermal expansion of the job as a result decrease in dimensional deviation desirably with machining time.

ACKNOWLEDGEMENT

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MICROCONTROLLER BASED THREEWAY CONTROLLED HIGHLY SECURED DOOR USING GSM AND DTMF TECHNOLOGY

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ABSTRACT: Now a day's technology and advance science are growing faster than imagination and going to beyond the general capability. Majority systems are now controlled automatically which must be high secured and precise. A door is a very important term for any security and safety that is why this paper presents the design, construction, working principle and control systemof a highly secured door which will be controlled automatically. This project developsa system that all of its operations are controlled by intelligent software inside the microcontroller, GSM, DTMFtechnology. The door is designed and constructed for industrial control room, main door of any institution, emergency door, hidden door, vault room, store room and basically for restricted entrance. This door can be controlled in three way such that by mobile phone using SMS or ring, by switch and by password using keypad. A camera is used in the upward of the door for recognizing stranger or knocker and monitoring him or her from room.In this project, low cost, secure, ubiquitously accessible, auto-configurable, remotely controlled solution for automation of door will be introduced. The approach discussed in this paper will be achieved the target to control industrial appliances remotely using the microcontroller based system satisfying user needs and requirements.

Keywords: *Short message service (SMS), Global System for Mobile Communication (GSM), Microcontroller, DTMF decoder, secured door.*

1. INTRODUCTION

The new age of technology has redefined communication. Most people nowadays have access to mobile phones and thus the world indeed has become a global village. GSM [1] based remote management control is a subject of growing interest which has found application in different areas. Tan, Lee, and Mok, 2007 developed an automatic power meter reading system using GSM network. It utilizes the GSM network to send power usage reading to authorize office to generate the billing cost and send back the cost to the respective consumer through SMS. Microcontroller is a one kind of computer which is run by some predefined program. By using the blessing of science, a highly secured and automatic door system has demonstrated in this paper.The main focus of this paper is to monitor and regulate the direction of a dc-motor remotely using 3 ways and sensing the door position as closed or opened. The state of close or open of the door depends on sensor that means when specific point of door comes in contact with each other then the sensor senses and the motor will stop or start. The switch will be placed inside of room at convenient place which can be operated by sitting in a chair near desk, the keypad will placed at outside of the door which will be operated by password and the very common own mobile phone can be used for controlling the door from anywhere and anytime.

2. THE BLOCK DIAGRAM FOR THE PROPOSED SYSTEM

Basically, the proposed system has done to serve remote control of a motor via three control units such as mobile phone, keypad, switch and total system is processed by DTMF signals based on GSM modem, DTMF decoder, Micro controllers, Driving circuit, and other required electronics such as transistors, resistors, LEDs, LCD, IC etc. The bock diagram of this system is shown in **Figure 1**.

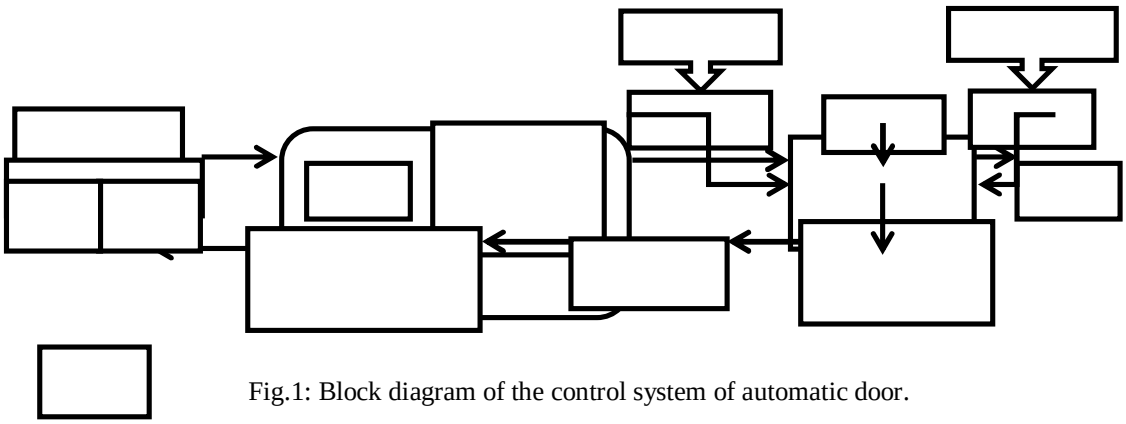


Fig.1: Block diagram of the control system of automatic door.

3. BUILDING SYSTEM ARCHITECTURE

3.1. MOBILE PHONE

In this era mobile phone is a very common and cheap electronic device which supports GSM/GPRS network. The actuality of the use of mobile [2] in tele-remote system is inspired by many factors such as the mobile phone is very available, easily portable and a common GSM device, the low cost of mobile communication,no extra remote control device is necessary and the use of DTMF Signals instead of Radio Frequencies (RF) signals.

3.2. GSM MODULE

GSM module [3] is used to establish communication between a computer and a GSM-GPRS system. Global System for Mobile communication (GSM) is an architecture used for mobile communication in most of the countries. GSM module consists of a GSM modem assembled together with power supply circuit and communication interfaces (like RS-232, USB, etc) for computer. The MODEM is the soul of such modules. SIM300 is a Tri-band GSM/GPRS engine that works on frequencies EGSM 900MHz, DCS 1800MHz and PCS 1900 MHz, SIM300 provides GPRS multi-slot class 10 capability and supports the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4.

3.3. DTMF DECODER

DTMF is a system of signal tones used in telecommunications. There are twelve standard signals and four extra buttons “A”, “B”, “C”, “D”, which normally are unseen on telephone keypad. Each signal is comprised from two tones “low” and” high” as shown**Table 1**.

Table 1. Decoded frequency of different button.

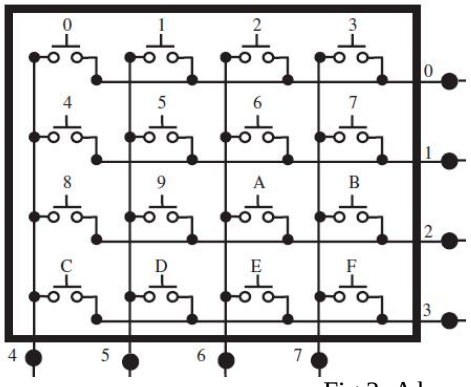
Frequency	1209 Hz	1336 Hz	1477 Hz	1633 Hz
697 Hz	1	2	3	A
770 Hz	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D

When a button is pressed on a keypad, a connection is made that generates two tones at the same time. These two tones identify the pressed key to controlled device. The calculation of the frequency for each keypad button is performed by adding the frequencies of a row and a column for every corresponding button.DTMF decoder grab the tone signal from receiver mobile station and generates 4 digit binary codes [4]. This 4 digit binary code sends to a microcontroller input. Micro controller checks the inputs and if the program logic satisfies the input logic then it turns on either off the motor.

3.4. KEYPAD

A keypad is simply an extension of the simple switch configuration. A typical keypad [5] configuration and interface are shown in **Figure 2**. Hexadecimal keypad is provided in this figure. A single row of keypad switches is asserted by the microcontroller, and then the host keypad port is immediately read. The combination of a row and a column assertion can be decoded to determine which key has been pressed as illustrated in the **Table 2**. Keypad rows are continually asserted one after the other in sequence.

Table 2.Decimal code on pressed key.



Key pressed by user	Row asserted by microcontroller				Column response from keypad switch				Row/Column combination read at micro port
	3	2	1	0	7	6	5	4	
0	1	1	1	0	1	1	1	0	0xEE
1	1	1	1	0	1	1	0	1	0xDE
2	1	1	1	0	1	0	1	1	0xBE
3	1	1	1	0	0	1	1	1	0x7E
4	1	1	0	1	1	1	1	0	0xED
5	1	1	0	1	1	1	0	1	0xDD
6	1	1	0	1	1	0	1	1	0xBD
7	1	1	0	1	0	1	1	1	0x7D
8	1	0	1	1	1	1	1	0	0xEB
9	1	0	1	1	1	1	0	1	0xDB
A	1	0	1	1	1	0	1	1	0xBB
B	1	0	1	1	0	1	1	1	0x7B
C	0	1	1	1	1	1	1	0	0xE7
D	0	1	1	1	1	1	0	1	0xD7
E	0	1	1	1	1	0	1	1	0xB7
F	0	1	1	1	0	1	1	1	0x77
none	X	X	X	X	1	1	1	1	0xXF

Fig.2:.A hexadecimal keypad configuration.

3.5. MOMENTARY CONTACT PUSH-BUTTON SWITCH

A momentary contact push- button switch [5] comes in two varieties: normally closed (NC) and normally open (NO).When the push- button portion of the switch is depressed the connection between the two switch contacts is made. The connection is held as long as the switch is depressed. When the switch is released, the connection is opened.

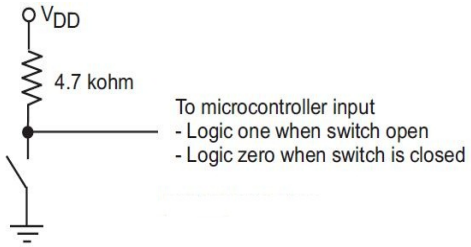


Fig.3:. Switch interface.

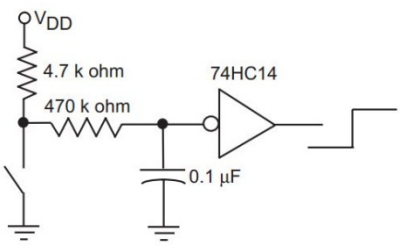


Fig.4:. Switch interface equipped with debouncing circuity.

A common switch interface is shown in **Figure 3**. A hardware debounce circuit is illustrated in **Figure 4**. The node between the switch and the limiting resistor of the basic switch circuit is fed to a low pass filter (LPF) formed by the 470-kΩ resistor and the capacitor.

3.6. MICROCONTROLLER

The ATmega32 [6] is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega32 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed. The ATmega32 provides the following features: 32K bytes of In-System Programmable Flash Program memory with Read-While-Write capabilities, 1024 bytes EEPROM, 2K byte SRAM, 32 general purpose I/O lines, Internal and External Interrupts, 10-bit ADC with optional differential input stage with programmable gain, etc. It receives decoded data from GSM, DTMF, sensor,

keypad, switch and generates voltage output. The rotation of motor totally depends upon the voltage output of microcontroller.

3.7. LCD

The other common peripheral device used here to highlight is a standard Hitachi 44780-based liquid crystal display [7]. LCDs come in different shapes and sizes that can support different numbers of rows of text and different numbers of characters per row. The standard choice for the number of characters and rows which is used in this project is 20 × 2. The LCD displays messages and password instructions to the user that generated by microcontroller.

3.8. MOTOR DRIVER

L293D [8] is a dual H-bridge motor driver integrated circuit (IC) and shown in **Figure 5**. Motor drivers act as current amplifiers since they take a low-current control signal and provide a higher-current signal. This higher current signal is used to drive the motors.The motor operations of two motors can be controlled by input logic at pins 2 & 7 and 10 & 15 as shown in Figure 5. Input logic 00 or 11 will stop the corresponding motor. Logic 01 and 10 will rotate it in clockwise and anticlockwise directions, respectively.

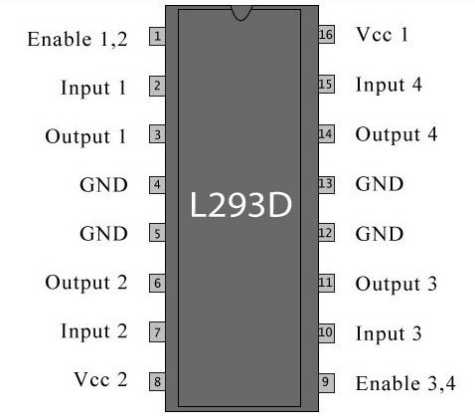


Fig.5: Pin diagram of L293D IC.

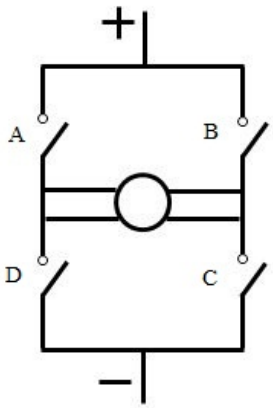


Fig.6: Motor rotation controlling switch.

A stepper motor (or step motor) is a brushless, synchronous electric motor that can divide a full rotation into a large number of steps. **Figure 6** shows the rotation controlling function unit. The motor driver operate this switch. When switch A and C is close then motor rotates clockwise, when switch B and D is close then motor rotates anticlockwise.

4. SYSTEM FLOWCHART

Figure 7 shows the process of working of the automatic controlled door system. After initializing the system, the sensor senses the door position and then it works as user input command.

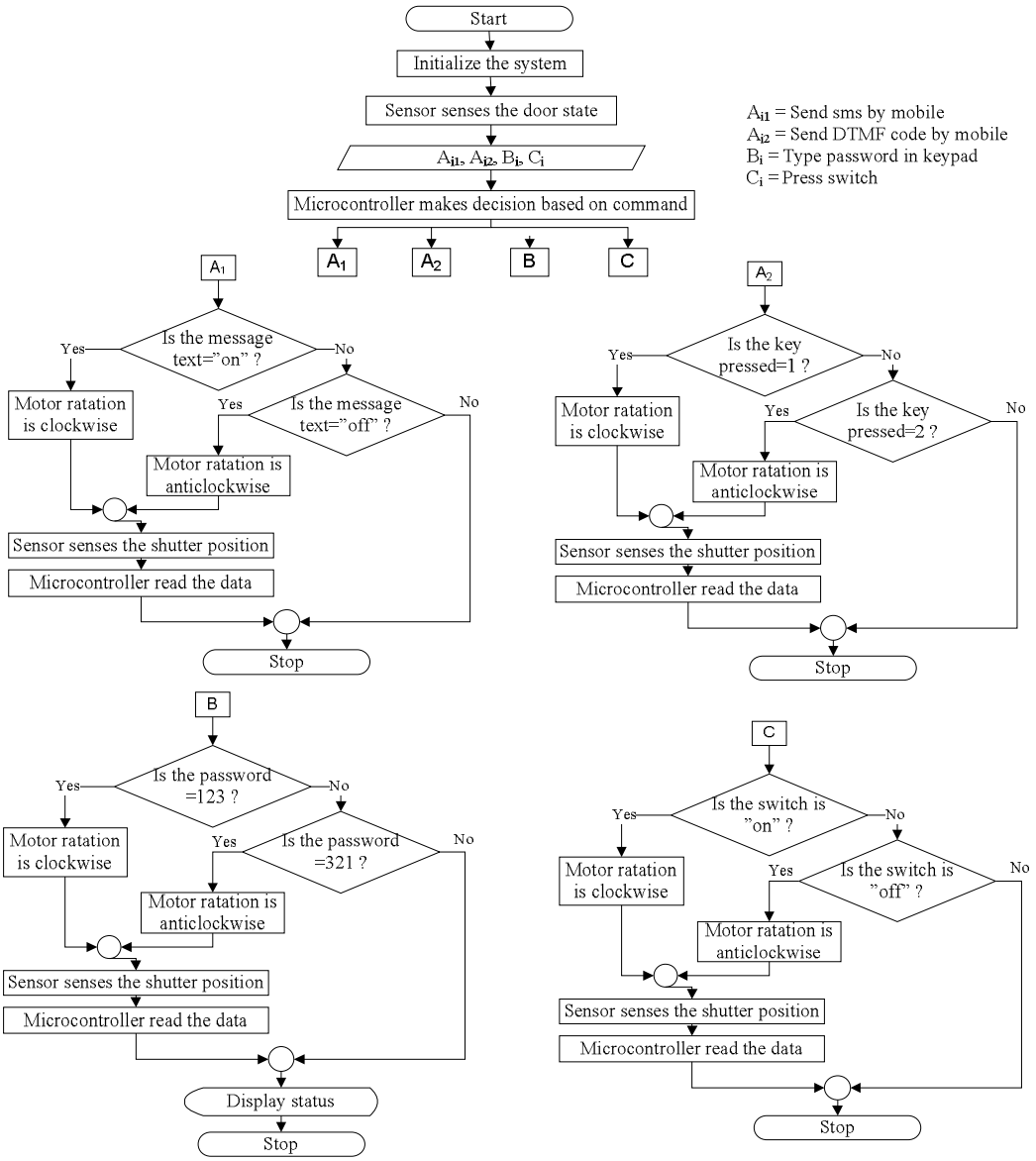


Fig.7: A details flowchart of this entire system.

5. MAIN IMPLEMENTING PROCEDURE

For control -1, a mobile phone is used to send a message or the DTMF code from a user (remote location) to the control system regardless of time and space. A GSM modem receives SMS messages and converts them into suitable required code for later controlling actions. A DTMF decoder decodes the signals and sends them to microcontroller. Microcontroller is the main device in the board of the control system, which receives the decoded DTMF signals and SMS messages from a GSM, Processes them, and then produces output control signals. For control-2, a keypad is used for controlling the door which is password protected. Sensor at first senses the door condition and then asks for desired password. If

password matches with system coded password then it will works otherwise it will show further instructions in LCD board and generates output voltage signals.For control-3, a push button switch is used for opening or closing the door. At first sensor senses the door position and then it starts its work according to user desire. Thus it generates output voltage signals. The driving system consists of relays, transistors, resistors, LEDs, and other required electronics. The driving system gets signals from microcontrollers and directs them to regulate the movement of the dc- motor. The liquid crystal display (LCD) is used to display the command (coded signals) and SMS messages.**Table 3** shows the shortcut of control key of the entire system.

Table 3. Three way control shortcut system.

Control and input					Motor rotation	Door state
Mobile	SMS text	On	DTMF code	1	Clockwise	Open
		Off		2	Anticlockwise	Close
keypad	Password	123			Clockwise	Open
		321			Anticlockwise	Close
Switch	position	On			Clockwise	Open
		Off			Anticlockwise	Close

6. DESIGN AND CONSTRUCTION OF THE DOOR

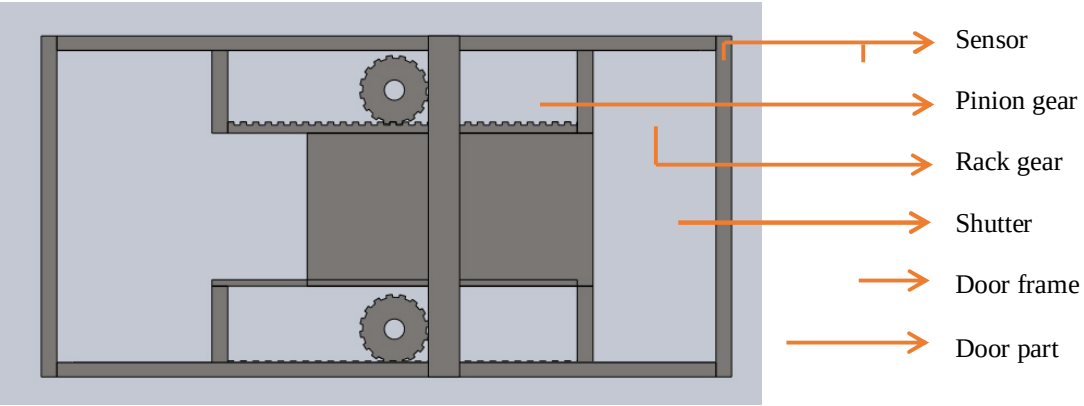


Fig.8: Design and construction of door system.

Figure 8 shows the design and construction model of proposed 3-way control door system. The door material is steel. Here rack and pinion gear is used to open and close the door. Two rack and pinion gear set are taken to operate the door because the door weight is too high, so high energy is needed to move the shutter of the door. The pinion gear is fixed at a point and attached to a motor shaft as if it can rotate with respect to shaft axis. The rack gear is welded in the movable shutter part. Here pinion is driver and rack is driven gear. Two inductive proximity sensors are used in the upper of frame and shutter as shown in the **Figure 8**. The main function of this sensor is to identify the door position means whether the door is open or close. If it can sense that the door is open or close then it generate electrical signal to the microcontroller and microcontroller take decision and perform operation according to user valid command. The controlling circuit unit will set up near the door. The total controlling unit and gear part will be covered by steel sheet of concrete wall but it should be kept a repairable way for future

maintenance. A camera can also be set in front of the door for recognizing knocker or authorized people. This automatic door system assures a complete security for property.

7. CONCLUSION

The project which is development of a GSM based control system for controlling door has designed considering some factors such as economic application, design economy, availability of components and research materials, efficiency, compatibility, reliability, security and durability. Since the door is controlled without using conventional lock so there is no risk of losing key or breaking it. Basically the door is designed for remotely control and high security. That is why mobile phone is given priority for controlling system.However, network transmission, signals transmission, disconnection from service Provider Company, battery problem of mobile phone, physical destruction of mobile phone may be occurred at any time. For this reason, keypad system has been embedded to the total control system which will be operated by password and set in front of the door. The optional switch is also embedded in the control system which will be operated from inside or secured place of driver.So it can be said that the system which is designed in this paper is optimum, easy to excess, economical and ensures better security for valuable property.

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DESIGN AND FABRICATION A SIMPLE LINE TRACKING AUTONOMOUS ROBOT

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ABSTRACT: This is a very simple and fundamental line tracking robot. It can follow through a black line. Two stepper motors are used to move the wheel and LDR sensor circuit is used to detect the white line. To control the stepper motors microcontroller is used. C programming is used here as programming language. This robot can follow any path of black line. As it is an autonomous robot, it does not need to keep any type of control over it during its moving along the line.

Keywords: Stepper motor, LDR sensor, robot and autonomous

1. INTRODUCTION

In many industries some works performed by men are so difficult as well as risky. In this purpose we can use this type of autonomous robot. This robot can be modified to large size robot for industrial purpose. Not only does a robot work faster, the fact that a fully equipped and optimized robot that can run for 24 hours a day, 365 days a year without breaks makes it more efficient and safe than workers[1].

Autonomous robot means that kind of robot which performed and controlled by programming automatically without any additional command or control over it during its movement. A line tracking autonomous robot can follow a path of line of any color. This line tracking autonomous robot is completely automatic and can move sensing white line by its sensor. When there will no path, it will stop its running[2].

Disregarding the early machines that were made to mimic humans and their actions and concentrating on the recent history, one can see a close relationship between the state of industry, the revolution in numeric and computer control of machinery, space explosion, and vivid imagination of creative people. Starting with karel Capek and his book, Rossam's Universal robots, and continuing with movies like flash Gordon Metropolis, lost in space, The Day the earth stood still, and the Foreman's job[2].

The aim of this research is to design an autonomous robot, to complete the robot construction and to interface the robot with micro controller using programming language, i.e. to control the robot by micro controller for automatic movement.

2. DESIGN AND CONSTRUCTION OF THE ROBOT

The most important portion of this project is the part of construction and implementation. This autonomous robot is designed as pre programmed with the help of computer interfacing. We used micro controller to control the two stepper motors and two LDR sensor circuit to detect the white line. Two power transistor circuits are used here to switching the stepper motors. An op-amp is used in the sensor circuit as voltage comparator.

We initially designed this robot using manual drawing. After manual drawing we drowned the robot design in AutoCAD 2006 with proper dimensions (Fig.1). The three dimensional view of the line tracker is shown in Fig.2. Then we went for manufacturing and fabrication. Some portions of this design are full calculative as well as some portions are assumed. For example we cannot design properly the spur gears as the terms and specifications of gear are not understood by the milling machine operators in the workshop. So we showed them a sample of our assumed spur gears and they made those for us.

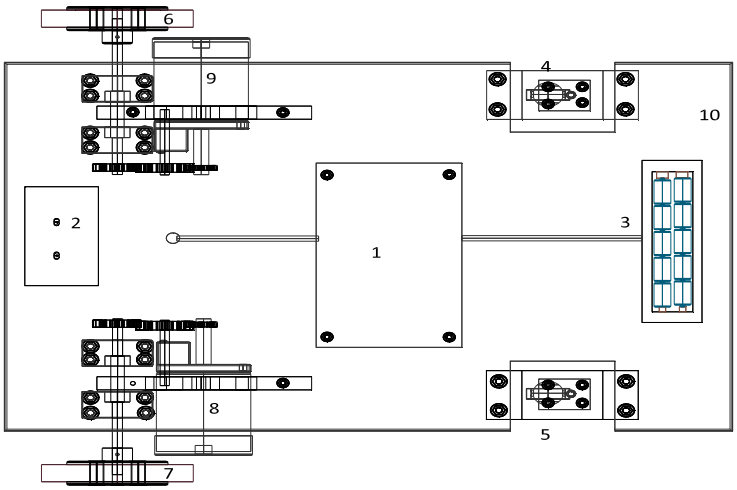

Fig.1 Schematic View of the Robot The complete design of the robot (top view): 1: Circuit box, 2: Sensor circuit, 3: Battery box, 4: Back free wheel 1, 5: Back free wheel 2, 6: Front power wheel 1, 7: Front power wheel 2 8: Stepper Motor 1, 9: Stepper Motor 2 and 10: Base

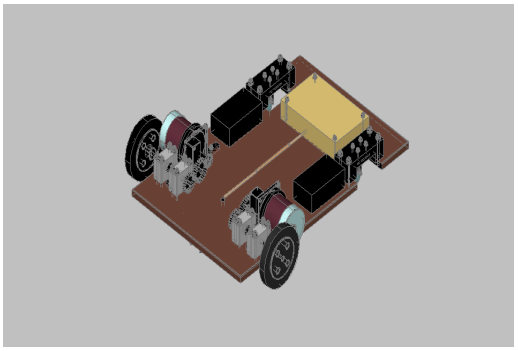

Fig.2 Three dimensional view of the robot

2.1 MECHANICAL CONSTRUCTION

The mechanical construction consists of a base, wheels with 2:1 gear mechanism. A flat surface plate made of plywood is used as the base of the robot where the stepper motor, nylon box, circuit box, battery boxes are fixed on the surface of the base. Clamps are used to hold the stepper motors and the batteries with the base. There are four bearings used in the two front power wheels. The shafts of the front power wheel shafts are stainless steel (SS) metal. Back wheels can move freely in 360^0 on the plane of the floor. We did not use any pin joint here. All of the joints here made with nuts and bolts and all nuts and bolts are of SS metal. Materials of mechanical construction are shown in Table 1

Table 1 Materials and Components of the robot

Plywood	Nylon block
Nylon shafts	Nuts and bolts8. Wooden block
Rubber	S S metal shafts (8mm diameter)
Bearing	MS metal pins
Clamps	

2.2 ELECTRICAL CONSTRUCTION

The electrical construction consists of stepper motor and its controller, LDR based color sensor circuit and transistor switching circuit. A voltage comparator op-amp is also used in the color sensor.

Integrated circuits contain transistors, capacitors, resistors and other parts packed in high density on one chip. Although the function is similar to a circuit made with separate components, the integral structure of the components are different in an integrated circuit. In this project we used two IC, one op-amp IC (LM324) and a micro controller IC (PIC 16F72)(Fig.3)[3].

Materials of electrical construction are

1. Stepper motor, 1.8^0/phase, 0.96A, 8.4v, 220gm
2. Microcontroller : PIC 16F72A
3. Crystal: 20MHz
4. LDR
5. 3 volt White LED
6. Op-Amp: LM 324
7. Transistor: BD 135 (NPN)
8. Resistance:330Ω,10kΩ,1kΩva. pot.
9. Electrolyte Capacitor:1000µF 50V, 2200µF 50V
10. COM port
11. IC base
12. Vero board
13. Electric wires
14. Battery: 6V, 4A/h

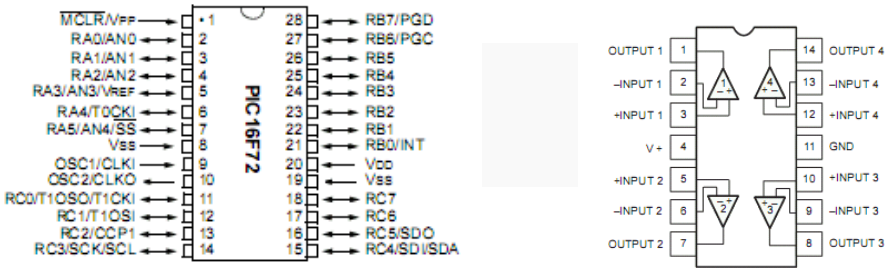

Fig.3 Electrical Circuit of the Robot : PIC 16F72 and LM324

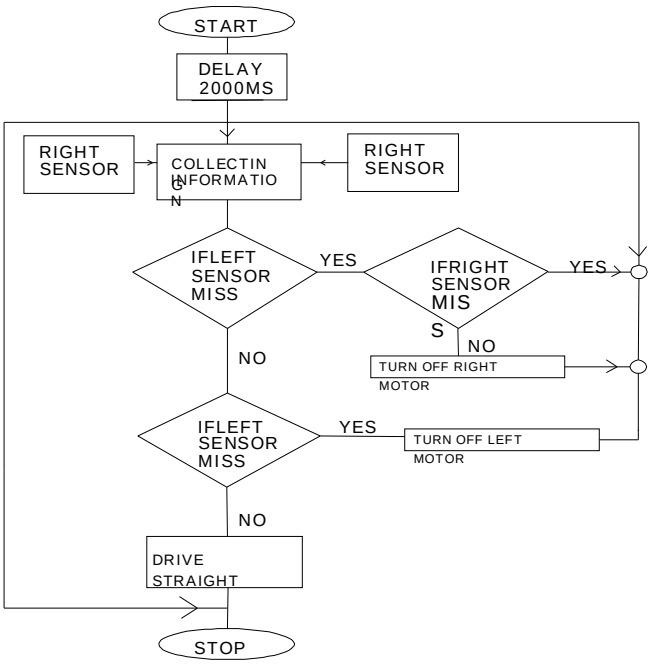

Fig 4: Flow chart of the Line Tracking Autonomous robot

3. METHODOLOGY

We used here the logic of differential moving of wheel to follow the white line. The sensor circuit (see Electrical Construction) has two LDR (left and right LDR) and two bright LED (left and right LED). The reflected light of LEDs from the floor falls on the LDR and the LDR shows various resistances. We measured the resistance of LDR when light reflects from the white line. Reflected light from other color gives various resistances by the LDR. So this resistance difference gives the direction of the path of white line. When the two LDR gives the same resistance then the two stepper

motor rotates in same speed. When left LDR gives different resistance then the right stepper motor rotates slowly and when the right LDR gives the different resistance then the left stepper motor rotates slowly. Thus the robot maintains its position correctly.

3.1 Programming Language and Flow Chart

Programming language C is used here. The flow chart is given below-

4. DISCUSSION

According to the aim of this research design and construction an autonomous robot model has been completed successfully. The robot can run automatically which is fully controlled by the programmed microcontroller. This line tracking autonomous robot can follow a path of black color line. It moves sensing black line by its sensor. When there will no path, it will stop its running automatically. In many industries some works performed by men are so difficult as well as risky. In this purpose we can use this type of autonomous robot.

5. CONCLUSION

From the above aim and discussion the following conclusion can be drawn

1. It can follow black color line.
2. It can distinguish between multiple lines.
3. It can follow any kind of zigzig and curved lines.

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CFC APPROACH IN TECHNOLOGY TRANSFER – A CASE STUDY OF DHOLAIKHAL LIGHT ENGINEERING CLUSTER

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1. BACKGROUND

Dholaikhal is known country's largest engineering cluster as a producer of engineering products and different types of repair jobs required by the agricultural, industrial and transport sector. About 5000 light engineering (LE) SMEs are operating in this cluster. Entrepreneurs in this cluster, however, are less educated and only a few of them are formally trained. Most of the machines they use are age-old machines imported from India and Pakistan (e.g., SEDF, 2007). SME LE firms have no facility to test metal and ensure proper hardness of engineering products. Price of the products is reasonable. Particularly in the face of competition from foreign products, even in the domestic market, there is an urgent need to improve the product quality and quantity. The local light engineering firms are also eying an export market, but both the product quality and the volume of production per worker need to be improved in order to compete in the international market. In this regard, establishment of CFC (common facility center) will play a critical role in the form of transferring modern technology to LE firms at Dholaikhal. CFC will be used jointly by small LE firms of Dholaikhal cluster, who cannot afford the expensive machinery and manpower needed individually.

TYPE OF ACTIVITIES OF CFC:

a. Metal testing facility of CFC will help entrepreneurs to identify materials of foreign made goods and select proper substitute materials if original materials are not available in the country.
b. One CNC training centre will operate at CFC. Workers of light engineering (LE) firms will be trained on CNC technology, helping LE firms to procure modern technology for mass production.
c. Different types of heat treatment processes (softening, hardening and surface hardening) will be available at the proposed CFC to help entrepreneurs in producing reliable quality of machinery and spare parts.

2. VALUE ADDITION OF DHOLAIKHAL LIGHT ENGINEERING CLUSTER

Researcher examined each activity within the value addition process of LE product and determines the value-added assessment. The following budget line items have been added up while getting at total cost of production:

- ✓ Cost of raw materials
- ✓ Wages
- ✓ Power
- ✓ Other expenses

Gear (Textile Industry)

Product Name	Metal Cost	Wages	Power	Other Expenses	Per unit cost (Tk)	Per unit price (Tk)
Gear	1,500	1,500	100	500	3,600	5,000

Value Addition of Gear (Textile Industry) = (Unit Price –Metal Cost)
= (BDT 5,000- BDT 1,500) =BDT 3,500
Percentage of Value Addition = (3,500/ 1,500) =233%
(Source: Industry Research)

3. APPROACH & METHODOLOGY

The study applied a mix of the secondary literature review and interviews with president & secretary general of Bangladesh Engineering Industry Owners' Association (BEIOA) and entrepreneurs of LE firms at Dholaikhal to develop general idea on proposed CFC and its importance to relax key constraints of the cluster. The overall paper was completed as outlined below.

3.1 Desk Research

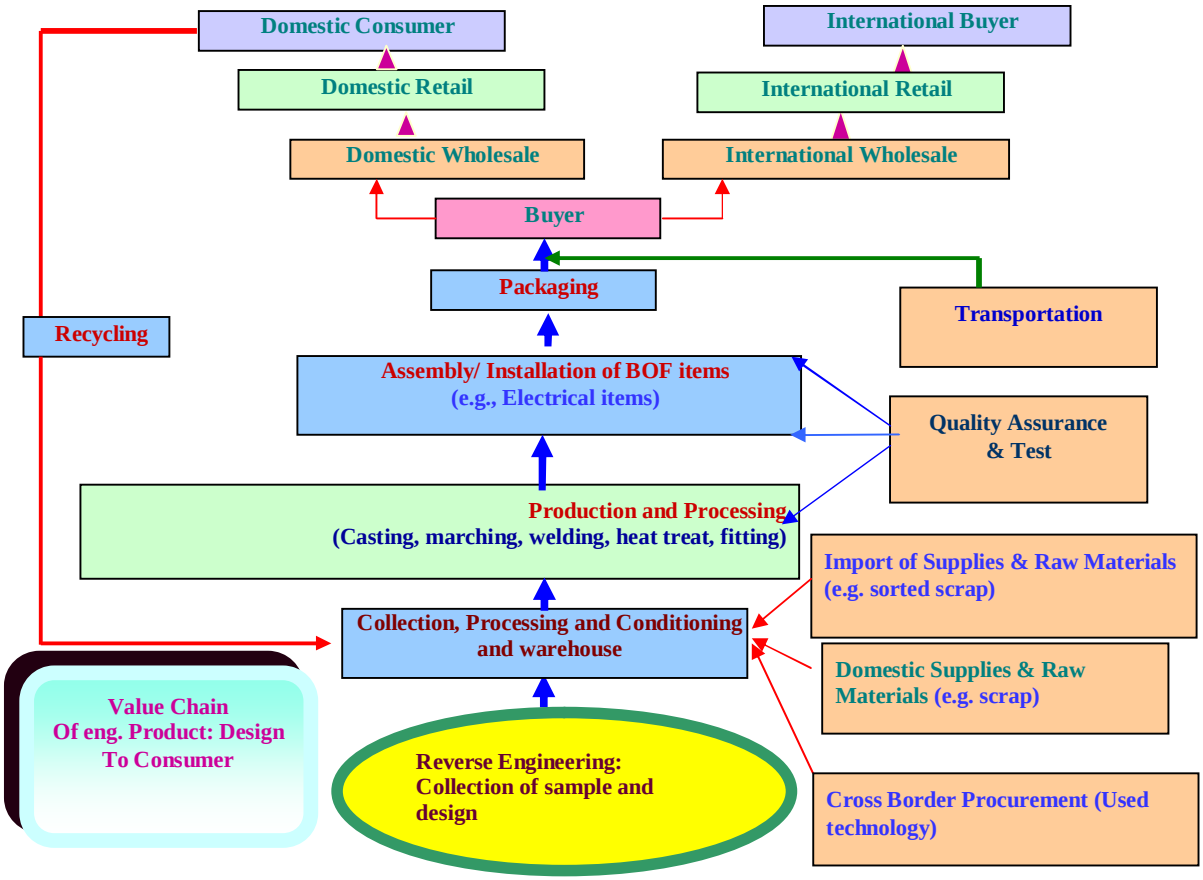
Relevant data, research findings, published research reports and policy documents (Industrial Policy 2010 and Export Policy 2012-15) were collected. These documents were studied to create a basis of proposing technical aspects of proposed CFC.

3.2 Field Visits and Consultation with Stakeholders

This was backed up with meetings with the representatives of Bangladesh Engineering Industry Owners' Association and visits to few light engineering firms at Dholaikhal cluster.

3.3 Value Chain Mapping of Dholaikhal LE cluster

The value chain of Dholaikhal LE cluster describes the full range of activities, which are required to bring a product or service from conception, through the different phases of receiving work order, designing of product, procuring materials, manufacturing, delivery to final consumers, logistics, sales-after customer service. This value chain analysis helped finding out constraints of Dholaikhal cluster. The following figure shows a typical value chain.



(Source: Industry Research)

4. CONSTRAINTS OF DHOLAIKHAL LIGHT ENGINEERING CLUSTER

(a) Constraints Related to Absence of CFC

Due to non-existence of CFC at Dholaikhal cluster, the light engineering firms can not access to necessary services like metal testing, CNC technology training and heat treatment facility. These services are required to ensure quality product on mass scale.

(b) Constraints Related to Raw materials

Sometimes testing of raw materials is required for some specialized job. Normally, this facility is not available at Dholaikhal cluster or any other light engineering cluster.

(c) Constraints Related to Finance

Lengthy and complicated lending procedure to receive bank loans.
High interest rate on bank loan.
Non-availability of sufficient working capital.
Non-availability of venture capital

(d) Constraints Related to Modern Technology

Light engineering firms use conventional technology due to lack of availability of skilled manpower in CNC technology.

(e) Constraints Related to Quality Certification

There is no institution to undertake standardization and testing of machinery and spare parts. Even though, BSTI provides standard of different products manufactured in Bangladesh, till now it has made very few standards on light engineering products. Due to lack of quality certification, local machines and spare parts face branding problem compared to imported product.

5. RECOMMENDATIONS

a) Establishment of CFC at Dholaikhal cluster with facilities of metal testing, CNC training and heat treatment that will be jointly used by cluster engineering firms.

CFC for Light Engineering Cluster – Mardan, Pakistan

The agriculture light engineering cluster of Mardan is scattered in Takht Bhai, Gujar Garhi and Sher Garh. There are more then 200 small and medium level of enterprises involved in making of Agricultural tools and implements. A Common Facility Center (CFC) was established in the cluster to provide advanced machinery and training facility to engineering SMEs. The CFC was established in at a suitable location in Mardan in close vicinity to the industrial clusters in coordination with the stakeholders.

b) Set up testing facility at Dholaikhal light engineering cluster to relax raw material related constraints.

c) Most cluster light engineering firms rely on informal sector financing to meet their needs. For ensuring good credit environment, following steps are considered:

- Bangladesh Bank should introduce special credit facility for commercial banks so that commercial banks will offer single digit loans to light engineering firms.
- Introduce factoring or account receivable based funding to meet working capital requirement of engineering firms.

d) Develop adequate skilled manpower in CNC technology and create special fund for cluster engineering firms to procure modern machinery.

e) For testing and certification to meet the quality standards of locally manufactured machines and spare parts, there is need to strengthen BSTI with new technology and skilled manpower to prepare quality standards and conduct testing.

6. IMPLEMENTING AND MANAGEMENT MODALITIES

Bangladesh Industrial Technical Assistance Centre (BITAC) will be the implementing agency of CFC. This CFC will be run on the basis of PPP including govt. and private sector stakeholders (BITAC, BSTI, BUET and Bangladesh Engineering Industry Owners' Association).

Brief Action Plan of Common Facility Centre at Dholaikhal Cluster

Background: Dhaka Dholaikhal light engineering cluster suffers from absence of dedicated CFC.

- Key stakeholders group: Light engineering SMEs at Dholaikhal.
- Overall Cost = Tk. 8 crore
- Type of activities:
    - Procurement of CNC training equipment

  Purchase of CNC training materials and equipment
- Specification of related outputs and results: This cluster benefits permanently from training facilities in CNC operation, programming and trouble shooting.
- *Estimated cost:* Tk 5 Crore
    - Procurement of metal testing equipment

  Purchase of metal testing lab. machinery and equipment
- Specification of related outputs and results: This cluster benefits permanently to identify composition of metal.
- *Estimated cost:* Tk 50 lac
    - Procurement of heat treatment plant.

  Purchase of heat treatment plant.
- Specification of related outputs and results: This cluster benefits by treating metal of product for higher longevity.
- Estimated cost: Tk 2.5 Crore

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RELOCATION OF AQUACULTURE TO BIRC

CSIRO Marine & Atmospheric Research
Bribie Island Queensland
AusTender Reference: CSIRO RFT2010-061

EXECUTIVE SUMMARY: This report presents a critical study regarding the Government Tender "Relocation of Aquaculture to BIRC" project. It discovers the project scope, objectives, assumptions and constraints about the project from the project management perspective. A high level project time frame and budget is also outlined in this report which will be followed by a detailed study if the project is approved. And finally, higher level risk analysis is carried out to identify potential threats to the project success. All these studies, eventually, facilitates the steering committee to decide whether to bid for the Tender or not. However, the report enlightens the alignment of our organizational strategic mission and planning to the success of this project. Once authorized by the steering committee, a detail project management plan will be prepared.

1. PROJECT PURPOSE AND JUSTIFICATION

The CISRO Marine and Atmospheric research Aquaculture is being relocated at Bribie Island Queensland. In order to keep up to date with the latest developments, an upgrade in the existing laboratories and research centres is required. The tropical climate of Queensland will play a critical role in understanding native aqua organism and therefore help in research and development of native aquaculture.

The Bribie Island Research Centre (BIRC) was one of the first dedicated multi-functional aquaculture research facilities built in Australia. The growing emphasis on aqua farming and research by the Government of Australia has underlined the need for having a centre that can be utilized for research and breeding for a long time to come. Commercial scale production facilities enable research teams to conduct research that can have direct, industry-wide application. The centre plays a significant role in technological development and extension to the aquaculture industry in tropical and subtropical Queensland.

2. PROJECT DESCRIPTION

This Construction work consists of some demolition and refurbishment work in the Aquaculture of BIRC, Queensland. Our company has the internal resource and expertise required for the demolition, masonry, reinforced concrete and timber work. However it is proposed to get outside subcontractors for the electrical, mechanical and hydraulic work to successfully complete the project. The old Crustacean Building and a new Nutrition Building and tunnel house are also need to be constructed/ refurbished. Project management department of our organization will work as a coordinator of all the subcontractors and the internally sourced construction teams.

3. PROJECT METHODOLOGY AND APPROACH

The project management approach will include four process groups and a control system. The development phases of the project are defined (PMBOK, 2008) in the figure below.

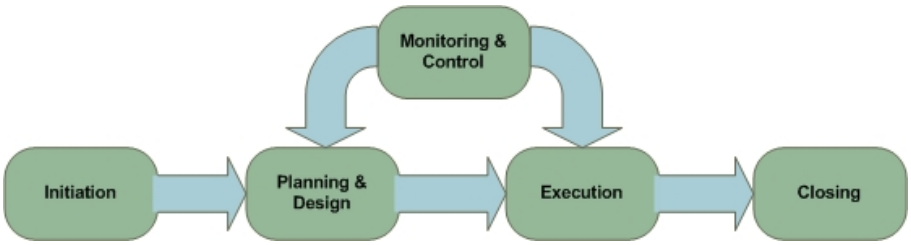

Fig 1: Project process flow chart

3. PROJECT SCOPE

The high level project scope is illustrated below. A detailed scope will be developed once the project is approved to carry on.

3.1 IN SCOPE

Deliverables that are within the project boundary is identified as in scope. Any change to the scope statement should be processed through a defined change control process. The scopes are

- ✓ The refurbishment of the existing Crustacean Building (comprising the Maturation Building and the Hatchery). This refurbishment includes demolition of existing redundant services, some architectural alterations and installation of new services, particularly new sea water management systems.
- ✓ The construction of the new Nutrition Building including associated services.
- ✓ A new Tunnel House, essentially a fabric shelter also including sea water delivery systems.
- ✓ The project includes a system of water collection, heating and delivery (serviced through equipment housed in a new steel workshed), a number of external slabs and minor road works.

3.2 OUT OF SCOPE

Anything that is not within the territory of the project contract is out of scope. The out of scopes are identified below.

- ✓ Installation of any Aquaculture Equipment at the construction site.
- ✓ Any transfer of aqua reserve/life to the constructed hatchery and other reservoirs.
- ✓ Any water treatment system.
- ✓ Any electrical wiring extension work from current power substation tot the buildings constructed.

4. PROJECT OBJECTIVES AND SUCCESS CRITERIA

In order to achieve success in the Project the following objectives are to be met within designated quality and project budget.

- ✓ Complete the demolition and excavation work within first 25 days.
- ✓ Complete Hydraulic Pump work and Mechanical piping within next 32 days.
- ✓ Complete base, wall and roof work within next 31 days.
- ✓ Complete electrical, painting and safety systems within next 35 days.
- ✓ Complete other auxiliary water heating system, slight road works and slabs within another 16 days.
- ✓ The project should be completed within an approximate budget of AUD 6.5 million.
- ✓ All three building construction should comply with the National Code of Practice for the Construction Industry, August 2009.
- ✓ The Project sponsor suggested that the project can be marked as successful if the staff turnover during the project remains below 5%. This rate will, however, indicate a good organizational and project management level maturity.
- ✓ The project will be considered as successful if our standard client (CSIRO, in this project) satisfaction survey provides a feedback of no less than 7.5 out of 10.

5. ASSUMPTIONS, DEPENDENCIES, CONSTRAINTS

5.1 Assumptions

The following is a list of assumptions. Upon agreement and signature of this document, all parties acknowledge that these assumptions are true and correct:

- ✓ This project has the full support of the project sponsor, stakeholders, and all other departments.
- ✓ The fund for the project will be allocated timely.
- ✓ Management will ensure that project team members are available as needed to complete project tasks and objectives.
- ✓ The CSIRO will not change the project scope again.

5.2 DEPENDENCIES

✓ The subcontractors Jeffry & Hudson, Signature Australia will deliver their mechanical, Hydraulic and Electrical work on scheduled time according to the project plan.

✓ The Third party quality assurance check will be performed on time and it will not cause any further delay to the project time schedule.

5.3 CONSTRAINTS

✓ The project is primarily constrained by the time frame. It will have to be finished by March 2011.

✓ The Construction work is constrained by the quality of the work. The auditing agency will check it against National Standard for Construction Work [NOHSC: 1016 (2005)

6. PROJECT REQUIREMENTS

The project must meet the following requirements in order to achieve success.

✓ National Standard for Construction Work [NOHSC: 1016 (2005)].

✓ The National Code of Practice for the Construction Industry, in conjunction with the Australian Government Implementation Guidelines for the National Code of Practice.

✓ Project Quality Standard AS ISO 10006.

✓ Environmental Standard ISO 14001:2004.

✓ Risk Management Standard AS/NZS ISO 31000:2009.

✓ Occupational Health and safety standard AS/NZS 4801:2001.

7. RISK ANALYSIS (HIGH LEVEL)

The project will use the following Risk Heat Matrix to determine qualitative risk levels:

		Consequence				
		Negligible	**Minor**	**Moderate**	**Major**	**Severe**
Likelihood		**1**	**2**	**3**	**4**	**5**
Almost Certain	**5**	M / 5	H / 10	H / 15	E / 20	E / 25
Likely	**4**	M / 4	E / 8	H / 12	H / 16	E / 20
Possible	**3**	L / 3	E / 6	E / 9	H / 12	H / 15
Unlikely	**2**	L / 2	L / 4	E / 6	E / 8	H / 10
Rare	**1**	L / 1	L / 2	L / 3	E / 4	E / 5

Fig 2: Risk heat matrix (Finley & Fisher, 1994.)

The project will not accept any high or extreme level risks. Any risks above this level must be treated until they are brought down to an acceptable level. The acceptance line in the above heat matrix maps the boundary where risks above must be treated, and below are currently deemed acceptable.

An initial high level risk assessment has been carried out at this stage. However detailed Risk analysis will be performed afterword and appropriate risk mitigation strategies will be undertaken along with appointing dedicated risk owner for potential risks.

#	Risk Area	Likelihood	Risk Owner	Project Impact Mitigation Plan
1	What if the project funding is not available at the right time leading to a delay in the project schedule	Medium	Project Sponsor	Proper planning and on time approval from the authorization bodies can reduce the time lag.
2	What if few shipments from the suppliers missed the dead line of arrivals leading to a project delay	High	Project Manager	Project Manager should schedule the delivery dates with some spare time so that it cannot impact the critical path of the project.
3	What if an unexpected land profile/soil quality is discovered after land excavation leading to a additional reinforced material for the foundation.	Low	Project Team	Proper land/soil testing must have been performed according to The National Standard for Construction Work [NOHSC: 1016 (2005)] to avoid such incident.
4	What if the regular operation of aqua centre at BIRC has been disrupted due to the construction work and noise leading to customer complaint or even contract breach	Low	Project Manager	Proper Occupational Health and safety measures should be taken according to the AS/NZS 4801:2001 to Environmental Management System ISO 14001:2004
5	What if the client denies accepting the project delivery due to any quality issue leading to a major economic loss to the company.	Low	Project Manager	A regular quality assurance check should be performed after every milestones and the client should be involved in this process.

8. WORK BREAKDOWN STRUCTURE (HIGH LEVEL)

A high level work breakdown structure (WBS) is demonstrated below. However, a detailed WBS will be developed using critical path method (CPM) and PERT analysis should we get the project.

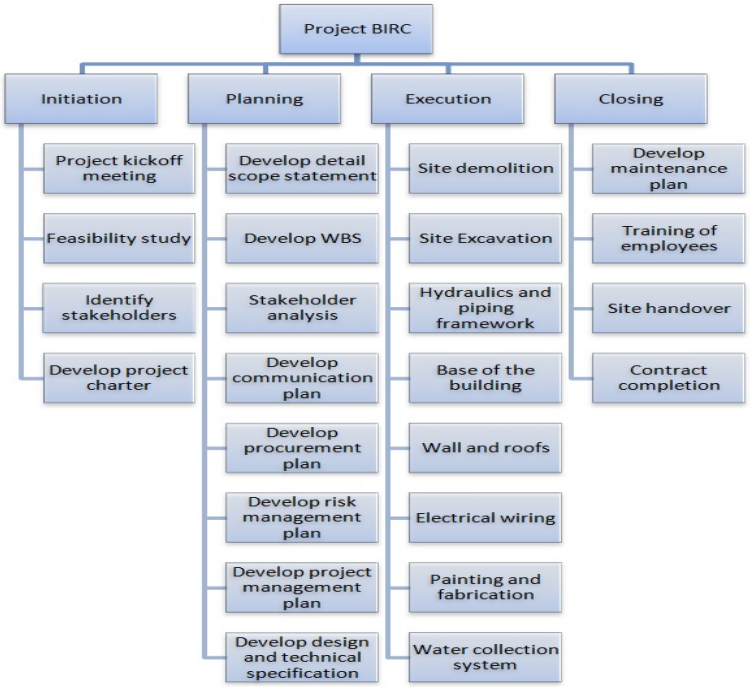

Fig 3: Project work breakdown structure

9. ESTIMATED HIGH LEVEL BUDGET

Project Budget	
Project Component	**Component Cost**
• Personnel Resources	$1,100,000
• Hardware- Demolition and Construction	$2,450,000
• Pumps and piping Material	$1,750,000
• Electrical wiring and other stuffs	$550,000
• Others	$350,000
Total	**$6,200,000**

10. PROJECT TIMEFRAME

Estimated time frame	
Project Milestone	**Target Date (dd/mm/yyyy)**
• Project Start	01/09/2010
• Complete Demolition work	12/09/2010
• Complete Excavation	25/09/2010
• Complete Hydraulic Pump work and Mechanical piping	28/10/2010
• Complete base of the Building	25/11/2010
• Complete Walls and roofs Construction	29/12/2010
• Complete electrical Wiring and Connection	16/01/2011
• Complete painting and safety systems	04/02/2011
• Complete water heating system, road works and slabs	20/02/2011
• Project Complete	12/03/2011

11. PROJECT TEAM GOVERNANCE STRUCTURE

Project Role	**Project Team Member(s)**	**Responsibilities**
Portfolio Manager	Mr. Ashley Jones	Aligning project goals and objectives to the company strategy and planning.
Project Sponsor	Mrs. Jenifer Hodge	Managing External Issues of the Project and reporting the Portfolio manager monthly.
Project Manager	Mr. Noor Alam	Managing project and reporting to the Project Sponsor fortnightly.
Project Team	Mr. Joe Bond	Coordinating the in source construction work
	Miss Sara Paxton	Coordinating the outsourced work (Subcontractors)

12. Conclusion

There are many factors and processes that will influence project success, the ability to integrate costs and schedules will significantly enhance the ability to control project constraints of cost and time. The detailing of a work break down structure together with establishing a resource pool will provide the necessary information to apply appropriate cost estimation techniques to determining project costs and schedules. This will facilitate more accurate monitoring and control of the project. The stakeholder

management will play an important role because of complex project structure including internal and external subcontractors, CSIRO and BIRC. Therefore, appropriate change control process and procurement monitoring log are recommended in order to manage project time, cost and budget successfully.

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MACHINING OF AISI 4320 STEEL WITH UNCOATED CARBIDE TOOLS UNDER VARIOUS COOLANT SUPPLY PRESSURE

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.**ABSTRACT:** Although MRR increases with increase in velocities and feed rates but it raises temperature remarkably and such high cutting temperature adversely affects, directly or indirectly, chip formation, cutting forces, tool life, dimensional accuracy and surface integrity of the products. HPC (high pressure coolant) jet assisted turning is an effective method of machining, which allows overcoming the problems associated with the typical method and application if conventional coolant in turning steels.
This paper deals with experimental investigation on the role of HPC with variable pressure by cutting oil (HC straight run, VG 68) on cutting temperature, chip reduction coefficient and surface roughness in turning AISI-4320 steel at industrial speed-feed combinations by uncoated SNMG insert. The encouraging results include significant improvement in surface integrity and surface quality by HPC application mainly through reduction in the cutting zone temperature and favorable change in the chip-tool and work-tool interaction.

Keywords: Temperature, chip reduction coefficient, roughness, HPC and uncoated carbide.

1. INTRODUCTION

Mainly HPC has used in high production manufacturing industries where product quality and dimensional accuracy are needed within acceptable limit and difficult-to-machine materials are processed to get the desired job. High speed machining is needed to increase productivity in manufacturing technology and is largely related with high temperature, such high temperature generates lot of troubles. So, for reducing this high temperature HPC jet is used as a heat removing as well as lubricating agent.

To reduce the environmental and economical effects of usual coolant during machining, a number of attempts were made in the past to improve cooling/lubrication in high speed machining and in the case of machining of difficult-to-machine materials by the use of a high pressurized coolant/lubricant jet to overcome these problems. The results achieved by these investigators were very encouraging [1-5]. Cutting forces were reduced, chip shape, surface quality and tool life improved, thereby increasing the metal removal rate, and improving the overall performance of the machining operation. It was found that high-pressure jet of coolant, when applied at the chip-tool interface, could reduce cutting temperature and improve tool life to some extent by introducing a hydraulic wedge between chip-tool interface [2, 6-8]. High–pressure jet of conventional coolant has been reported to provide some reduction in cutting temperature [9]. It reduces temperature very quickly due to high pressure jet coolant reaches very easily in to the chip-tool interface. Mazurkiewicz et al. [2] reported that a coolant applied at the cutting zone through a high pressure jet nozzle could reduce the contact length and coefficient of friction at chip-tool interface and thus could reduce cutting forces and increase tool life to some extent.

It was reported [6] that coolant injection offers better cutting performance in terms of surface finish, tool force and tool wear when compared to flood cooling. The coolant jet under high-pressure is capable of creating a hydraulic wedge between the tool and the workpiece, penetrating the interface deeply with a speed exceeding that necessary even for very high-speed machining. This phenomenon also changes the chip flow conditions [10]. The penetration of the high-energy jet at the tool–chip interface reduces the temperature gradient and minimizes the seizure effect, offering an adequate

lubrication at the tool–chip interface with a significant reduction in friction. Excellent chip breakability has been reported when machining difficult-to-cut materials with high-pressure coolant supply [5, 11]. This is attributed to a coolant wedge which forms between the chip and the tool forcing the chip to bend upwards giving it a desirable up curl required for segmentation.

The majority of the cooling and lubricating aspects of a flood coolant stream are lost as the coolant is vaporized prior to entering the cutting zone [12]. It is the great problem of machining, HPC plays well role to minimize this type of problem. Frederick Mason [12] found better solution from it and he states that HPC systems generates high velocity coolant streams moving at several hundred mph. This high pressure-speed coolant easily penetrates the vapor barrier to effectively lubricates and cool the tool. In fact,, when machinists apply high pressure coolant to a longstanding process, which has always produced dark blue chips, they are open amazed that the same or even higher speeds and feeds produce shiny, silver chips that are cool to the touch. With the use of high-pressure coolant during machining, the tool life and surface finish are found to improve significantly [**2, 7,** 13, 14], which is said to be due to the decrease in heat and cutting forces generated.

The experimentally observed role of high-pressure coolant (HPC) in drilling AISI-4340 steel by HSS drill [7] may be summarized that the formation of chip under HPC condition is more favorable in compare to dry condition because of high lubrication capacity, roundness deviation was smaller at both the entrance and end of the holes under HPC condition in compare to dry condition. When high depth of cut used, the drilling with dry condition was not possible because of poor cooling and lubrication action, taper values and their dispersion were smaller under high-pressure coolant condition. Moreover, in both conditions the average taper values were positive i.e., the diameters in the entrance of the holes were bigger than at the end. The beneficial effects of HPC may be attributed to effective lubrication action, which prevents the chip sticking on the tool and makes the cut feasible.

It was found about the performance of high-pressure coolant jet on grind ability of steel [7] based on the experimental results that high-pressure coolant jet reduces grinding zone temperature significantly due to effective cooling and lubrication at the grinding zone area. HPC grinding yields to less significant lamellar chips compared with dry grinding and marked no substantial variation in length and shape of the chips can be found due to change in feed though. The sizes of the long lamellar chips observed to be larger than under dry grinding. High-pressure coolant grinding provides considerably less surface roughness in comparison with dry grinding. The aspect of high-pressure coolant grinding has expectedly always been free from surface burning. This can obviously be attributed due to lower temperature, retained grit sharpness and less rubbing.

he hardness of a workpiece plays an important role in the performance of tool which is observed [15] by the variation in cutting forces, surface roughness, flank wear and chip shape with workpiece hardness. The application of high-pressure coolant produces a great reduction in flank wear and hence tool life and produces a significant improvement in surface finish for both uncoated and coated inserts, in a certain range of hardness. This is because the cutting temperature and forces are reduced when using high-pressure coolant. The effective zone of high-pressure coolant in improving tool life and surface finish is found to be 35–40 HRC for the uncoated insert, whereas the optimal condition when using high-pressure coolant with a coated insert is 40 HRC. For both coated and uncoated tools, the use of high-pressure coolant below the optimal hardness is found to be detrimental to the flank wear and hence tool life. This is due to the wear mechanism, and may be prompted by the ductility of the material, resulting in edge chipping that causes large tool wear and thus shortens tool life. However, there is no significant difference in surface roughness with workpiece hardness for both types of insert, with the application of high-pressure coolant. Generally, the values of surface roughness are well below 1.0 μm, which is even better than for grinding or EDM.

Machining of Inconel 718 alloy with SiC whisker reinforced alumina ceramic tool [16] under high-pressure coolant supplies tends to improve tool life with increasing coolant pressure up to 15 MPa under finish machining conditions. Lower tool life was generated with 20.3 MPa coolant supply pressure due to accelerated notching. Lower cutting forces where generated when machining Inconel 718 with whisker reinforced ceramic tool at higher coolant supply pressures due to improved cooling and lubrication (low frictional forces) at the cutting interface and also as a result of chip segmentation caused by the high-pressure coolant jet. Accelerated notch wear on both flank and rake

faces of the SiC whisker reinforced alumina ceramic tool during machining can also be caused by water jet impingement erosion of the ceramic cutting tool by the high-pressure coolant. Very low surface roughness values were recorded when machining Inconel 718 alloy with the SiC whisker reinforced alumina ceramic tool. This is due to the big contact radius (6 mm) of the ceramic tools. Hardening of the top surface, up to 0.2 mm beneath the machined surfaces occurred when machining with conventional and high-pressure coolant supplies. This is associated with the increase in dislocation density due to plastic deformation of the machined surface. Plastic deformation of the surface layers extends on average to between 30 and 50 µm below the machined surface when machining with ceramic tools under the high-pressure coolant conditions investigated. Patrik Dahlman and Marcel Escursell [17] successfully showed the convenience of using ultra-high-pressure jet-assisted cooling to achieve good chip control. By introducing a hydraulic wedge between the tool and the chip, it is possible to break and curl the chip to the desired form, even with very soft material.

The present work experimentally investigates the role of variable pressure coolant (HPC) jet on cutting temperature, chip reduction coefficient and surface roughness in plain turning of AISI 4320 steel at industrial speed-feed condition by uncoated carbide inserts with ISO tool designations SNMG 120408.

2. EXPERIMENTAL PROCEDURE

HPC set-up consists of an electric motors (5 hp) coupled to a high-pressure vane pump, a composite unit of flow control valve and pressure compensating relief valve, a direction control valve and a filter as shown in Fig. 1. These devices are mounted at the top of a tank that is made of mild steel sheets and angle bars. This tank contains the cutting oil that is used as a HPC coolant and the capacity of the coolant tank is 200 litters. A coolant indicator is mounted beside the wall of coolant tank; it is used to know the quantity of coolant present in the tank during machining. A 5 hp motor is used to operate the vane pump and a gear coupling is used between the vane pump and motor to transmit power. This pump pressurized the coolant to pass through the flow control valve. Flow control valve controls the amount of flow and it is turned to regulate the coolant flow during machining. A relief valve has mounted with flow control valve regulating the composite. Relief valve control the pressure and discharge excess oil to the tank. A pressure gauge is also mounted to detect the pressure of coolant so that we can observe at what pressure the coolant is delivered during machining. A direction control valve is used for changing the direction of supply. A perfect nozzle is used to supply high pressure coolant towards the cutting zone. From the nozzle, pressurized fluid impinged at the chip-tool interface and reduces the cutting temperature.

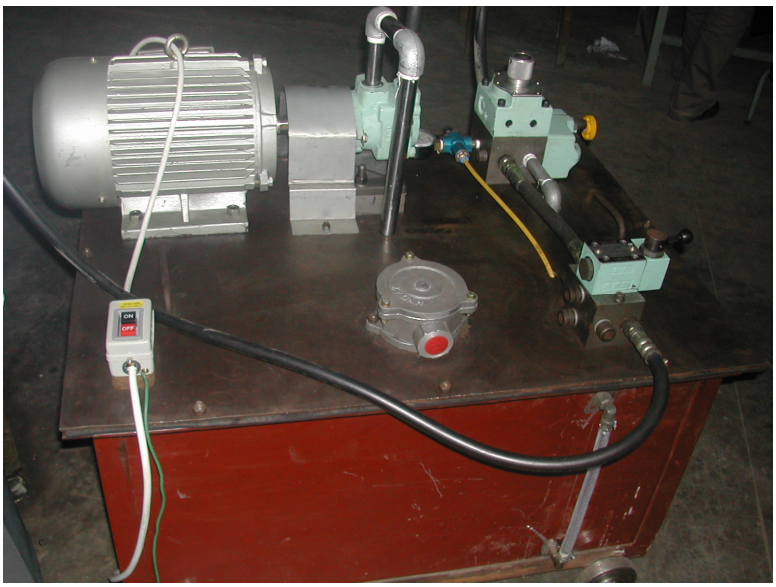
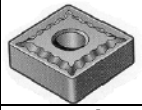


Fig.1 Photographic view of high-pressure coolant jet delivery system

The machining trials were carried out by turning AISI 4320 Steel rod having initial diameter 192 mm and length 520 mm in a high power rigid lathe (10 hp) by using uncoated carbide insert (SNMG 120408 TTR) with different combination of cutting speeds (V) and feed (f) under high-pressure coolant condition having various pressure and flow rates. Depth of cut is kept constant throughout the machining trials. HC straight run, VG 68 cutting oil were used during HPC jet assisted turning. The high pressure coolant was delivered at various pressures and directed through a nozzle on the tool holder to the region where the chip–tool contact is intimate. The conditions under which the machining tests have been carried out are briefly stated in Table 1. The average cutting temperature (θ_{avg}) was measured by simple but reliable tool work thermocouple technique with proper calibration. The roughness of the machined surface after each cut was measured by a Talysurf (Sutronic 3^{+}, Rank Taylor Hobson limited). The results are documented and plotted at various pressures having various combinations of speeds and feed.

Table 1. Experimental Conditions

Machine tool		:	Lathe Machine (10 hp)
Work material		:	AISI 4320 Steel (φ192 X 520 mm)
Cutting Insert		:	SNMG uncoated carbide insert.
			
Cutting oil		:	HC straight run, VG 68
Tool holder		:	PSBNR 2525M12 (ISO specification)
Working tool geometry		:	-6^{o}, -6^{o}, 6^{o}, 15^{o}, 75^{o} and 0. 8 mm
Process parameters			
	Cutting velocity, V_C	:	104 , 148 , 211 and 296 m/min
	Feed rate, S_o	:	0.10, 0.14, 0.18 and 0.22 mm/rev
	Depth of cut, t	:	1.5 mm
HPC supply		:	Pressure 30, 50, 70 & 90 bar and Flow rate 6 liter/minute through external nozzle.
Environments		:	High-pressure coolant (HPC) condition

3. EXPERIMENTAL RESULTS AND DISCUSSION

The average chip-tool interface temperature (θ_{avg}) has been determined using the tool work thermocouple technique and plotted against cutting speed for different feeds under HPC conditions having various pressures are shown in From Fig. 2 and Fig. 3. From Fig. 2 and Fig. 3, the effect of HPC jet pressure on average chip-tool interface temperature (θ_{avg}) under different cutting speeds, V and feed rate, f is showing as compared to each other. However, it is clear from the aforementioned figures that with the increase in V and f, average chip-tool interface temperature, (θ_{avg}) increased as usual under HPC condition, due to increase in energy input. It is also observed that temperature at the tool-workpiece is surprisingly reduced with increase in pressure at various speeds and feed rates but the impact of flow rates is ambiguous.

However, during machining at lower V when the chip-tool contact is partially elastic, where the chip leaves the tool, HPC is dragged in that elastic contact zone in small quantity by capillary effect and is likely to enable more effective cooling. With the increase in V the chip makes fully plastic or bulk contact with the tool rake surface and prevents any fluid from entering into the hot chip-tool interface. It is distinct from Fig. Fig. 2 and Fig. 3 that HPC cooling provided more improvement with the decrease in feed particularly at lower cutting speed. Possibly, the thinner chips, especially at lower chip velocity, are slightly pushed up by the HPC jet coming from opposite direction and enable it come closer to the hot chip-tool contact zone to remove heat more effectively. Further, at high cutting speed, the coolant may not get enough time to remove the heat accumulated at the cutting zone resulting in less reduction in temperature under HPC condition. However, it was observed that the HPC jet in its present way of application enabled reduction of the average cutting temperature by about 5% to 10% depending upon the levels of the process parameters, V and f with increasing pressure.

Even such apparently small reduction in the cutting temperature is expected to have some favourable influence on other machinability indices.

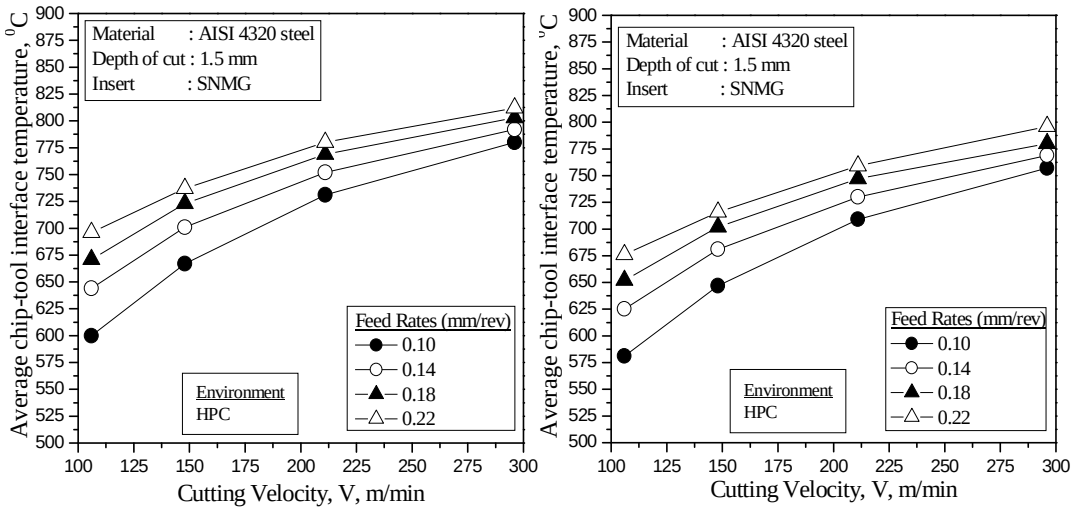


Fig. 2 Variation in chip-tool interface temperature with V at different f under HPC condition at (a) P=30 bar and (b) 50 bar, Q=6 L/min

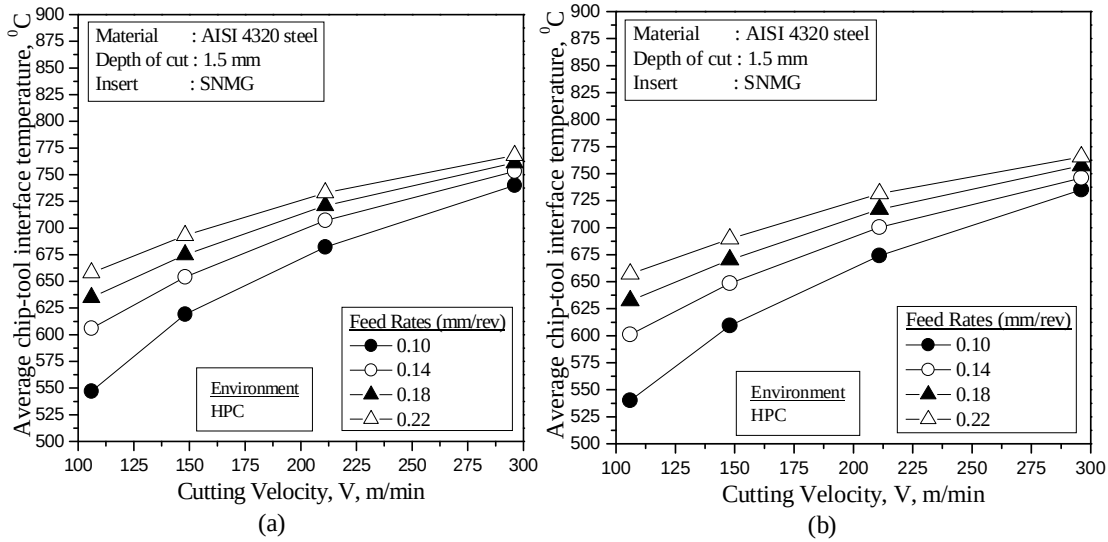


Fig. 3 Variation in chip-tool interface temperature with V at different f under HPC condition at (a) P=70 bar and (b) 90 bar, Q=6 L/min

Chip-reduction coefficient, ξ (ratio of chip thickness after and before cut) is also an important machinability index .The degree of chip thickness ratio plays vital role on cutting forces and hence on cutting energy requirements and cutting temperature. Almost all the parameters involved in machining have direct and indirect influence on the thickness of the chips during deformation. It was found that there is a reduced chip thickness (after cut) with the increase in pressure which indicates positive effects of pressure on cooling and lubrication during machining under HPC environment.
By HPC applications, chip reduction coefficient, ξ is reasonably expected to decrease for reduction in friction at the chip-tool interface and reduction in deterioration of effective rake angle by built-up edge formation and wear at the cutting edges mainly due to reduction in cutting temperature. It is apparent from Fig. 4 and Fig. 5 that the value of chip reduction coefficient, ξ gradually decreased with the increase in cutting speed, V though in different degree under HPC conditions having various pressures by straight cutting oil.

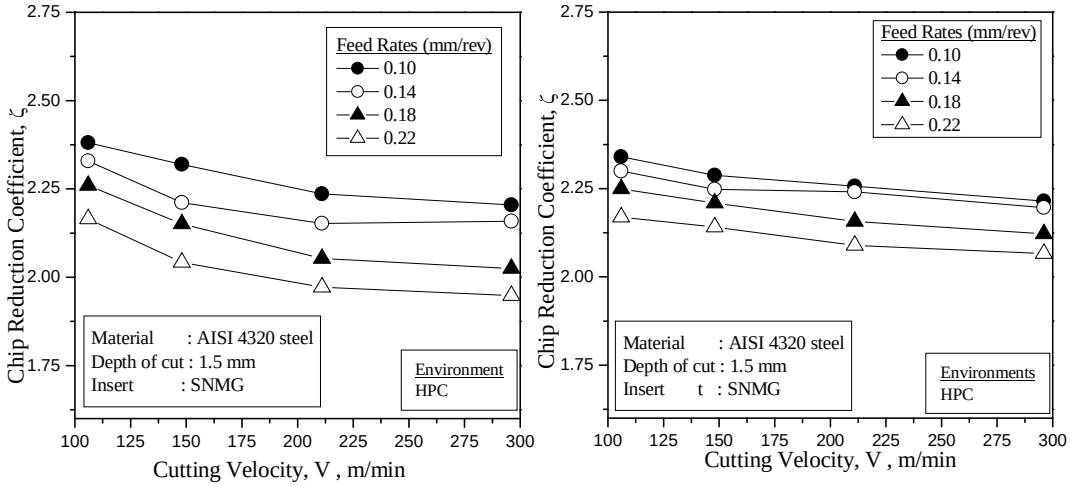


Fig. 4 Variation of chip reduction coefficient with V at different f under HPC condition at (a) P=30 bar and (b) 50 bar, Q=6 L/min

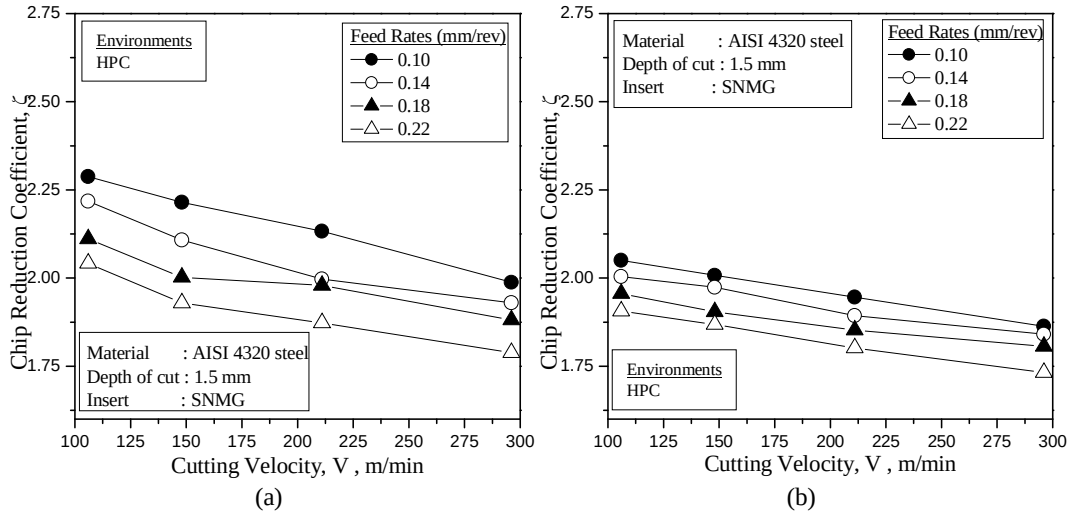


Fig. 5 Variation of chip reduction coefficient with V at different f under HPC condition at (a) P=70 bar and (b) 90 bar, Q=6 L/min

The value of chip reduction coefficient, ξ usually decreases with the increase in cutting speed, V particularly at its lower range due to plasticization and shrinkage of the shear zone for reduction in friction and built-up edge formation at the chip-tool interface due to increase in temperature and sliding velocity. In machining AISI 4320 steel by uncoated carbide tool, usually the possibility of built-up edge formation and size and strength of the built-up edge, if formed gradually increase with the increase in temperature due to increase in cutting speed, V and also feed rates, f and then decrease with the further increase in cutting speed, V due to too much softening of the chip material and its removal by high sliding speed.

The impact of three factors, namely, the feed, nose radius, and cutting edge angles, on surface roughness and developed the following equations to estimate the ideal roughness value

$R_a = f/32r$ [For non zero cutter radius (r)] … … … (1)

$R_a = f/4(\cot\alpha + \cot\beta)$ [For zero cutter radius (r)] … … … (2)

Where, R_a= ideal arithmetic average of surface roughness (mm), f=feed (mm/rev), r= cutter nose radius, α and β are the major cutting edge angle (MCEA) and end cutting edge angle (ECEA) respectively. Both equation clearly implies that the ideal roughness of the surface is a function of

only feed rate and tool geometry and best possible finish can be obtained for a given tool shape and feed. However, these equations hold true only if built up edge, chatter, inaccuracies in the machine tool movement and other factors are eliminated completely.

Fig. 6 and Fig. 7 clearly shows that surface roughness increases with the increase in feed, f and decreased with the increase in V. Increase in f raised R_a mainly according to the equation 1. Reduction in R_a with the increase in V may be attributed to smoother chip-tool interface with lesser chance of built-up edge formation in addition to possible truncation of the feed marks and slight flattening of the tool-tip. Increase in V may also cause slight smoothing of the abraded auxiliary cutting edge by adhesion and diffusion type wear and thus reduced surface roughness.

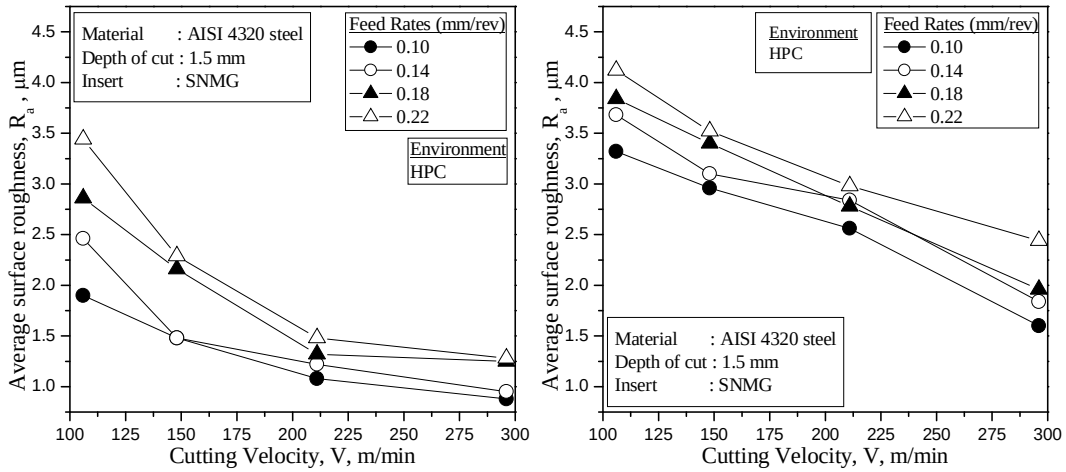


Fig. 6 Variation in R_a with V at different f under HPC condition at (a) P=30 bar and (b) 50 bar, Q=6 L/min

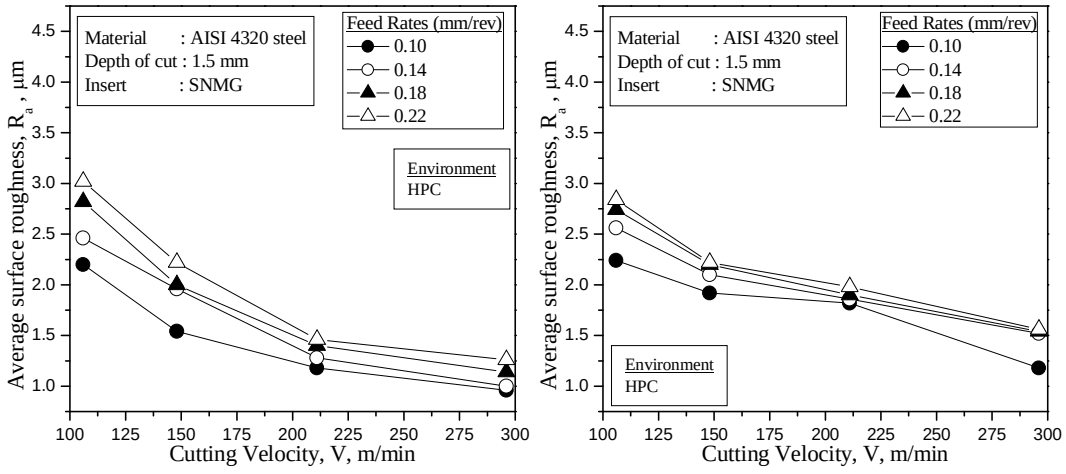


Fig. 7 Variation in R_a with V at different f under HPC condition at (a) P=70 bar and (b) 90 bar, Q=6 L/min

It is evident in Fig. 6 and Fig. 7 that HPC jet assisted cooling could provide marginal improvement in surface finish at the beginning of machining with the fresh cutting edges. The slight improvement in surface finish by HPC jet assisted cooling might be due to reduction in break-in wear and also possibly reduction or prevention of built-up edge formation depending upon the work material and cutting condition. This may reasonably be attributed to more stability of those alloy steel against attrition and built-up edge formation. From Fig. 6 and Fig. 7, it is noticeable that there is some

improvement in surface finish with increase in pressure though it is not uniform. It may be due to the controlling of deterioration of the auxiliary cutting edge by abrasive, chipping and built-up-edge.

4. CONCLUSIONS

i. High pressure coolant (HPC) jet assisted turning provided significant improvements expectedly in respect of surface finish throughout the V-f range undertaken mainly due to reduction in the average chip tool interface temperature. The present HPC systems enabled reduction in average chip-tool interface temperature upto 11% by changing pressure and even such apparently small reduction, unlike common belief, enabled significant improvement in the major machinability indices.
ii. Average cutting temperature at the chip-tool interface is highly influenced by mainly cutting speed along with feed rate and pressure. In case of chip reduction co-efficient, pressure plays the key role along with feed rate and pressure. On the other hand, surface roughness is highly influenced by the cutting speed along with feed rate.
iii. HPC reduced the cutting temperature; such reduction has been more effective for those tool-work combinations and cutting conditions, which provided higher value of chip reduction coefficient for adverse chip-tool interaction causing large friction and built-up edge formation at the chip-tool interface. Surface finishes is improved mainly due to reduction of wear and damage at the tool tip as well as friction and increased chip breakability by the application of HPC.

ACKNOWLEDGEMENTS

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