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Inventory system with postponed demands considering reneging pool's and rejecting Buffer's customers

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Abstract

This paper analyzes an (s, S) inventory system where arrival of customers form a Poisson process. When inventory level reaches to zero due to demand, further demands are sent to a pool, which has capacity M (<∞) and has a buffer with capacity less than a pool. When inventory level reduces to $I(t) \geq s+1$,demand from buffer customer or external customer can be met. But when $I(t) \leq s$,only external demand shall be met. Pooled as well as buffer customer(s) has to wait at least until the next replenishment. In this model, external customer can directly met this demands (i,e, at a negligible service time) but pooled customer should go to buffer first with parameter $\theta\beta$, Customers can lose patience and may decide to leave i.e., reneged occur at the rate $\theta(1-\beta)$. buffer customer may get the service with parameter μ or may be rejected at the rate $\mu(1-\delta)$. entering to the pool and buffer on the basic of FIFS. The system is analyzed in the steady state case. Some measures of the system performance in the steady state are derived and some numerical illustrations and sensitivity analysis are provided.

Key words: *Reneging, Postponed demand, pooled customer and Buffer customer*

Introduction

Postponement of work is a common phenomenon. This may be to attend a more important job than the one being processed at present or for a break or due to lack of quorum and so on. Postponement of service to customer takes place in different ways depending on the nature of the input and the service process. For example, in the priority inventory system products to customers of lower priority stands postponed when one of higher priority enters to the system. In the case of preemptive service, customers of lower priority in service pushed out the moment one with higher priority arrives.
In this paper, we consider an (s,S) inventory system. We assume that customers arrive to the system according to a Poisson process with rate $\lambda(>0)$. When inventory level depletes to s due to demands or decay or service to a pool customer, an order for replenishment is take placed. The lead time is exponentially distributed with parameter γ. When inventory level reaches to zero, the incoming customers are sent to a pool of capacity M .From the pool, customers will be further sent to buffer that has also a finite capacity equal to the size of the pool. Any demand that takes place when the pool is full and inventory level is zero, is assumed to be lost forever. After replenishment, as long as the inventory level is greater than s, the buffer customers are selected according to an exponentially distributed time lag. We also assume that some customers may be impatient and may leave the system.
The difference between the problem under discussion and classical (s,S) inventory models with lead time is that pooled and buffer customers will have to wait even when inventory level is positive; whereas in the latter backlogs are cleared partially or fully depending on the availability of the stock or just after the replenishment occur..
The paper is organized as follows. Section 2,3 provides the concept of the model and analysis in the steady state case. In section 4, some characteristics of the model are derived. Sections 5,6 presents the cost analysis and numerical results. Finally, sensitivity analysis is shown in section 7and the values of the all steady state probability vectors are given in Appendix.

1.1. **Assumptions :**

i. Inventory level is initially in S.

ii. Inter arrival times of demand are exponentially distributed with parameter λ.

iii. Lead time is exponentially distributed with parameter γ.

iv. Demands that arrive when the inventory level is 0 is sent to a pool with probability λ α of limited capacity M and customer with probability $\lambda(1-\alpha)$ will be lost to the system forever.

v. When inventory level $I(t) \geq s+1$ demands from buffer customers and external customer will be met. But when $I(t) \leq s$ only external demands will be met. And pooled customer as well as buffer customer(s) has to wait at least until the next replenishment. For external customer they can directly met their demands (i.e, at a negligible service time) but pool customers go to buffer with probability $\theta\beta$ and provided the service with parameter μ or reneging customer may leave the pool with probability $\theta(1-\beta)$.

vi. Buffer customer may get the service with probability $\mu\delta$ or may be rejectedat the rate $\mu(1-\delta)$ entering to the pool and buffer on the basis of First In First Serve (FIFS)

1.2 Notations used in the model

$I(t)$ = inventory level at time t , $P(t)$ = Number of customer in the pool, $B(t)$ = Number of customer in the Buffer, E_i's = State Spaces

2. The model we built up and analysis thereof

It can be verified that $\{I(t), P(t), B(t) = (i,j,k) | 0 \leq i \leq s : 0 \leq j \leq M : 0 \leq k \leq B\}$ is formed a three dimensional Markov process with state space $E = E_1 \times E_2 \times E_3$ where

$E_1 = \{0,1,2,........ S\}$, $E_2 = \{0,1,2......... M\}$, $E_3 = \{0,1,2......... B\}$

The infinitesimal generator of the process $\breve{A} = (a(i,j,k : l,m,n); (i,j,k), (l,m,n) \in E)$

Can be obtained using the following arguments;-

A. The arrival of a demand makes a transition from

$(i,j,k) \to (l = i-1, m = j, n = k)$ if $s+1 \leq i \leq S$

$(i,j,k) \to (l = i, m = j+1, n = k)$ if $i = 0; 0 \leq j \leq M-1$

B. The pool customer make a transition to buffer leaves the pool size less by one as a first come first serve basis.

$(i,j,k) \to (l = i, m = j-1, n = k+1), i = 0....S, 1 \leq j \leq M, 0 \leq k \leq B-1$

For reneging customer from the pool makes a transition reducing the size of the pool by one unit i, e $(i,j,k) \to (l = i, m = j-1, n = k)$; if $1 \leq i \leq S, 1 \leq j \leq M, 0 \leq k \leq B.$

C. When the buffer customer is picked up, it leaves the buffer size and inventory level less by one. $(i,j,k) \to (l = i-1, m = j, n = k-1)$; if $s+1 \leq i \leq S, 1 \leq k \leq B.$ Transition from

(i,j,k) to $(l=i+Q, m=j, n=k)$ if i ≤ s. Hence, we get

$$\widetilde{A}=\begin{cases}\lambda & : l=i-1, i=1,\ldots S \\ & m=j, j=0,1,\ldots, M \\ & n=k, k=0,1,\ldots B \\ \lambda\alpha & : l=i, i=0 \\ & m=j+1, j=0,1,\ldots, M-1 \\ & n=k, k=0,1,\ldots B \\ \theta\beta & : l=i, i=0,\ldots, S \\ & m=j-1, j=1,\ldots, M \\ & n=k+1, k=0,1,\ldots B-1 \\ \theta(1-\beta) & : l=i, i=0,\ldots, S \\ & m=j-1, j=1,\ldots, M \\ & n=k, k=0,1,\ldots B \\ \gamma & : l=i+Q, i=0,\ldots, s \\ & m=j, j=0,1,\ldots, M \\ & n=k, k=0,1,\ldots B \\ \mu\delta & : l=i-1, i=s+1,\ldots, S \\ & m=j, j=0,1,\ldots, M \\ & n=k-1, k=1,\ldots B \\ \mu(1-\delta) & : l=i, i=s+1,\ldots, S \\ & m=j, j=0,1,\ldots, M \\ & n=k-1, k=1,\ldots B \\ -(\lambda+\gamma+\mu+\theta) & : l=i, i=0,\ldots, s \\ & m=j, j=0,1,\ldots, M \\ & n=k, k=0,1,\ldots B \end{cases}$$

Where $P=(i,j,k), Q=(l,m,n)$

Define,

$A_{il}=(a((i,j,k),(l,m,n))); i,l\in E_1, j,m\in E_2, k,n\in E_3$

The infinitesimal generate $\breve{A}$ **can** be conveniently expressed as a partition matrix $\widetilde{A}=((A_{il}))$ Where A_{il} is a $(M+1)\times(B+1)$ sub-matrix

which is given

by, $$A_{il}=\begin{cases}A_1 & :\text{if } l=i-1, i=s+1,\ldots,S \\ A_2 & :\text{if } l=i, i=s+1,\ldots,S \\ A_3 & :\text{if } l=i, i=0 \\ A_4 & :\text{if } l=i+\gamma, i=0,\ldots,s \\ A_5 & :\text{if } l=i, i=1,\ldots,s \\ A_6 & :\text{if } l=i-1, i=1,\ldots,s \end{cases}$$ With

$$A_1=(a_{pq})_{(P_1\times Q_1)}=\begin{cases}\text{Along the diagonal elements is } \lambda \\ (p,q)\to(\text{p,q-1}):\text{is } \mu\delta \text{ if } p=M,\ldots,0; q=1,\ldots,B \\ \text{All other elements are 0}\end{cases}$$

$Where P_1=(M+1)(B+1), Q_1=(M+1)(B+1)$

$\tau=-\lambda-\theta, \xi=\theta(1-\beta), \eta=-\lambda-\theta-\mu(1-\delta), \zeta=-\lambda-\mu(1-\delta),$

$\omega=\theta\beta, \psi=\mu(1-\delta).$

$$A_2=(a_{pq})_{(P_1\times Q_1)}=\begin{cases}(p,q)\to(\text{p,q}):\text{is } \tau \text{ if } p=M,\ldots,1, q=0 \\ (p,q)\to(\text{p-1,q}):\text{is } \xi \text{ if } p=M,\ldots,1, q=0,\ldots,B \\ (p,q)\to(\text{p,q}):\text{is} -\lambda \text{ if } p=0, q=0 \\ (p,q)\to(\text{p,q-1}):\text{is } \psi \text{ if } p=M,\ldots,0, q=1,\ldots,B \\ (p,q)\to(\text{p,q}):\text{is } \eta \text{ if } p=M-1,\ldots,1, q=1,\ldots,B \\ (p,q)\to(\text{p,q}):\text{is } \eta_2 \text{ if } p=M, q=1,\ldots,B \\ (p,q)\to(\text{p,q}):\text{is } \zeta \text{ if } p=0, q=1,\ldots,B \\ (p,q)\to(\text{p-1,q+1}):\text{is } \omega \text{ if } p=M,\ldots,1, q=0,\ldots,B-1 \\ \text{All other elements are 0}\end{cases}$$

$Where P_1=(M+1)(B+1), Q_1=(M+1)(B+1)$

$\tau_1=-\gamma-\theta, \delta_2=-\lambda-\gamma-\theta, \xi_2=-\lambda-\gamma, \xi=\theta(1-\beta), \eta_1=-\gamma-\theta-\mu(1-\delta),$

$\zeta_2=-\lambda-\gamma-\theta-\mu(1-\delta), \omega=\theta\beta, \psi=\mu(1-\delta), \psi_2=-\lambda-\gamma-\mu(1-\delta).$

$$A_3=(a_{pq})_{(P_1\times Q_1)}=\begin{cases}(p,q)\to(\text{p,q}):\text{is } \tau_1 \text{ if } p=M, q=0 \\ (p,q)\to(\text{p-1,q}):\text{is } \xi \text{ if } p=M,\ldots,1, q=0,\ldots,B \\ (p,q)\to(\text{p-1,q}):\text{is } \phi \text{ if } p=M, q=0 \\ (p,q)\to(\text{p,q}):\text{is } \xi_1 \text{ if } p=0, q=0 \\ (p,q)\to(\text{p,q}):\text{is } \eta_1 \text{ if } p=M, q=1,\ldots,B \\ (p,q)\to(\text{p,q-1}):\text{is } \psi \text{ if } p=M,\ldots,0, q=1,\ldots,B \\ (p,q)\to(\text{p,q}):\text{is } \zeta_1 \text{ if } p=M, q=1,\ldots,B \\ (p,q)\to(\text{p-1,q+1}):\text{is } \omega \text{ if } p=M,\ldots,1, q=0,\ldots,B-1 \\ (p,q)\to(\text{p,q}):\text{is } \delta_1 \text{ if } p=0, q=1,\ldots,B \\ \text{All other elements are 0}\end{cases}$$

$Where P_1=(M+1)(B+1), Q_1=(M+1)(B+1)$

$\tau_1=-\gamma-\theta, \delta_1=-\alpha\lambda-\gamma-\mu(1-\delta), \xi_1=-\alpha\lambda-\gamma, \xi=\theta(1-\beta), \eta_1=-\gamma-\theta-\mu(1-\delta),$

$\zeta_1=-\alpha\lambda-\gamma-\theta-\mu(1-\delta), \omega=\theta\beta, \psi=\mu(1-\delta), \phi=-\alpha\lambda-\gamma-\theta.$

$$A_6=\text{diag}\left(\lambda \quad \lambda \ldots\ldots \quad \lambda\right)$$

So we can write the portioned matrix as follows

$$\widetilde{A}=(a_p)_{S(S+1)\times S(S+1)}=\begin{cases}(p\to\text{p});\text{is } A_2 \text{ if } p=S\ldots\ldots s+1 \\ (p,\to\text{p-1}):\text{is } A_1 \text{ if } p=S-1\ldots\ldots s+1 \\ (p\to\text{p}):\text{is} A_5 \text{ if } p=s\ldots\ldots\ldots 1 \\ (p\to\text{p-1}):\text{is} A_6 \text{ if } p=s\ldots\ldots\ldots 1 \\ (p\to\text{p}):\text{is } A_3 \text{ if } p=0\end{cases}$$

$$A_5=(a_{pq})_{(P_1\times Q_1)}=\begin{cases}(p,q)\to(\text{p,q}):\text{is } \tau_2 \text{ if } p=M;q=0\\(p,q)\to(\text{p-1,q}):\text{is } \xi \text{ if } p=M,\ldots 1;q=0,\ldots,B\\(p,q)\to(\text{p-1,q+1}):\text{is} \omega \text{ if } p=M,..1;q=0,..B-1\\(p,q)\to(\text{p,q-1}):\text{is } \psi \text{ if } p=M,..0;q=1,\ldots,B\\(p,q)\to(\text{p,q}):\text{is } \delta_2 \text{ if } p=M-1,..1;q=0\\(p,q)\to(\text{p,q}):\text{is } \xi_2 \text{ if } p=0;q=0\\(p,q)\to(\text{p,q}):\text{is } \eta_1 \text{ if } p=M;q=1,\ldots,B\\(p,q)\to(\text{p,q}):\text{is } \zeta_2 \text{ if } p=M-1,\ldots 1,q=1,\ldots,B\\(p,q)\to(\text{p,q}):\text{is } \psi_2 \text{ if } p=0,q=1,\ldots,B\\\text{All other elemants are } 0\end{cases}$$

$Where P_1=(M+1)(B+1), Q_1=(M+1)(B+1)$

$\tau_1=-\gamma-\theta, \delta_2=-\lambda-\gamma-\theta, \xi_2=-\lambda-\gamma, \xi=\theta(1-\beta), \eta_1=-\gamma-\theta-\mu(1-\delta),$

$\zeta_2=-\lambda-\gamma-\theta-\mu(1-\delta), \omega=\theta\beta, \psi=\mu(1-\delta), \psi_2=-\lambda-\gamma-\mu(1-\delta).$

$$A_4=\text{diag}\left(\gamma\ \gamma\ldots\ldots\gamma\right)$$

3. Steady State Analysis

It can be seen from the structure of matrix A that the state space E is irreducible. Let the limiting distribution be denoted by $\Pi(i,j,k)$:

$$\Pi^{(i,j,k)}=\underset{t\to\infty}{Lt}\Pr[I(t),P(t),B(t)=(i,j,k)],\ (i,j,k)\in E$$

Let $\Pi=\left(\Pi^{(S)},\Pi^{(S-1)},\ldots\ldots,\Pi^{(1)},\Pi^{(0)}\right)$ with

$$\Pi^{(K)}=\left(\left(\Pi^{(K,M,0)},\ldots..\Pi^{(K,0,0)}\right),\left(\Pi^{(K,M,1)},\ldots..\Pi^{(K,0,1)}\right),\ldots\ldots,\left(\Pi^{(K,M,B)},\ldots..\Pi^{(K,0,B)}\right)\right),\ \text{for } K=0,1,2,\ldots..,S$$

The limiting distribution exists, satisfies the following equation:

$$\Pi\widetilde{A}=0 \qquad \text{and} \qquad \sum_{i=0}^{S}\sum_{j=0}^{M}\sum_{k=0}^{B}\Pi^{(i,j,k)}=1$$

The first equation of the above yields the following set of equations:-

$$\begin{aligned}&\Pi^{(1)}A_6+\Pi^{(0)}A_3=0\\&\Pi^{(i+1)}A_6+\Pi^{(i)}A_3=0 && ;i=0\\&\Pi^{(i+1)}A_6+\Pi^{(i)}A_5=0 && ;i=1,2,\ldots..,\ s-1\\&\Pi^{(i+1)}A_2+\Pi^{(i)}A_5=0 && ;i=s\\&\Pi^{(i+1)}A_1+\Pi^{(i)}A_2=0 && ;i=s+1,s+2,\ldots..,\ Q-1\\&\Pi^{(i+1)}A_1+\Pi^{(i)}A_2+\Pi^{(i-Q)}A_4=0 && ;i=Q,Q+1,\ldots..,\ S-1\\&\Pi^{(S)}A_2+\Pi^{(s)}A_4=0\end{aligned}$$

The solution of the above equations (except the last one) can be conveniently expressed as:-

$$\Pi^{(i)}=\Pi^{(0)}\beta_i \qquad :i=0,1,\ldots\ldots\ldots,S$$

where,

$$\beta_i=\begin{cases}I & :i=0\\-A_3A_6^{-1} & :i=1\\(-1)^{i-1}\beta_1\left(A_5A_6^{-1}\right)^{\text{i-1}} & :i=2,3,\ldots,s\\(-1)^{s}\beta_1\left(A_5A_6^{-1}\right)^{\text{s-1}}\left(A_5A_1^{-1}\right) & :i=s+1\\(-1)^{i-1}\beta_1\left(A_5A_6^{-1}\right)^{\text{s-1}}\left(A_5A_1^{-1}\right)\left(A_2A_1^{-1}\right)^{\text{i-s-1}} & :i=s+1,\ldots.,Q\\-\beta_{i-1}\left(A_2A_1^{-1}\right)\text{-}\ \left(A_4A_1^{-1}\right)\beta_{i-Q-1} & :i=Q+1,\ldots\ldots,\ S\end{cases}$$

To compute $\Pi^{(0)}$,we can use the following equation

$\Pi^{(S)}A_2+\Pi^{(s)}A_4=0$ and $\sum\Pi^{(K)}e_{(M+1)\times(B+1)}=1$ which yield, respectively,

$\Pi^{(0)}\left(\beta_S A_2+\beta_s A_4\right)=0$ and $\Pi^{(0)}\left(I+\sum\beta_i\right)e_{(M+1)\times(b+1)}=1$

4. System Characteristics

a) Mean Inventory level

Let L_1 denote the average inventory level in the steady state. Then we have:- $L_1 = \sum_{i=1}^{S} i \sum_{j=0}^{M} \sum_{k=0}^{B} \Pi^{(i,j,k)}$

b) Mean Re-order rate

Suppose L_2 is the mean re-order rate. Then :- $L_2 = \sum_{j=0}^{M} \sum_{k=0}^{B} \lambda \, \Pi^{(s+1,j,k)} + \sum_{j=0}^{M} \sum_{k=1}^{B} \mu\delta \Pi^{(s+1,j,k)}$

c) Mean number of pool customers

The expected number of pool is $L_3 = \sum_{j=1}^{M} j \sum_{i=1}^{S} \sum_{k=1}^{B} \Pi^{(i,j,k)}$

d) Mean number of Buffer customers

The expected number of buffer customers L_4 is $L_4 = \sum_{j=0}^{M} \sum_{i=0}^{S} \sum_{k=1}^{B} k \Pi^{(i,j,k)}$

e) The average number of customer's lost to the system is

$$L_5 = \sum_{k=0}^{B} \lambda \, \Pi^{(0,M,B)} + \sum_{i=0}^{S} \sum_{j=1}^{M} \sum_{k=0} (1-\beta)\theta \prod^{(i,j,k)} + \sum_{i=0}^{S} \sum_{j=0}^{M} \sum_{k=1}^{B} (1-\delta)\mu \prod^{(i,j,k)}$$

f)The probability that the external demands will be satisfied after immediately it's arrival is,

$$L_6 = \sum_{i=s+1}^{S} \sum_{j=0}^{M} \sum_{k=0}^{B} \Pi^{(i,j,k)}$$

g)The probability that the external demand arrival enter the pool is $L_7 = \sum_{j=0}^{M-1} \sum_{k=0}^{B} \Pi^{(0,j,k)}$

h)The probability that an buffer customer will be $L_8 = \sum_{i=1}^{S} \sum_{j=0}^{M} \sum_{k=1}^{B} \Pi^{(i,j,k)}$

5. Cost Function

Define

$C_1 =$ Inventory holding cost of the system, $C_2 =$ Cost of re-order of the system

$C_3 =$ Cost for pool customers in the system, $C_4 =$ Cost for buffer customers in the system

$C_5 =$ Cost of customers lost to the system, So the total expected cost of the system is

$$E(TC(S,s,M,B)) = C_1 L_1 + C_2 L_2 + C_3 L_3 + C_4 L_4 + C_5 L_5$$

$$E(TC(S,s,M,B)) = C_1 \left(\sum_{i=1}^{S} i \sum_{j=0}^{M} \sum_{k=0}^{B} \Pi^{(i,j,k)} \right)$$

$$+ C_2 \left(\sum_{j=0}^{M} \sum_{k=0}^{P} \lambda \, \Pi^{(s+1,j,k)} + \sum_{j=0}^{M} \sum_{k=1}^{P} \mu\delta \, \Pi^{(s+1,j,k)} \right) + C_3 \left(\sum_{j=1}^{M} j \sum_{i=0}^{S} \sum_{k=0}^{B} \Pi^{(i,j,k)} \right) + C_4 \left(\sum_{j=0}^{M} \sum_{i=0}^{S} \sum_{k=1}^{B} k \Pi^{(i,j,k)} \right)$$

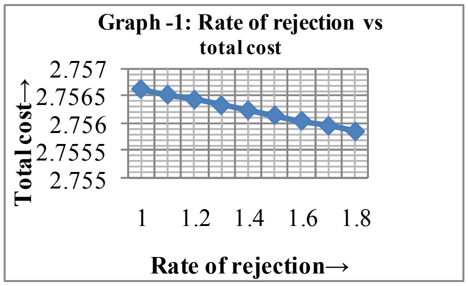
$$+ C_5 [(\lambda \Pi^{(0,M,B)}) + \sum_{i=0}^{S} \sum_{j=1}^{M} \sum_{k=0}^{B} (1-\beta)\theta \, \Pi^{(i,j,k)} + \sum_{i=0}^{S} \sum_{j=0}^{M} \sum_{k=1}^{B} (1-\delta)\mu \, \Pi^{(i,j,k)}].$$

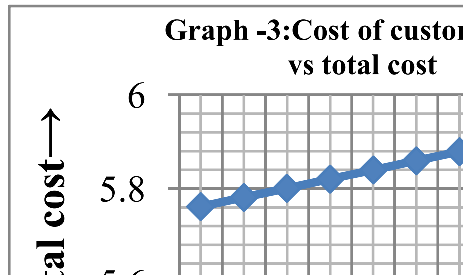
Numerical Illustration: Since analytical expression are impossible to arrive at, by giving values to the underlying parameters we provide some simple numerical illustrations. Consider a service providing organization that provides services. If maximum capacity of the system is S= 3 units, Reorder level s=1,Number of pool customers M=3, Number of Buffer customers B=2, Inventory arrival rate λ=0.9, Service rate μ=0.9, Replenishment rate γ=5,Rate of Reneging θ=0.001, Rate of Rejection δ=0.9, Rate of customer entering to the pool α=0.5, Rate of customer entering to the Buffer =0.7.On the basis of the above mentioned specifications we have calculated the values of various system characteristics of the paper and results are given in appendix

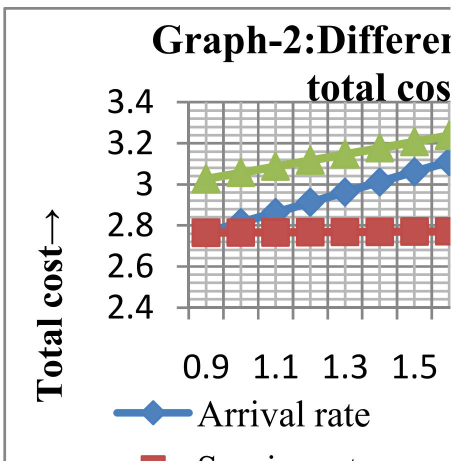
Mean Inventory level (L_1)	2.2802
Mean Re-order rate (L_2)	0.45085
Mean number of pool customers (L_3)	2.99519
Mean number of Buffer customers (L_4)	0.01950

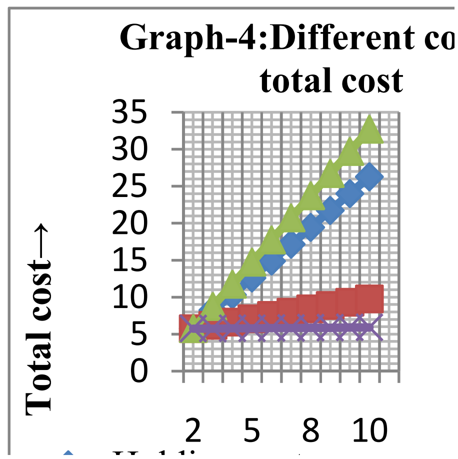
The average number of customer's lost to the system is (L_5)	0.27167
The probability that the external demands will be satisfied after immediately it's arrival is (L_6)	0.401525
The probability that the external demand arrival enter the pool is L_7	0.000007638
The probability that an buffer customer will be L_8	0.018056
Total expected cost of the system	3.45252

Sensitivity Analysis:









Form the graph-1, It is observed that if the rate of rejection is increased then the total cost is decreased in a significant amount. Form graph-2, It is observed that the arrival rate is vital to the system, the service rate and the reneging rate has little impact. The result is obvious as the rate each increased it has impact one higher reordering, lost sales and also increased the cost of carrying pool and Buffer customers. The reason is that increasing service rate is simple imply less per unit customers carrying cost to the pool and Buffer. Form graph-3, It is observed that the cost of customer lost to the system is a great change in cost. Form graph-4, It is observed that the cost for buffer customer and reorder cost increase the total cost slightly but holding cost and cost for pool customer increase the total cost high. Thus it has grate impact to the system.

Conclusion

This paper represents a model of Stochastic Inventory control. In this model external customers can directly met their demands at a negligible service time. Here we considered a Pool and a Buffer system. When inventory level reaches to zero, the customer should enter into the Pool. Here reneging case may also occur i, e if a customer looses patience he/she may leave the system without getting service. Pool customers go to Buffer and then get service. Pool and Buffer customers can be serviced with the basis of first come first serve(FIFS). More interesting problem can be tackled in future in Markovian set up related to the current research work.

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Appendix

Steady State Probability Vectors of the Model

S =3		S=1		S=2		S=0	
$\Pi^{(3,3,0)}$	0.3925895	$\Pi^{(1,3,0)}$	0.08732252	$\Pi^{(2,3,0)}$	0.482603329	$\Pi^{(0,3,0)}$	0.015720518
$\Pi^{(3,2,0)}$	0.001316205	$\Pi^{(1,2,0)}$	0.0003350798	$\Pi^{(2,2,0)}$	0.0019463693	$\Pi^{(0,2,0)}$	0.000056602
$\Pi^{(3,1,0)}$	0.000011075	$\Pi^{(1,1,0)}$	0.0000026774	$\Pi^{(2,1,0)}$	0.000015738	$\Pi^{(0,1,0)}$	0.000000448
$\Pi^{(3,0,0)}$	0.000000096	$\Pi^{(1,0,0)}$	0.0000000231	$\Pi^{(2,0,0)}$	0.00000013649	$\Pi^{(0,0,0)}$	0.000000003
$\Pi^{(3,3,1)}$	0.00670746	$\Pi^{(1,3,1)}$	0.00132873	$\Pi^{(2,3,1)}$	0.007325147	$\Pi^{(0,3,1)}$	0.00023396
$\Pi^{(3,2,1)}$	0.00022881	$\Pi^{(1,2,1)}$	0.000103913	$\Pi^{(2,2,1)}$	0.000623007	$\Pi^{(0,2,1)}$	0.000018785
$\Pi^{(3,1,1)}$	0.000027061	$\Pi^{(1,1,1)}$	0.000000807	$\Pi^{(2,1,1)}$	0.0000047937	$\Pi^{(0,1,1)}$	0.000000139
$\Pi^{(3,0,1)}$	0.000000023	$\Pi^{(1,0,1)}$	0.0000000068	$\Pi^{(2,0,1)}$	0.00000004127	$\Pi^{(0,0,1)}$	0.000000001
$\Pi^{(3,3,2)}$	0.00064431	$\Pi^{(1,3,2)}$	0.000115936	$\Pi^{(2,3,2)}$	0.0006596806	$\Pi^{(0,3,2)}$	0.000018845
$\Pi^{(3,2,2)}$	0.000000416	$\Pi^{(1,2,2)}$	0.0000017642	$\Pi^{(2,2,2)}$	0.0000107298	$\Pi^{(0,2,2)}$	0.000000376
$\Pi^{(3,1,2)}$	0.000000363	$\Pi^{(1,1,2)}$	0.0000001429	$\Pi^{(2,1,2)}$	0.0000008750	$\Pi^{(0,1,2)}$	0.000000025
$\Pi^{(3,0,2)}$	0.000000002	$\Pi^{(1,0,2)}$	0.0000000011	$\Pi^{(2,0,2)}$	0.00000000708	$\Pi^{(0,0,2)}$	0.000000000

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Bank Management under Data Mining Environment towards Fraud Detection

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Abstract

Banking system is very essential in our daily life and it is very important to manage all the transactions in bank with secure and easy process. In the information superhighway we can incorporate the support of technology to make efficient and secure transactions with increasing data rate. Bank fraud detection is very essential part of the daily tractions to assure better transactions. This work emphasis on the improvement of the start-of -the -art in commercial practice through machine learning data mining. Proper technology to assess huge amounts of transaction data to count efficient fraud detectors in an exact time is a fundamental problem. We analyze the date set by K-Medoids Algorithm (KMA) and trained the system using Artificial Neural Network (ANN). Besides the KMA, we also imposed Fuzzy K-Means and Fuzzy K-modes algorithms. After proper training to the ANN, we noticed that K-Medoids Algorithms is better only for the linear and Quantitative data set. On the contrary, Fuzzy K-Means is better when there are lots of mixed data sets, I mean both for Qualitative and Quantitative. We suggest both of the algorithms for separate environments and policies.

Keywords*:* Bank fraud detection, machine learning data mining, Artificial Neural Network (ANN), K-Medoids Algorithm (KMA), Fuzzy K-Means and Fuzzy K-modes algorithms.

1. Introduction

The banking industry of Bangladesh has been growing fast during the last decade. Banks are the engines that drive the operations in the financial sector, which is vital for the economy and social change. After Independence, the banks have passed through three stages. They have moved from the character based lending to ideology based lending to today competitiveness based lending in the context of Bangladesh's economic liberalization policies and the process of linking with the global economy. Today, the banking system has entered into competitive markets in areas covering resource mobilization, human resource development, customer services and credit management as well. While the operations of the bank have become increasingly significant banking frauds in banks are also increasing and fraudsters are becoming more and more sophisticated and ingenious. In a bid to keep pace with the changing times, the banking sector has diversified its business manifold. And the old philosophy of class banking has been replaced by mass banking. The challenge in management of social responsibility with economic viability has increased. Bank frauds are the failure of the banker. It does not mean that the external frauds do not defraud banks. But if the banker incorporate the support of technology to make efficient and secure transactions through machine learning data mining it would be possible to reduced bank frauds.

2. The Banking Industry of Bangladesh

Pursuant to Bangladesh Bank Order, 1972 the Government of Bangladesh reorganized the Dhaka branch of the State Bank of Pakistan as the central bank of the country, and named it Bangladesh Bank with retrospective effect from 16 December 1971.Bangladesh Bank has been entrusted with all of the traditional central banking functions including the sole responsibilities of issuing currency, keeping the reserves, formulating and managing the monetary and credit policy, regulating the banking system, stabilizing domestic and external monetary value, preserving the par value of Bangladesh Taka, fostering economic growth and development and the development of the country's market. After the independence, banking industry in Bangladesh started its journey with 6 nationalized commercialized banks, 2 State owned specialized banks and 3 Foreign Banks. In the 1980s banking industry achieved significant expansion with the entrance of private banks. The reform process was first initiated in 1982 when two of the six nationalized commercial banks were denationalized and a number of licenses were awarded for private sector commercial banks. Now, banks in Bangladesh are primarily of two types: Scheduled Banks: The banks which get license to operate under Bank Company Act, 1991 (Amended in 2003) are termed as Scheduled Banks. Non-Scheduled Banks: The banks which are established for special and definite objective and operate under the acts that are enacted for meeting up those objectives, are termed as Non-Scheduled Banks. These banks cannot perform all functions of scheduled banks. As of 15 December 2012, at present banking sector of Bangladesh comprises four categories of 57 scheduled banks. Among them four are the state owned commercial banks (SCBs), 6 are the state owned development banks (SDBs), thirty seven are the private commercial banks(PCBs) and ten are the foreign owned commercial banks(FCBs) (Bangladesh Bank website).

3. Bank Fraud

The uses of online transaction are growing day by day. From the study of ACNielsen study conducted in 2013, 67% of the world's population is shopping online [1]. Germany and Great Britain are two pivotal countries those are clearly ahead of online shopping, and credit card is the most popular mode of payment (59 percent). Approximately 650 million transactions per year were reportedly carried out by Barclaycard, the famous credit card company in the United Kingdom [2]. Retailers like Wal-Mart, Bata, and E-bay online system are typically handle much larger number of credit card transactions including online and regular purchases. The excessive data sets of credit card user throughout the world are rising and the opportunities for attackers to steal credit card details and, subsequently, commit fraud are also increasing. In a report from the USA the total credit card fraud is reported to be $5.7 billion in 2012 and estimated to be $7.0 billion in 2012, out of which $2.6 billion and $2.7 billion, respectively, are the estimates of online fraud [3]. Credit-card-based purchases can be categorized into two types: 1) physical card and 2) virtual card. In a physical-card based purchase, direct transactions are occurred at the various outlet or retailers or shopping mall. The persons who are responsible for the fraudulence activities try to steal the pin code or steal cards at various market places. If credit card users do not have much knowledge on online transactions and they are reluctant of the security of the card information, it can lead to a substantial financial loss to the credit card company. In virtual purchase, only digits are inputs to the system and submit to the desired places (card number, expiration date, and secure code) is required to make the payment. Such purchases are normally done on the Internet or over the telephone. To commit virtual transactions fraud, only serial number is enough to make the crime. The only way to identify this kind of crime is to analyze the spending amounts on every card and to compare any inconsistency with respect to the "usual" spending amounts. Fraud detection based on the analysis of existing purchase data of cardholder is a promising way to reduce the rate of successful credit card frauds.

4. Literature Review

Credit card fraud detection has drawn a lot of research interest and a number of techniques, with special emphasis on data mining and neural networks, have been suggested. Ghosh and Reilly [4] have proposed credit card fraud detection with a neural network. They have built a detection system, which is trained on a large sample of labeled credit card account transactions. These transactions contain example fraud cases due to lost cards, stolen cards, application fraud, counterfeit fraud, mail-order fraud, and non received issue (NRI) fraud. Recently, Syeda et al. [5] have used parallel granular neural networks (PGNNs) for improving the speed of data mining and knowledge discovery process in credit card fraud detection. A complete system has been implemented for this purpose. Stolfo et al. [6] suggest a credit card fraud detection system (FDS) using Metalearning techniques to learn models of fraudulent credit card transactions. Metalearning is a general strategy that provides a means for combining and integrating a number of separately built classifiers or models. A Metaclassifier is thus trained on the correlation of the predictions of the base classifiers. The same group has also worked on a cost-based model for fraud and intrusion detection [7]. They use Java agents for Metalearning (JAM), which is a distributed data mining system for credit card fraud detection. A number of important performance metrics like True Positive—False Positive (TP-FP) spread and accuracy have been defined by them. Aleskerov et al. [8] present CARDWATCH, a database mining system used for credit card fraud detection. The system, based on a neural learning module, provides an interface to a variety of commercial databases. Kim and Kim have identified skewed distribution of data and mix of legitimate and fraudulent transactions as the two main reasons for the complexity of credit card fraud detection [9]. Based on this observation, they use fraud density of real transaction data as a confidence value and generate the weighted fraud score to reduce the number of misdetections. Fan et al. [10] suggest the application of distributed data mining in credit card fraud detection. Brause et al. [11] have developed an approach that involves advanced data mining techniques and neural network algorithms to obtain high fraud coverage. Chiu and Tsai [12] have proposed Web services and data mining techniques to establish a collaborative scheme for fraud detection in the banking industry. With this scheme, participating banks share knowledge about the fraud patterns in a heterogeneous and distributed environment. To establish a smooth channel of data exchange, Web services techniques such as XML, SOAP, and WSDL are used. Phua et al. [13] have done an extensive survey of existing data-mining-based FDSs and published a comprehensive report. Prodromidis and Stolfo [14] use an agent-based approach with distributed learning for detecting frauds in credit card transactions. It is based on artificial intelligence and combines inductive learning algorithms and Metalearning methods for achieving higher accuracy. Phua et al. [15] suggest the use of Metaclassifier similar to [6] in fraud detection problem .They consider naïve Bayesian, C4.5, and Back Propagation neural networks as the base classifiers. A Metaclassifier is used to determine which classifier should be considered based on skewness of data. Although they do not directly use credit card fraud detection as the target application, their approach is quite generic. Vatsa et al. [16] have recently proposed a game-theoretic approach to credit card fraud detection. They model the interaction between an attacker and an FDS as a multi stage game between two players, each trying to maximize his payoff. The problem with most of the abovementioned approaches is that they require labeled data for both genuine, as well as fraudulent transactions, to train the classifiers. Getting real-world fraud data is one of the biggest problems associated with credit card fraud detection.

5. The K-Medoids Clustering Method

i. Determine ***k*** data set arbitrarily
ii. For each pair of non-identified data set ***h*** and determined data set ***i***, calculate the total swapping cost TC_{ih}
iii. For each pair of ***i*** and ***h***,
    1. If $TC_{ih} < 0$, ***i*** is changed by ***h***
    2. Then assign each non-determined data set to the most similar data set.
iv. repeat steps 2-3 until there is no change

Total swapping cost

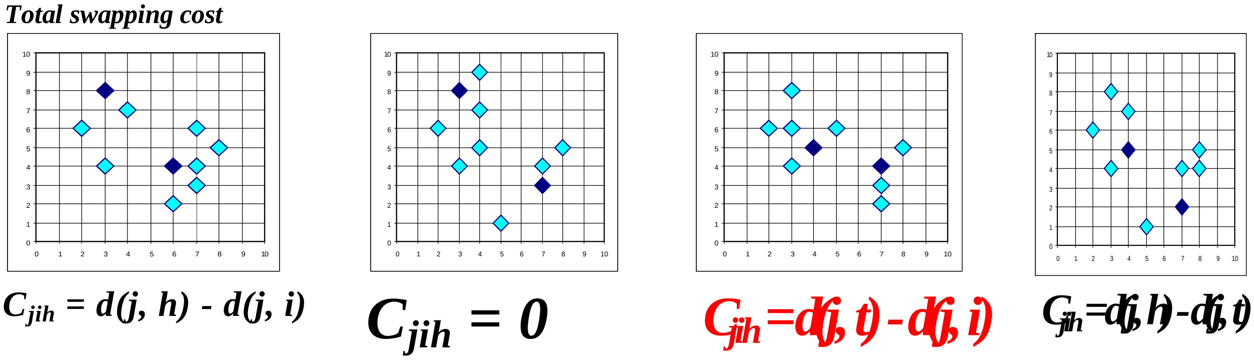

Figure 1: The K-medoids clustering for various customer segmented mentioned at table 1.

6. The *K-Means* Clustering

Given *m*, the *m-Means* algorithm is implemented in 4 steps:

i. Partition objects into *m* nonempty subsets
ii. Calculate pivotal points as the centroids of the clusters of the new orientation. The
iii. Partitioned each object to the cluster with the nearest pivotal point.
iv. Go back to Step 2, stop when no more new assignment.

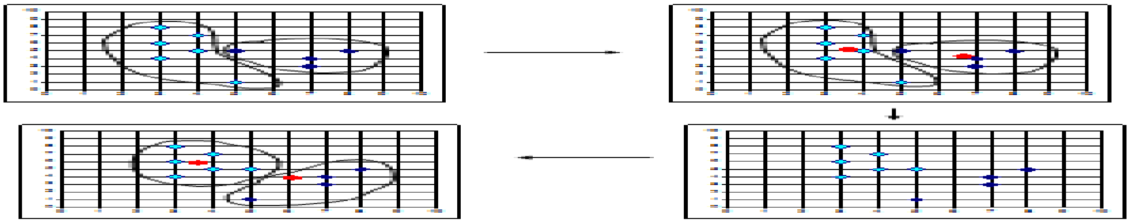

Figure 2: K-Means Clustering Algorithm.

7. Principal Component Analysis

From k original variables: $x_1,x_2,...,x_k$:

Produce k new variables: $y_1,y_2,...,y_k$:

$y_1 = a_{11}x_1 + a_{12}x_2 + ... + a_{1k}x_k$

$y_2 = a_{21}x_1 + a_{22}x_2 + ... + a_{2k}x_k$

...

$y_k = a_{k1}x_1 + a_{k2}x_2 + ... + a_{kk}x_k$ From k original variables: $x_1,x_2,...,x_k$:

8. Methodology

Here we have segmented the three categories of the customers based on their attitudes, gestures, patients, movements, demands, body languages, communication skills and literacy. According to the algorithms of K-Means and K-Medoids Clustering, we have noticed that K-Medoids perform very well and finally the Principle Component Analysis (PCA) correlates all the classifications results. We define a threshold value of standard behavior after talking with Branch managers of five banks including two governmental Banks. Based on their opinion we then check this parameter with the K-Medoids Algorithm threshold value. Then we finalized the value is θ=0.24. The flow chart of the process is given below.

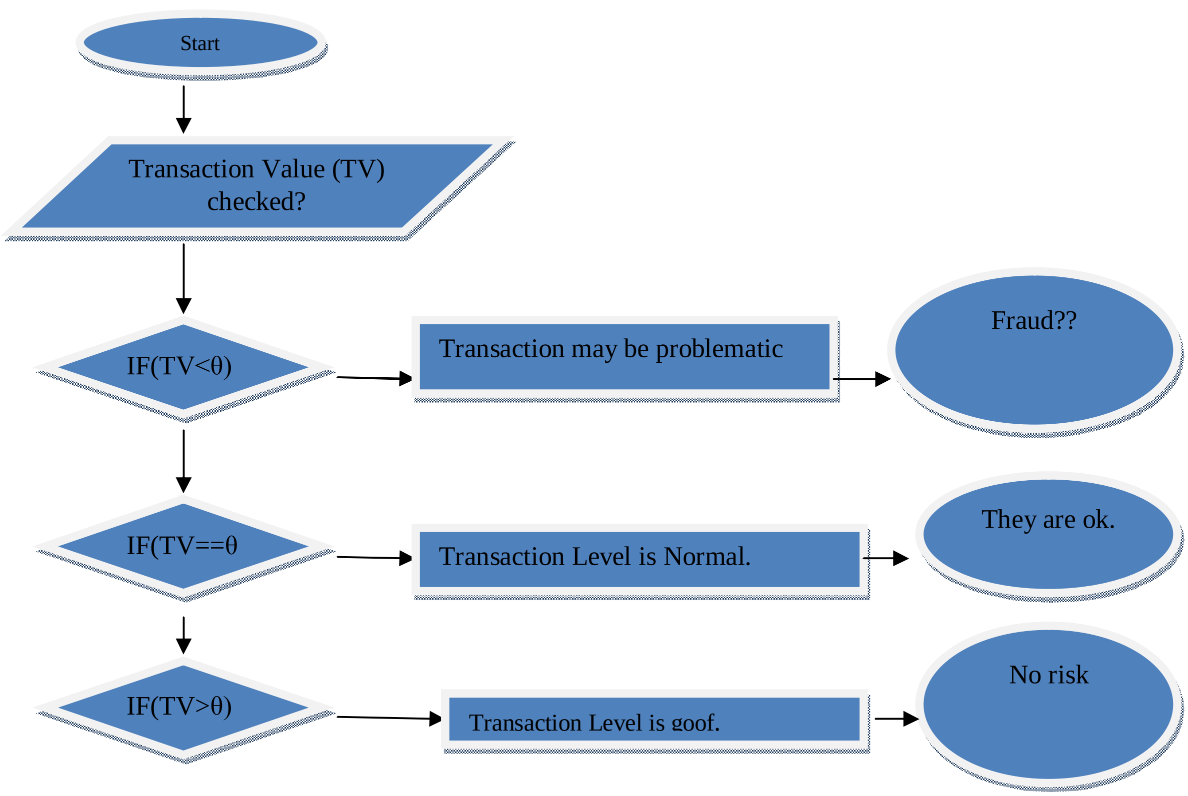

Figure 3: Flowchart for behavior clustering.

9. Result

Bank Name	Customer Name	Loan ID	Loan Account	Location	Fraudness
Brack Bank	Tapos Bormon	4001	124782	Patiya	Normal
Brack Bank	Afjal Hossain	4012	783141	Do	Normal
Brack Bank	Abdul Aziz	4902	321574	Do	Normal
Brack Bank	Hira Das	4092	492345	Do	Normal
Brack Bank	Morjina Begum	4982	438921	Do	Normal
Dhaka Bank	Earsad Ullah	8723	234120	Do	Normal
Dhaka Bank	Emam Uddin	8701	234045	Do	Normal
Dhaka Bank	Abul Khair	8728	230912	Do	Normal
Dhaka Bank	Towhidul Islam	8723	234570	Do	Normal
Dhaka Bank	Karim Uddin	8703	249072	Do	Normal
UCBL Bank	Jahedul Islam	5423	764848	Do	Normal
UCBL Bank	**Nishita Shaha**	**3452**	**658392**	**Do**	**Problematic**
UCBL Bank	MNormaltar Hossain	4563	652310	Do	Normal
UCBL Bank	Abutahar Mia	4567	680213	Do	Normal
UCBL Bank	Khursad Fazil	7832	602343	Do	Normal
Janata Bank	Asis Mia	0923	984536	Do	Normal
Janata Bank	Farhan Ali	0876	908765	Do	Normal
Sonali Bank	Tipu Sultan	3424	214567	Do	Normal
Sonali Bank	Korim Monshi	3214	213468	Do	Normal
Agrani Bank	Absar Mia	0123	987566	Do	Normal
Agrani Bank	Josim Uddin	0342	982342	Do	Normal

10. Conclusion

In this work we have found that the unexpected transactions may causes to identify the fraud on credit card transactions. Besides, clustering algorithm used here as K-Medoids algorithm with K-means clustering. But K-medoids performed better classification. After better clustering, the PCA helps us to predict according to the data set. From various bank we have checked more than ten thousand transactions. We have checked all the regular uses of the data set. We only get Nisitha Shaha as the victims who lost her Credit card and consequently get deprived the theft made the illegal transactions. These identification methods will helps to make an automated system for banking system. We have faced problems on extreme data set. To accomplish the total task we need huge data set that have some idea related on fraud transactions.

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Inventory System with Postponed Demands and Service Facilities-MAM Approach

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Abstract

In this paper, we consider an (s, S) inventory system with random service time Primary demands occur according to Poisson process with parameter λ. In this system, there is a finite buffer whose capacity varies according to the inventory level at any given time. When the maximum buffer size is reached, further demands join a pool of infinite capacity with probability Υ and with probability $(1-\Upsilon)$ it is lost forever. When inventory level is larger than the number of customers in the buffer, an external demand can enter the buffer for service. A pooled customer is transferred to the buffer for service at a service completion epoch with probability p if the inventory exceeds $s+1$ and provided the number of customer in the buffer is less than the nimber of items held in the inventory. It is assumed that initially the inventory level is S. When inventory level reaches s an order for replenishment is placed. The lead time is exponentially distributed with parameter β. We obtain the steady state system size distribution. Some performance measures are obtained and a few numerical illustrations provided.

***Key words**: Postponed demand, Finite buffer, Replenishment, Service facilities.*

1. Introduction

In most of the inventory models it is assumed that the inventory deplete at a rate equal to demand rate. However, it becomes unrealistic for the service facilities where the stocked item is delivered to the customers after some service is performed. In this paper we consider an (s, S) inventory system with service facilities. Arrival of demands form a Poisson process with parameter $\lambda(> 0)$ to a buffer of finite capacity equal o the inventory level at any given time t. When the maximum buffer size is reached, further demands join a pool of infinite capacity, with probability γ or with probability $(1-\gamma)$ it is lost forever, Pooled customers are taken for service at a service completion epoch if the inventory level is at least $s+1$. The service time is assumed to be exponentially distributed with parameter μ. It is also assumed that initially the inventory level is S. When inventory level reaches s due to service, an order for replenishment is placed. The lead time is exponentially distributed with parameter β.

The literature available on inventory system with service facilities is too limited. Berman, Kim and Shimshak [2] consider an inventory system with service in which they assume that both the demand and the service rate are deterministic and constant and as such queues can form only during stock out period. They determine optimal order quantity the minimize the total cost per unit time. Later Berman an Kim [3, 4] analyze the non-deterministic inventory model for service facilities. They analyze the system in which customers arrive at a service facility according to Paisson process where service times are exponentially distributed and each customer demands exactly one unit of the item in the inventory both zero and positive lead time cases are discussed. Krishnamoorthy et al [9] analyze a retrial production inventory system with service time in which primary demands occur according to Markovian Arrival Process (MAP). Using matrix analytic method they carry out the steady state analysis of the system and some performance measures and obtained. Berman and Sapna [5, 6] investigate inventory control at a service facility, which uses one item if inventory for service provided. Assuming Poisson arrival process, arbitrarily distributed service times and zero lead times they analyze the system with the restriction that, waiting space is finite. Under a specific cost structure they derive the optimum ordering quantity that minimizes the long run expected cost rate. Arivarignan, Elango and Arumugam [1] consider a perishable inventory system with service facility where arrival times of customers form a Poisson process. Each customer requires a single item which is delivered through a service of random duration having exponential distribution. Krishnamoorthy and Mohammad Islam [7, 8] analyze an inventory system with postponed demands both, for perishable and non-perishable inventoried items. With demands forming a Poisson process they analyze the model under the additional assumptions, when inventory level reaches zero due to demands, further demands are sent to a pool of capacity $M\ (<\ \infty)$. Demand to the pooled customers are satisfied only after replenishment against the order placed on reaching the level s. Further they are served only if the inventory level is at least $s\ +\ 1$. They study the system both in transient and steady state cases. Mohammad Ekramol Islam(2012) further improved the model in this direction and considered (s,S) Inventory system with postponed demands at a service facility

1.1. The Notations

The notations used in the sequel are explained below:

$I(l)$=Inventory level at time l; this takes value $\{0, 1, \dots, S\}$

$B(t)$=Number of customers in the buffer at time t

$N(t)$=Number of customers in the pool at time t

A'-Transpose of a matrix A

e-Denote the column vector of I's

2. The Steady State Analysis of the Model

$\{(N(t), I(l), B(l)), t\geq 0\}$ is a continuous time Markov chain with state space given by

$$\Omega\ =\ \{i, j, k);\ i\geq 0, 0\ \leq j\ \leq S, 0\leq k\leq j\}$$

These states are arranged in the lexicographic order. Define the following auxiliary matrices for use in sequel.

(1) $$B_0 = \begin{bmatrix} A_{00} & & \tilde{A}_{10,Q} & & & \\ \tilde{A}_{10} & \tilde{A}_{11} & & \tilde{A}_{10,Q+1} & & \\ & \ddots & & \ddots & & \\ & & & & \tilde{A}_{S-1,S-1} & \\ & & & & \tilde{A}_{S,S-1} & \tilde{A}_{S,S} \end{bmatrix}$$

Where

(2) $A_{00} = -\lambda\gamma - \beta$

(3) $$\tilde{A}_{11} = \begin{bmatrix} -\lambda-\beta & \lambda \\ 0 & -\lambda\gamma-\beta-\mu \end{bmatrix}$$

(4) $$\tilde{A}_{ii} = \begin{bmatrix} -\lambda-\beta\beta & & \\ & -\lambda-\beta-\mu & \lambda \\ & \ddots & \ddots \\ & & -\lambda\gamma-\beta-\mu \end{bmatrix} for\ 2 \leq i \leq s$$

(5) $$\tilde{A}_{ii} = \begin{bmatrix} -\lambda & \lambda & & \\ & -\lambda-\mu & \lambda & \\ & \ddots & \ddots & \ddots \\ & & & -\lambda\gamma-\mu \end{bmatrix} for +1 \leq i \leq s$$

(6) $$\tilde{A}_{1,0} = \begin{bmatrix} 0 \\ \mu \end{bmatrix}$$

(7) $$\tilde{A}_{i,i-1} = \begin{bmatrix} 0 \\ I_i \end{bmatrix} for\ 2 \leq i \leq s$$

(8) $\tilde{A}_{0,Q} = [\beta, 0, \dots, 0]$

(9) $\tilde{A}_{i,i+Q} = [I_{i+1}, 0, 0, \dots, 0]\beta\, for\ 1 \leq i \leq s$

(10) $$A_1 = \begin{bmatrix} A_{00} & & \tilde{A}_{0,Q} & & & \\ \tilde{A}_{10} & \tilde{A}_{11} & & \tilde{A}_{1,Q+1} & & \\ & \ddots & & \ddots & & \\ & & & & \tilde{A}_{S-1,S-1} & \\ & & & & \tilde{A}_{S,S-1} & \tilde{A}_{S,S} \end{bmatrix}$$

Where

(11) $\tilde{A}_{i,i-1} = \begin{bmatrix} 0 \\ I_i \end{bmatrix} for\ 2 \le i \le s$

(12) $\tilde{A}_{i,i-1} = \begin{bmatrix} 0 \\ I_i \end{bmatrix} \left(\mu(1-p)\right) for\ s+1 \le i \le S$

(13) $$\tilde{A}_2 = \begin{bmatrix} C_{00} & & & & \\ \tilde{C}_{10} & \tilde{C}_{11} & & & \\ & \tilde{C}_{21} & \tilde{C}_{22} & & \\ & & \ddots & \ddots & \\ & & & \tilde{C}_{ss-1} & \tilde{C}_{ss} \end{bmatrix}$$

Where

(14) $C_{00} = 0$

(15) $\tilde{C}_{ii}$ are matrices of all elements with zeros for $s+1 \le i \le S$

(16) $\tilde{C}_{ii-1}$ are matrices of all elements with zeros for $1 \le i \le S$

(17) $$\tilde{A}_{ii-1} = \begin{bmatrix} 0 & & & & \\ & p\mu & & & \\ & & p\mu & & \\ & & & \ddots & \\ & & & & p\mu \\ & & & & 0 \end{bmatrix} for\ s+1 \le i \le S$$

where $\tilde{C}_{ii-1}$ is a $(i+1) \times 1$ matrix

(18) $$A_0 = \begin{bmatrix} B_{00} & & & \\ & \tilde{B}_{11} & & \\ & & \ddots & \\ & & & \tilde{B}_{SS} \end{bmatrix}$$

(19) $B00 = \lambda\gamma$

(20) $\tilde{B}_{ii} = (a_{i+1},\ a'_{i+1})\lambda\gamma\ \ 1 \le \mathrm{i} \le \mathrm{S}$

Where $ai+1$ is a column vector of zeros except last entry which is 1

$\tilde{B}_{ii}$ is the $(i+1) \times (i+1)$ matrix.

The Markov chain $\{(N(t), I(t), B(t)), t \ge 0\}$ has the generator Q in partitioned from given by

$$Q = \begin{bmatrix} B_0 & A_0 & 0 & 0 & 0 & \cdots \\ A_2 & A_1 & A_0 & 0 & 0 & \cdots \\ 0 & A_2 & A_1 & A_0 & 0 & \cdots \\ 0 & 0 & A_2 & A_1 & A_0 & \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \end{bmatrix}$$

where, the sentries in Q are given by (1) to (20).

Let $A = A_0 + A_1 + A_2$ and π denote the steady-state probability vector of A, i,e,

$$\pi A = 0, \pi e = 1$$

The vector π can be partitioned as

$$\pi(i) = (\pi(i,0), (i,1), \dots\dots, \pi(i,i));\ i = 0, 1, \dots\dots . S$$

Then the π's can be calculate as

$$\pi(s-i) = \pi(s)\beta_{s-i}$$

$$\pi(S - i) = \pi(s)\beta_{s-i}$$

Where

$$\beta_{(s-i)} = \begin{cases} -\beta_{s-i+1}\left(\tilde{A}_{s-i+1,s-i} + \tilde{C}_{s-i+1,s-i}\right)\left(\tilde{A}_{s-i,s-i} + \tilde{B}_{s-i,s-i} + \tilde{C}_{s-i,s-i}\right) & if\ i = 1, 2, \dots, s \\ I & if\ i = 0 \end{cases}$$

$$\beta_{(S-i)} = \begin{cases} \left[-\beta_{S-1+1}\tilde{A}_{S-i+1,S-i} - \beta_{s-i}\tilde{A}_{s-i,S-i}\right]\left(\tilde{A}_{S-i,S-i} + \tilde{B}_{s-i,S-i} + \tilde{C}_{S-i,S-i}\right)^{-1} & if\ i = 1, 2, \dots, s \\ -\tilde{A}_{sS}\left(\tilde{A}_{S,S} + \tilde{B}_{S,S} + \tilde{C}_{S,S}\right)^{-1} & if\ i = 0 \end{cases}$$

$$\pi(i) = \beta_{i+1}\left(A_{i+1,i} + C_{i+1,i}\right)\left(A_{i,i} + B_{i,i} + C_{i,i}\right)^{-1} if\ I = Q - 1, Q - 2, \dots, s + 1$$

We have the following result on system stability

Lemma 2.1.

$$\sum_{i=s+2}^{S}\sum_{j=1}^{i-1}\pi(i,j) > \left(\frac{\lambda\gamma}{p\mu}\right)\sum_{i=0}^{s}\pi(i,i)$$

Proof. From the well-known result [Neuts (1981) theorem 1.7.1] on the positive recurrence of Q, which states that-

$$\pi A_0 e < \pi A_2 e$$

and by exploiting the structure of the matrices A_0 and A_2, the stated result follows.

Theorem 2.2. When the stability condition holds the steady state probability vector x of Q which satisfies $xQ = 0, x\,e = 1$ exists.

The steady state probability vector

$$x = (x(0), x\,(1), x(2), \dots)$$

where components are given by

$$x(i) = x(0)\ Ri, i \geq 0$$

Where R is the minimal non-negative solution of the matrix quadratic equation:-

$$R^2A_2 + RA_1 + A_0 = 0$$

The vector x(0) can be calculated using the equation

$$x(0)[B_0 + RA_2] = 0$$

together with the normalizing condition

$$x(0)(1 - R)^{-1}e = 1$$

Proof. Follows immediately from the well-known result on matrix-geometric methods (see Neuts (1981).

For calculating the rate matrix R one can use Logarithmic Reduction Algorithm

3. System Performance Measures

Steady state probability vector $x = (x(0), x\,(1), x(2), \dots)$ can be partitioned as

$$x\,(i) = (y(i,j,k));\ i \geq 0, 0 \leq j \leq S, 0 \leq k \leq j$$

Some of the system performance measures are given below:

(1) The probability mass function of number of customer in the pool: The probability that there are I customers in the pool is given by

$$P_i = x(i)e = x(0)R^i e; i \geq 0$$

(2) Expected Inventory level in the system: Expected inventory level in the system is given by-

$$\alpha_1 = \sum_{i=0}^{\infty}\left[\left\{\sum_{j=1}^{S} j \sum_{k=0}^{j} y(i,j,k)\right\}\right] e$$

(3) Expected number of customers in the buffer is,

$$\alpha_2 = \sum_{i=0}^{\infty}\left[\sum_{j=1}^{S} j \sum_{k=1}^{j} k y(i,j,k)\right] e$$

(4) Expected number of customers in the pool,

$$\alpha_3 = \sum_{i=0}^{\infty} i x(i) e = x(0)R(I-R)^{-2}\, e$$

(5) Average customers lost to the system is,

$$\alpha_4 = \lambda(1-\gamma)\sum_{i=0}^{\infty}\left[\sum_{j=k=0}^{S} y(i,j,k)\right] e$$

(6) Expected rate that a customer will enter the pool is,

$$\alpha_5 = \lambda\gamma\sum_{i=0}^{\infty}\left[\sum_{j=k=0}^{S} y(i,j,k)\right] e$$

(7) The average rate at which the pooling customers will enter the buffer is given by

$$\alpha_6 = p\mu\sum_{i=0}^{\infty}\left[\sum_{j=s+1}^{S} \sum_{k=1}^{j} y(i,j,k)\right] e$$

4. Cost Function

Define

$C_1 =$ Inventory holding cost of the system, $C_2 =$ Cost for buffer customers in the system

$C_3 =$ Cost for pool customers in the system, $C_4 =$ Cost of customers lost to the system, So the total expected cost of the system is

$$E(TC(S,s,P)) = C_1\alpha_1 + C_2\alpha_2 + C_3\alpha_3 + C_4\alpha_4$$

$$E(TC(S,s,P)) = C_1 \textstyle\sum_{i=0}^{\infty}\left[\left\{\sum_{j=1}^{S} j \sum_{k=0}^{j} y(i,j,k)\right\}\right] e + C_2 \sum_{i=0}^{\infty}\left[\sum_{j=1}^{S} j \sum_{k=1}^{j} k y(i,j,k)\right] e$$

$$+ C_3 \textstyle\sum_{i=0}^{\infty} i x(i) e + \quad + C_3 \sum_{i=0}^{\infty} i x(i) e$$

By using the above cost function, we can exploit a lot of interesting feasure and can make a sensitivity analysis.

4. Numerical Illustration

We provide a simple numerical illustration based on our performance measure by fixing Fixed $S = 5, s = 2, Q = 3, \lambda = 0.5, \mu = 0.7, \beta = 0.6, p = 0.6, \gamma = 0.6, C_1 = 1, C_2 = 2, C_3 = 1,. C_4 = 2.$ In table 1-5, we provide measures of the system performance by fixing the parameter's values involved in the system, we vary over the parameters λ, μ, β, p and γ. For different values of these parameters corresponding values of the system measures are provided.

Table: 1. Arrival rate Vs Different performance measures

	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$	$\lambda = 0.5$	$\lambda = 0.6$
α_1	3.54122	3.44974	3.27038	3.1189	3.00847
α_2	0.362165	0.593453	0.85437	1.14709	1.47747
α_3	0.0427584	0.176074	0.551752	1.71793	9.46571
α_4	0.00222627	0.00937859	0.0246719	0.050412	0.0882317
α_5	0.3394	0.0140679	0.0370079	0.075618	0.132348
α_6	0.103909	0.143281	0.175928	0.203971	0.229517

Table: 2. Service rate Vs Different performance measures

	$\mu = 0.6$	$\mu = 0.7$	$\mu = 0.8$	$\mu = 0.9$	$\mu = 1.0$
α_1	3.15381	3.1189	3.10037	3.09042	3.0852
α_2	1.44111	1.14709	0.945552	0.800566	0.692144
α_3	3.87896	1.71793	1.07129	0.778464	0.617492
α_4	0.0634823	0.050412	0.0419241	0.0361165	0.0319699
α_5	0.0952251	0.075618	0.0628862	0.0541748	0.0479548
α_6	0.125296	0.146179	0.167062	0.207452	0.208827

Table: 3. Replenishment rate Vs Different performance measures

	$\beta = 0.4$	$\beta = 0.5$	$\beta = 0.6$	$\beta = 0.7$	$\beta = 0.8$
α_1	2.7194	2.9549	3.1189	3.24018	3.33281
α_2	1.10445	1.12528	1.14709	1.16721	1.18511
α_3	6.50534	2.68521	1.17793	1.29464	1.06335
α_4	0.0695216	0.0576941	0.050412	0.0456062	0.042261
α_5	0.104282	0.0865412	0.075618	0.0684092	0.0633917
α_6	0.178756	0.193112	0.203971	0.212473	0.219313

Table: 4. Probability of transferring the pool customer to buffer Vs Different performance measures

	$p = 0.4$	$p = 0.5$	$p = 0.6$	$p = 0.7$	$p = 0.8$
α_1	3.1357800	3.12578	3.11890	3.11374	3.06936
α_2	1.1719900	1.15660	1.14709	1.14089	1.00008
α_3	4.2286200	2.41191	1.17793	1.35453	0.68010
α_4	0.0505280	0.05041	0.05041	0.05048	0.04668
α_5	0.0757921	0.07562	0.07562	0.07571	0.04669
α_6	0.1381150	0.171072	0.20397	0.23680	0.25003

Table: 5. Joining probability to pool Vs Different performance measures

	$\gamma = 0.4$	$\gamma = 0.5$	$\gamma = 0.6$	$\gamma = 0.7$	$\gamma = 0.8$
α_1	3.14825	3.13416	3.1189	3.10209	3.08329
α_2	1.05942	1.10032	1.14709	1.20083	1.26299
α_3	0.65343	1.05776	1.17793	2.90313	5.41881
α_4	0.06727	0.059313	0.050412	0.04035	0.02885
α_5	0.04484	0.059312	0.075618	0.094147	0.11539
α_6	0.196428	0.199945	0.203971	0.208600	0.213959

5.Sensitivity Analysis

Table: 6 . Arrival rate Vs Different performance measures

Arrival Rate	Total Cost	Service rate	Total cost	Replenishment	Total cost
0.2	4.3127609	0.6	9.92768646	0.4	11.5726832
0.3	4.83147718	0.7	7.30193400	0.5	8.0052482
0.4	5.5802158	0.8	6.1466122	0.6	6.9618340
0.5	7.231834	0.9	5.5422490	0.7	6.9604524
0.6	9.856552	1.0	5.1509190	0.8	6.8586410

Form the table 6, It is observed that the arrival rate is has a vital impact to the system. The result is obvious as the rate is increased it has impact on higher reordering, lost sales and also increased the cost of carrying pool and Buffer customers. The service rate increase indicates cost decrease as because of less cost of customers lost and less waiting time to pool and buffer customers. Finally we can see that replenishment rate increase results cost decrease.This is obvious as more replenish will support more service, less the cost of lost sales as well as less cost for pool and buffer.

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Cell Formation in a Batch Oriented Production System Using a Local Search Heuristic with a Genetic Algorithm: An Application of Cellular Manufacturing System

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Abstract

Cellular manufacturing is a production strategy which is capable of solving certain problems in a batch manufacturing system. A batch manufacturing system produces some intermediate varieties of products with intermediate volumes. Production equipment in batch manufacturing must be capable of performing a variety of tasks. One of the fundamental problems in cellular manufacturing system is the formation of part families and machine cells that is the cell formation. For cell formation the part families are identified that require similar processing on a set of machines. In turn, these machines are grouped into cells. Each cell is capable of satisfying all the requirements of the part family assigned to it. In this paper an approach is used to form the part families and machine cell in a batch oriented production system. This approach combines a local search heuristic with a genetic algorithm. The genetic algorithm is used to generate the sets of machine cells. The local search heuristic is applied to the sets of machines cells generated by the genetic algorithm. The objective of the heuristic is to construct a set of machine/part groups and improve it, if possible. The result obtained by this approach is compared with the existing initial machine part matrix. Grouping efficacy of the existing initial machine part matrix is 24.56%. After this approach, the grouping efficacy of the final machine part matrix is 54.25%. The result with a grouping efficacy is higher than the existing initial machine part matrix. The grouping efficacy has improved by 29.69%. So this approach can useful in cell formation in any batch oriented production system.

Keywords: *Cell Formation, Batch Production System, Cellular Manufacturing System, Genetic Algorithm, Local Search Heuristic.*

1. Introduction

The group technology (GT) concept in manufacturing was first introduced by Flanders in 1925. In 1959, Mitrofonov published a book on scientific principles of GT and Burbidge in 1960 proposed a systematic planning approach for GT called production flow analysis. From then onwards there has been a lot of methods, models and algorithms developed for finding the solution for the primary problem of design of manufacturing cells. In the last three decades of research in cell formation, researchers have mainly used zero-one machine component incidence matrix as the input data for the problem.

1.2 Different Approach for Cell Formation Problem

1.2.1 Graphical Approach

Graphical method is first approach used by the researcher to solve the cell formation problem in GT. Rajagopalan & Batra (1975) used graph theory to solve the grouping problem. They developed a machine graph with as many vertices as the number of machines. Kumar et al. (1986) solved a graph decomposition problem to determine machine cells and part families for a fixed number of groups and with bounds on cell size. Their algorithm for grouping in flexible manufacturing systems is also applicable in the context of GT. Vannelli and Kumar (1986) developed graph theoretic models to determine machines to be duplicated so that a perfect block diagonal structure can be obtained. Later Kumar and Vannelli (1987) developed a similar procedure for determining parts to be subcontracted in order to obtain a perfect block diagonal structure.

1.2.2 Array-Based Clustering Techniques

Array-based clustering methods perform a series of column and row permutations to form product and machine cells simultaneously. Existing cluster analysis methods are reviewed and a new approach using a rank order clustering algorithm is described which is particularly relevant to the problem of machine-component group formation by King (1980).A comprehensive comparison of three array-based clustering techniques is given by Chu and Tsai (1990). The quality of the solution given by these methods depends on the initial configuration of the zero-one matrix. An efficient nonhierarchical clustering algorithm, based on initial seeds obtained from the assignment method, for finding part-families and machine cells for group technology (GT) is presented by Gupta & Seifoddini (1990) which aim was to minimize the inter-cell movements and blanks (machine idling). Another efficient nonhierarchical clustering algorithm, based on initial seeds obtained from the assignment method, for finding part-families and machine cells for group technology (GT) is presented by Srinivasan & Narendran (1991) which aim is to minimize the exceptional elements (inter-cell movements) and blanks (machine idling). Later a clustering approach of the non-hierarchical type was proposed by Nair & Narendran TT (1998) which clusters machines and components on the basis of sequence data. The algorithm gives encouraging results which provide better optimum solution than the previous approaches.

1.2.3 Mathematical Programming Methods

Mathematical programming methods treat the clustering problem as a mathematical programming optimization problem. At first Choobineh (1988) used a cluster algorithm to form the part families and an integer programming model. Then Gunasingh & Lashkari (1989) formulated an integer programming problem to group machines and products for cellular manufacturing systems. A mathematical model and solution procedure for the group technology configuration is proposed by Askin & Chiu (1990) for the grouping of individual machines into cells and the routing of components to machines within cells. A nonlinear mathematical programming model is developed by Adil, Rajamani, & Strong (1997) for cell formation that identifies part families and machine groups simultaneously which objective is the minimization of the weighted sum of the voids and the exceptional elements. Another mathematical programming model for the cell formation problem with multiple identical machines, which minimizes the intercellular flow, is presented by Xambre & Vilarinho (2003). After that, Tsai & Lee (2006) developed a multi-functional MP model that incorporates the merits of related CF models based on the systematic study of MP models. A comprehensive mathematical model for the design of CMS based on tooling requirements of the parts and tooling available on the machines was proposed by Defersha & Chen (2006). Mahdavi et al. (2007) formulated a new mathematical model for cell formation in cellular manufacturing system (CMS) based on cell utilization concept which objective is to minimize the exceptional elements (EE) and number of voids in cells to achieve the higher performance of cell utilization.

1.2.4 Genetic Algorithm Based Technique

Zulawinski, Punch & Goodman (1995) developed a grouping genetic algorithm for Bin balancing which is better suited for grouping problems than the classical representations. After their approach, genetic algorithms become more popular to the researchers for finding the optimum solution for the cell formation problem. Cheng et al. (1998) formulated the cell formation problem as a travelling salesman problem (TSP) and a solution methodology based on genetic algorithms (GAs) is proposed to solve the TSP-cell formation problem. Onwubolu and Mutingi (2001) developed a genetic algorithm (GA) meta-heuristic based cell formation procedure having the objective function of minimizing the intercellular movement and cell load variation. Zolfagharia and Liang (2003) proposed a new genetic algorithm (GA) for solving a general machine/part grouping (GMPG) problem where processing times, lot sizes and machine capacities are all explicitly considered. An approach has taken by Goncalves and Resende (2004) for solving the manufacturing cell formation problem in the term of group efficacy where they also used a local search heuristic genetic algorithm. Another genetic algorithm approach was done by Chiang & Lee (2004) for cell formation and inter-cell layout to minimize the actual inter-cell flow cost, instead of the typical measure that optimizes the number of inter-cell movements. Yasuda, Hu and Yin (2005) proposed an efficient method to solve the multi-objective cell formation problem (CFP) partially adopting Falkenauer's grouping genetic algorithm (GGA). James, Brown & Keeling (2007) presented a hybrid grouping genetic algorithm for the cell formation problem that combines a local search with a standard grouping genetic algorithm to form machine-part cells. Pillai et al. (2008) suggested a new approach for forming part families and machine cells, which can handle all the change in demands and product mix without any relocation. Tariq, Hussain and Ghafoor (2009) developed an approach that combines a local search heuristic (LSH) with genetic algorithm (GA). The results show that new approach not only converges to the best solution very quickly but also produces solutions that are as accurate as any results reported so far in literature.

1.2.5 Others Different Approaches

Waghodekar & Sahu (1984) presented a heuristic approach based on the similarity coefficient of the product type for the problem of machine-component cell formation in group technology. Then Seifoddini & Wolfe (1986) developed a Similarity Coefficient Method (SCM) method to form the machine cells in group technology applications which is more flexibility into the machine-component grouping process and more easily lends itself to the computer application. Askin and Subramaniam (1987) proposed a heuristic approach to the economic determination of machine groups and their corresponding component families for group technology. After that, Srinivasan, Narendran & Mahadevan (1990) presented an assignment model to solve the grouping problem where a similarity coefficient matrix is used as the input to the assignment problem. A non-heuristic network approach is developed by Vohra et al. (1990) to form manufacturing cells with minimum intercellular interactions. At first Kumar & Chandrasekharan (1990) proposed the concept of grouping efficacy which objective is to maximize the group efficiency by reducing the number of voids in the cell and inter-cell movements for the cell formation in group technology. Later Boctor (1991) suggested a new linear zero-one formulation to avoid the disadvantages of other alternative formulations to solve the cell formation problems which having better computational feasibility and efficiency. A network flow methodology was developed by Lee & Garcia-Diaz (1993) to measure the functional similarity between machines and then to group the machines into cells in such a way that all the parts in each family can be processed in a machine cell. Heragu & Kakuturi (1997) solved a real-world machine grouping and layout problem in which the objective is not only to identify machine cells and corresponding part families but also to determine a near-optimal layout of machines within each cell and the cells themselves. Sarker (2001) presented a critical review of existing grouping measures, introduces a new measure called ‘doubly weighted grouping efficiency measure. After that, Kim, Baek & Baek(2004) deal with the multi-objective machine cell formation problem to determine the part route families and machine cells. A new Branch-and-Bound (B&B) enhancement is then proposed by Boulif and Atif (2006) to improve the GA's performance which is used to solve the cell formation problem by using the binary coding system.

1.3 Comparison among Our Approach and Other Different Approaches

Array-based clustering methods perform a series of column and row permutations to form product/part and machine cells simultaneously. The main problem in array-based clustering methods is that the quality of the solution given by these methods depends on the initial configuration of the zero-one matrix. But in case of our approach, the quality of solution does not depend on the initial configuration of the zero-one matrix. Hierarchical methods have the disadvantages of not forming part and machine cells simultaneously. Our approach overcomes these disadvantages. One limitation of graphical method is that the machine cells and part families are not formed simultaneously. But our method overcomes these limitations. Mathematical programming methods can solve the machine part grouping problem simultaneously by considering the within-cell layout. But this technique is slightly complex and time consuming.

All the above techniques for cell formation problems are slightly complex and time consumable. None of the approaches presented above guarantees optimal solutions. So that the modern researchers have the tendency to continue their research activities in the field of group technology for machine part cell formation problem by using genetic algorithm. The objective of this paper is to present a procedure for obtaining product-machine groupings when the manufacturing system is represented by a binary product-machine incidence matrix. The approach combines a genetic algorithm with a local search heuristic. The genetic algorithm is responsible for generating sets of machines cells. The local search heuristic is applied on the set of machines cells with the objective of constructing sets of machine/product groups and improving their quality.

2. Research Methodology

For conducting thesis Data were collected from "OTOBI Limited"Savar factory which is a leading furniture manufacturing company in Bangladesh. In this paper a genetic algorithm approach is used to create the chromosome. The chromosome contains the information for the machine cell. According to the chromosome the number of machine cell has been selected and the machines have been inserted to the cells. After that the initial machine cell has been formed. The local search heuristic has been applied then to form the part families. Then the machine part matrix has been formed and the corresponding grouping efficacy has been calculated. Then with the help of part families the local search heuristic has been applied again to obtain the new machine cell. Then again the machine part matrix has been formed with the part families and the new machine cell and the corresponding grouping efficacy has been calculated. This process has been continued until the optimum solution has been found.

3. Measure of Performance

Grouping efficacy $$\mu = \frac{N_1 - N_1^{OUT}}{N_1 - N_0^{IN}} \qquad (1)$$

Where,

N_1 = total number of 1's in the matrix; N_1^{OUT} = total number of 1's outside the diagonal blocks;

N_0^{IN} = total number of 0's or blank space inside the diagonal blocks.

4. Machine part cell formation

In this paper we attempt to solve the machine part cell formation problem using zero one matrix, to minimize the inter-cellular movements and maximize the utilization of machines within a cell. Table 4.1 represents a 15×19 matrix (zero values are replaced by spaces in order to make the table more readable).

Table 4.1: Initial machine part incident matrix

Part	**Machine**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1						1		1		1					1			
2	1						1		1		1					1			
3	1				1		1		1				1						
4	1				1		1		1				1						
5		1						1		1		1						1	
6		1						1		1							1		1
7		1						1		1				1					
8		1				1		1		1		1						1	
9	1						1		1		1							1	
10	1						1		1		1							1	
11		1						1	1									1	
12	1						1			1								1	
13		1				1		1		1					1			1	
14		1	1																
15		1		1															

Here on the table "1" represents that the part has an operation on the machine and "blank space" represents that the part has no operation on the machine. The objective of this is to produce a matrix such as the one in table 6.1.

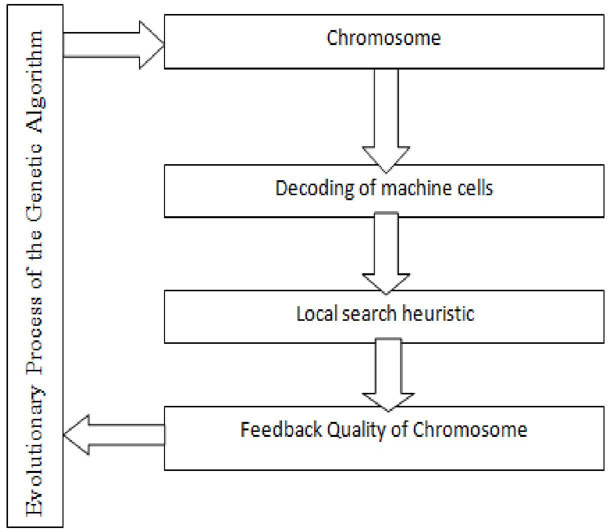

Fig. 5.1 Sequence of steps applied to each chromosome generated by the genetic algorithm.

In this paper combines a genetic algorithm with a local search heuristic. The genetic algorithm is used to generate sets of machine cells. The evolutionary process, embedded in the genetic algorithm, is responsible for improving the grouping quality of the sets of machine cells generated. The local search heuristic is applied to the sets of machines cells generated by the genetic algorithm. The objective of the heuristic is to construct a set of machine/product groups and improve it, if possible. The heuristic feeds back to the genetic algorithm the grouping efficacy of the set of machine/product groups it constructs. Fig. 5.1 shows the sequence of steps applied to each chromosome generated by the genetic algorithm.

5. Result analysis

5.1 Chromosome & Decoding of Machine Cell

Now for our approach suppose we start with the initial set of chromosome given by the genetic algorithm created randomly which is shown below.
Chromosome = 1421123324221142545 12345
For the left string, digit length indicates total machine number, each digit position indicates the corresponding machine number and each digit represents the machine cell it goes. For the right string, digit length indicates total number of machine cell and each digit represents the corresponding machine cell.
Here number of cells = 5
Machine cell 1 = {1, 4, 5, 13, 14}
Machine cell 2 = {3, 6, 9, 11, 12, 16}
Machine cell 3 = {7, 8}
Machine cell 4 = {2, 10, 15, 18}
Machine cell 5 = {17, 19}
The initial machine cell obtained is given below.
M1INITIAL = {(1, 4, 5, 13, 14), (3, 6, 9, 11, 12, 16), (7, 8), (2, 10, 15, 18), (17, 19)}

5.3 Fitness Function

The fitness function is defined over the genetic representation and measures the quality of the represented solution. The fitness function is always problem dependent. It is assigned to the chromosome according to the problem. Fitness function is used as an objective function which is the basis of genetic algorithm approach to get the optimum result. The optimum result is gained by evaluating the chromosome according to the fitness value of it using different operation of Gas.

5.4 Local Search Heuristic

The heuristic consists of an improvement procedure that is repeatedly applied. Each iteration ***K*** of the procedure starts with a given initial set of machine cells $M_K^{INITIAL}$ and produces a set of part families P_K^{FINAL} and a set of machine cells M_K^{FINAL}. Two block-diagonal matrices can be obtained by combining $M_K^{INITIAL}$ with P_K^{FINAL} and M_K^{FINAL} with P_K^{FINAL}. From these two matrices, the one with the highest grouping efficacy is chosen as the resulting block-diagonal matrix of the iteration ***K***. The procedure stops if $M_K^{INITIAL} = M_K^{FINAL}$ or if the grouping efficacy of the block-diagonal matrix resulting from iteration ***K*** is not greater than the grouping efficacy of the block-diagonal matrix resulting from the previous iteration ***K***-1, (for ***K***>2). Otherwise, the procedure sets $M_K^{INITIAL} = M_K^{FINAL}$ and continues to iteration ***K***+1.

Each iteration ***K*** of the local search heuristic consists of following two steps:

Step 1: Assignment of parts to the initial set of machine cells $M_K^{INITIAL}$. (Note that the initial the set of machine cells of iteration 1, $M_1^{INITIAL}$; is supplied by the genetic algorithm). Parts are assigned to machine cells one at a time (in any order). A part is assigned to the cell that maximizes an approximation of the grouping efficacy, that is, a part is assigned to the machine cell C*, given by

$$C^* = \text{argmx} = \frac{N_1 - N_1^{OUT}}{N_1 - N_0^{IN}} \quad (2)$$

Where,

argmax = argument that maximizes expression,

N_1 = total number of 1's in the matrix;

N_1^{OUT} = total number of 1's outside the diagonal blocks if the part is assigned to cell C;

N_0^{IN} = total number of 0's or blank space inside the diagonal blocks if the part is assigned to cell C.

In this step, the heuristic generates a set of part families P_K^{FINAL}. Let μ_K^1 be the efficacy of the block-diagonal matrix defined by $M_K^{INITIAL}$ and P_K^{FINAL}.

Step 2: Assignment of machines to the set of part families P_K^{FINAL} obtained in step (1). Machines are assigned to part families, one at a time (in any order). A machine is assigned to the part family that maximizes an approximation of the grouping efficacy, that is, a machine is assigned to the part family F*, given by,

$$F^* = \text{argmax} = \frac{N_1 - N_1^{OUT}}{N_1 - N_0^{IN}} \quad (3)$$

Where,

argmax argument that maximizes expression,

N_1 = total number of 1's in the matrix;

N_1^{OUT} = total number of 1's outside the diagonal blocks if the part is assigned to cell F;

N_0^{IN} = total number of 0's or blank space inside the diagonal blocks if the part is assigned to cell F.

In this step, the local search heuristic generates a new set of machine cells $M_K^{INITIAL}$: Let μ_K^2 be the efficacy of the block-diagonal matrix defined by M_K^{FINAL} and P_K^{FINAL}.

The block-diagonal matrix resulting from the iteration has a grouping efficacy given by $\mu_K = \max(\mu_1^K, \mu_2^K)$. If $M_K^{FINAL} = M_K^{INITIAL}$ or $\mu_K \leq \mu_{K-}(k \geq 2)$; then the iterative process stops and the block-diagonal matrix of iteration ***k*** -1.is the result. Otherwise, the procedure sets $M_{K+1}^{INITIAL} = M_K^{INITIAL}$ and continues to step (1) of iteration ***k*** +1.

From the calculations the final machine cell and the corresponding part families are

M_2^{FINAL}= {(5.6, 13,14,15), (1,7,9,11,16), (2,8,10,12,18)}
P_2^{FINAL}= {(3,4),(1,2,9,10),(14,15),(5,6,7,8,11,12,13)}
The resulting machine part matrix combining $M_2^{FINAL}$and P_2^{FINAL} is given table 6.1.

Table 6.1: Final machine part matrix

Part	Machine																		
	5	6	13	14	15	1	7	9	11	16	3	4	17	19	2	8	10	12	18
3	1		1			1	1	1											
4	1		1			1	1	1											
1						1	1	1	1	1									
2						1	1	1	1	1									
9						1	1	1	1										1
10						1	1	1	1										1
14											1				1				
15												1			1				
5															1	1	1	1	1
6													1	1	1	1	1		
7				1											1	1	1		
8		1													1	1	1	1	1
11								1							1	1		1	1
12						1	1										1	1	1
13		1			1										1	1	1		1

The grouping efficacy is :Objective function = Fitness function = $\mu_2^2 = \mu_{Final} = \dfrac{70-19}{70+22} = 55.43\%$

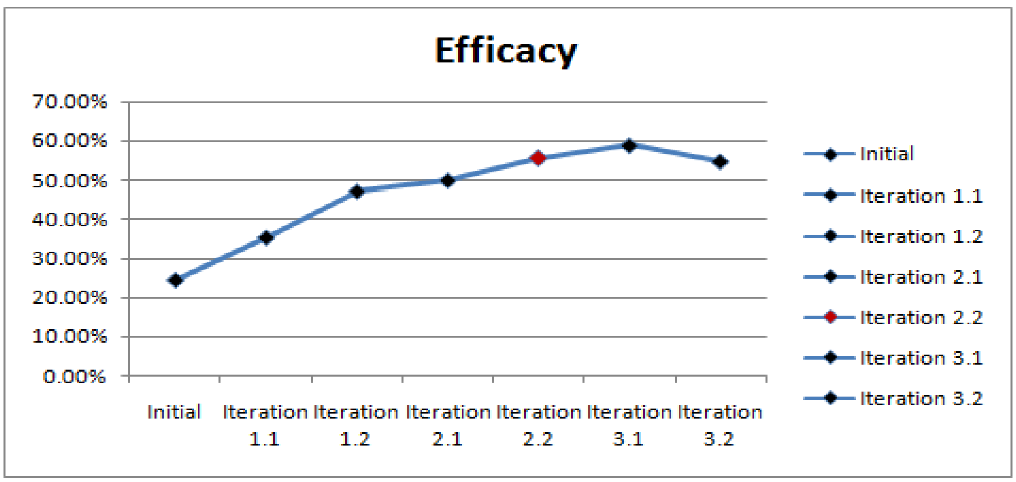

Fig. 6.1: Grouping efficacy at different iterations

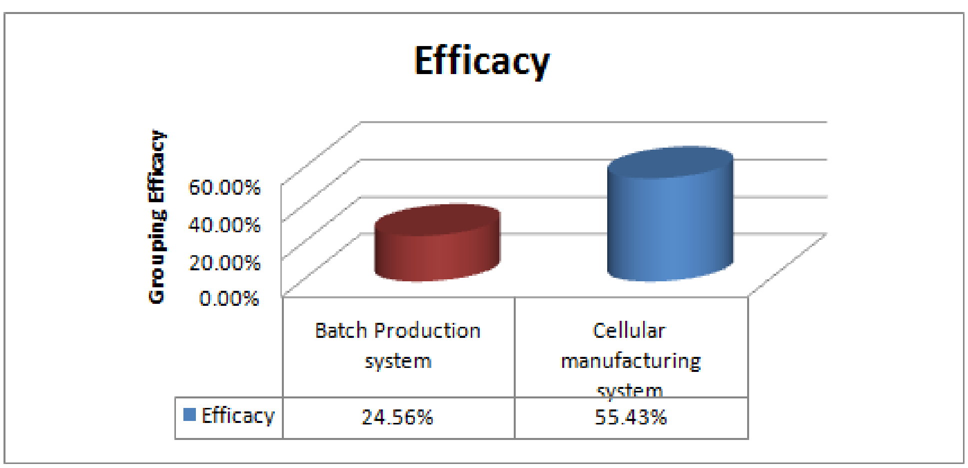

Fig. 6.2: Grouping efficacy comparison

6. Conclusions

The grouping efficacy is evaluated in terms of intercellular movements and utilization of machines in a cell. The aim of this paper was machine part cell formation in a batch oriented production system. The cell formation has been done for an existing problem. For this cell formation, an approach is used which is a combination of a genetic algorithm and a local search heuristic. The measure of performance to evaluate the performance of machine part cell, the grouping efficacy has been chosen. The grouping efficacy for the existing machine part cell is 24.56%. The grouping efficacy of the final machine part cell using our method is 55.43%. The grouping efficacy has been improved about 30.87%. This is an indication of more utilization of the machines. The resulting grouping efficacy obtained is 55.43%.

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Genetic Algorithms to Resolve Facility Layout Problem of an Industry in Bangladesh

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Abstract

The facilities layout is also called plant layout for a manufacturing plant. Plant layout design is one of the strategic fields that determine the long run efficiency of operation. The layout consists of all equipments and machineries within the building structure. The handling system consists of the mechanisms needed to satisfy the required facility interactions. Traditional approaches to the plant layout problem have assumed that the volume of flow between pairs of departments is deterministic. But it has been seen that production plans are subject to revisions due to changes in demand, product mix, new technology, etc. A project is conducted to optimize the layout design of the production line at the shop floor of a company named Bangladesh Cable Shilpha Ltd., Khulna, aiming at overcoming the current problems attributed to the inefficient layout. A Genetic Algorithm layout technique is used to generate a near optimal layout based on formal methods that are rarely used in practice.

Keywords: *Facility layout, flexible manufacturing, stochastic programming.*

1. Introduction

Plant layout problems can occur in a large number of ways and can have significant effects on the overall effectiveness of the production system. Effective facilities planning can reduce material handling cost by at least 10 to 30%. The size of the investment in new facilities each year makes the field of facilities planning important. The objectives of the Plant Layout Strategy are to meet the requirement of minimizing the investment in equipment and material handling cost, product design and volume, process equipment and capacity: minimize overall production time; maintain flexibility of arrangement and operation; minimize variation in types of material handling equipment; facilitate the manufacturing process, quality of work life: provide for employee convenience, safety and comfort; facilitate the organizational structure and building and site constraints: utilize existing space most effectively. Layouts can be classified as seven types: fixed position layout; process oriented layout, also called job shop; group layout; office layout; retail/service layout; warehouse layout; product-oriented layout. It is highly desirable that the optimum plant layout need to be designed. Unfortunately, the magnitude of the problem is so great that true system optimization is beyond current capabilities. The approach normally taken in solving the plant layout problem is to try to find a satisfactory solution. Previously, facilities layout problems were solved primarily by using iconic models. Then analytical approaches were developed. A number of different procedures have been developed to aid the facilities planner in designing layouts. These procedures can be classified into two main categories: construction type and improvement type. Construction type layout methods basically involve developing a new layout from scratch. Improvement procedures generate layout alternatives based on an existing layout. Based on the above two procedures, many algorithmic approaches have been developed. Some of them are Systematic Layout Planning (SLP) procedure, steepest descent search method by pair wise exchange, graph-based construction method, programming, network, Tabu search, simulated annealing and genetic algorithm. Based on these approaches, many computer-aided layout routines have been developed.

A number of design goals can be modeled as layout objectives. In addition, a set of constraints often has to be satisfied to ensure the applicability of the layouts. Efficient calculations of objectives and constraints are necessary to solve the layout problems in reasonable time since the analysis of objectives and constraints can be computationally expensive and a large number of evaluations may be required to achieve convergence. The search space of the layout problem is non-linear and multi- model, making it vital to identify a suitable algorithm to navigate the space and find good quality solutions.

The layout goals are usually formulated as objective functions. The objectives may reflect the cost, quality, performance and service requirements. Various constraints may be necessary to specify special relationships between components. The specifications of components, objectives, constraints, and topological connections define a layout problem and an optimization search algorithm takes the problem formulation and identifies promising solution by evaluating design alternatives and evolving design states. Analysis of objectives and constraints vary from problem to problem. However, the optimization search technique and geometric representation and the resulting interference evaluation are problem independent and are, thus, the focus for a generic layout tool [1].
The primary objective of the design problem is to minimize the costs associated with production and materials movement over the lifetime of the facility. Such problems occur in many organizations, including manufacturing cell layout, hospital layout, semiconductor manufacturing and service center layout. For US manufacturers, between 20% and 50% of total operating expenses are spent on material handling and an appropriate facilities design can reduce these costs by at least 10%-30% [2,3].

Altering facility designs due to incorrect decisions, forecasts or assumptions usually involves considerable cost, time and disruption of activities. On the other hand, good design decisions can reap economic and operational benefits for a long -time period. Therefore, the critical aspects are designs that translate readily into physical reality and designs that are "robust" to departures from assumptions.

The project manager or planner usually performs the task of preparing the layout based on his/her own knowledge and expertise. Apparently, this could result in layouts that differ significantly from one person to another. To put this task into more perspective, researchers have introduced different approaches to systematically plan the layout of production sites [4,5].

Facility layout planning can generally be classified according to two main aspects: (1) method of facility assignment and (2) layout planning technique.

Mathematical techniques usually involve the identification of one or more goals that the sought layout should strive to achieve. A widely used goal is the minimization of transportation costs on site. These goals are commonly interpreted to what mathematicians term "objective functions". This objective function is then optimized under problem-specific constraints to produce the desired layout. Systems utilizing knowledge-based techniques, in contrast, provide rules that assist planners in layout planning rather than perform the process based purely on a specified optimization goal(s).

Usually the selected fitness function is the minimum total costs of handling of work pieces. In general, those costs are the sum of the transport costs (these are proportional to the intensity of the flow and distances) and other costs.

An effective facility layout design reduces manufacturing lead-time, and increases the throughput, hence increases overall productivity and efficiency of the plant. The major types of arrangements in manufacturing systems are the process, the flow line or single line, the multi-line, the semi-circular and the loop layout. The selection of a specific layout defines the way in which parts move from one machine to another machine. The selection of the machine layout is affected by a number of factors, namely the number of machines, available space, similarity of operation sequences and the material handling system used. There are many types of material handling equipment that include automated guided vehicles, conveyer systems, robots, and others. The selection of the material handling equipment is important in the design of a modern manufacturing facility [6].

The problem in machine layout design is to assign machines to locations within a given layout arrangement such that a given performance measure is optimized. The measure used here is the minimization of material handling cost. This problem belongs to the non-polynomial hard (NP-hard) class. The problem complexity increases exponentially with the number of possible machine locations.

2. Algorithms for workstation layout

In plant layout problem, many researchers describe the problem as one of optimizing product flow, from the raw material stage through to the final product. This is achieved by minimizing the total material handling costs. Solving the problem it is required to know the distances between departments (usually taken from their centroids), the number of trips between departments, and the cost per unit.

The layout space is defined as the mathematical representation of the space of configurations mapped against the cost per configuration. Deterministic algorithms are unable to navigate such a space for globally near-optimal solutions, and stochastic algorithms are usually required for solutions of good quality.

For instance, a flexible manufacturing system (FMS) consisting of N machines will comprise a solution space with the size N. The problem is theoretically solvable by testing all possibilities (i.e., random searching of the solution space). For arranging the devices in the FMS the number of possible solutions is equal to the number of permutations of N elements.

Various models and solution approaches have been proposed during past three decades. Heuristic techniques were introduced to seek near-optimal solutions at reasonable computational time for large scaled problems covering several known methods such as improvement, construction and hybrid methods, and graph-theory methods [10]. However, the area of researches is still always interesting for many researchers, since today the problems are solved by new methods and with the possibility of application of much greater computation capacity of modern computers.

A variety of optimization algorithms have been applied to the layout problem. Some of the approaches may be efficient for specific types of problems, but often place restrictions on component geometry, allowable degrees-of-freedom, and the objective function formulation. Others are applicable to a wider variety of problems but may require prohibitively long computing time to solve even simplistic problems. Layout algorithms can be classified into different categories according to search strategies used for design space exploration. The target of all methods is the minimum transport costs, but they differ in exactingness, particularly in the length of the procedure. However, it cannot be decided with certainty which basic method and/or method of improvement of the layout is the best.

3. Mathematical model

The facility layout problem is the assignment of M machines to N locations in a manufacturing plant. During the manufacturing process, material flows from one machine to the next machine until all the processes are completed. The objective of solving the facility layout problem is therefore to minimize the total material handling cost of the system. To determine the material handling cost for one of the possible layout plans, the production volumes, production routings, and the cost table that qualifies the distance between a pair of machines/locations should be known.

The total cost function is defined as:

$$C = \sum_{i=1}^{M} \sum_{j=1}^{M} G_{ij} C_{ij} L_{ij} \quad (1)$$

Where,

Gij =amount of material flow among machines i and j (i,j=1,2, .,M)

Cij =unit material handling cost between locations of machines i and j (i,j=1,2, ,M)

Lij =rectilinear distance between locations of machines i, and j.

C =total cost of material handling system.

The evaluation function considered in this paper is the minimization of material handling cost, and criterion most researchers prefer to apply in solving layout problems. However, the proposed approach may be applied to other functions as well.

To solve the problem it is necessary to know the matrix of the transport quantities between the individual devices N in a time period. Also the variable transport costs, depending on the transport means used, must be known. For example: connection between two devices can be performed by another transport device. The costs of transport between two devices can be determined if their mutual distance Lij is known. During execution of the GA the value Lij changes with respect to the mutual position of devices and with respect to position in the arrangement.

Fitness function thus depends on the distance Lij between the devices. The distance between serving points is multiplied by coefficients Gij and Cij, which measure the amount of material flow and the handling cost between devices, their constants are defined by input matrix, as shown in Table 1 and Table 2. The value of the cost function is thus the sum of all values obtained for all the pairs of devices. The aim of optimization process is to minimize this value. Fitness is based on the principle that the cost of moving goes up with the distance.

4. Genetic algorithms

4.1. Approach

Early researchers of the facilities layout problem believed that the best approach to solutions was through the development of the general quadratic assignment problem (QAP). By using the this, the facilities layout problem can be optimally solved by applying implicit enumeration approaches such as cutting plane, branch and bound approaches, or other operations research techniques. The exact solution is obtained from optimal methods in a reasonable time only when the problem size is small. It has been shown that the solution times for the QAP are likely to increase exponentially as a function of the number facilities to be located. GAs have received a great deal of attention in the recent literature due to the fact that they do not rely on analytical properties of the function to be optimized which make them well suited to a wide class of optimization problems. The starting point in GA presented in this work was an initial population of solutions (which was randomly generated). Process shop layout and its randomly generated chromosomes are shown on figure 1. This population undergoes a number of transformations designed to improve the solutions provided. Such transformations are made in the main loop of the algorithm, and have three basic stages: selection, reproduction, and replacement, as discussed below. Each of the selection-transformation cycles that the population undergoes constitutes a generation; hopefully, after a certain number of generations, the population will have evolved towards the optimum solution to the problem, or at least to a near-best solution.

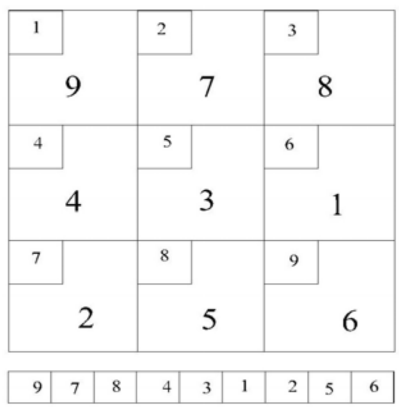

Fig. 1. Type of layout used in calculations and its chromosome representation

The selection stage consists of sampling the initial population, thereby obtaining a new population with the same number of individuals as the initial one. This stage aims at improving the quality of the population by favoring those individuals that are more adequate for a particular problem (the quality of an individual is gauged by calculating its fitness, using equation 1, which indicates how good a solution is).

The selection, mutation, and crossover operators were used to create the new generation of solutions. A fitness function evaluates the design and decides which will be the survivors into the next generation. Selection is accomplished by copying strings from the last generation into the new generation based on a fitness function value. Mutation is the process of randomly changing one bit of information in the string and it prevents GAs from stagnating during the solution process. Crossover is responsible for introducing most new solutions by selecting two parent strings at random and exchanging parts of the strings. The outline of the genetic search process used in this paper is summarized as follows:

1. To randomly generate an initial population of chromosomes with a population size ,P.
2. To evaluate each chromosome in the population according to the material handling cost equation.
3. To determine the average fitness for the whole population.
4. To use elitist strategy to fix the potential best number of chromosomes by deleting the worst number of each generation, and copying the best numbers into the succeeding generation. The total number of chromosome is kept constant for computational economy and efficiency. The average of whole chromosome acts as a guide to which chromosomes are eliminated and which of them 'gets reproduced' in the next generation. The process is applied to eliminate members with a fitness value $P(k)$ greater than 1.5 times the average of the chromosomes and copying the best number of chromosomes instead.
5. To apply the Monte Carlo selection technique to select parent chromosome from the current population. That is used for choosing randomly the parents for the crossover and mutation.
6. To apply the crossover and mutation operators to generate a new population based on the values of crossover and mutation probabilities (pc and pm, respectively). The rest of the population is brought from the previous population which has the best fitness value.

7. To check the pre-specified automatic stopping criterion. If the stopping criterion is reached, the search process stops. It will be needed to proceed the next generation, and to go to step 2. The flow chart of the GA optimization procedure is shown in Fig. 2.

4.2. String representation

The technique of GAs requires a string representation scheme (chromosomes). The entire manufacturing plant/department is divided into N grids and each grid represents a machine location. In this study, a form of direct representation for strings is used. Fig. 3 shows different examples of different types of production plant layout with their encoded chromosomes representation. This chromosome string representation indicates one of the possible machine layout plans of each production type. Examples of flow shop layout containing 9 machines/departments, production flow line contains 5 workstations, multi-line production system contains 6 machine locations, and a closed-loop layout type of 8 machines are presented in the figure.

4.3. Selection operator

The selection operator is applied to select parent chromosomes from the population. A Monte Carlo selection technique is applied. A parent selection procedure operates as follows:

1. To calculate the fitness F_{sum} (Eq. (1)) of all population members.
2. To generate a random number (n) between 0 and F_{sum}.
3. To return the first population member whose fitness, when added to the fitness of the preceding population members, is greater than or equal to n

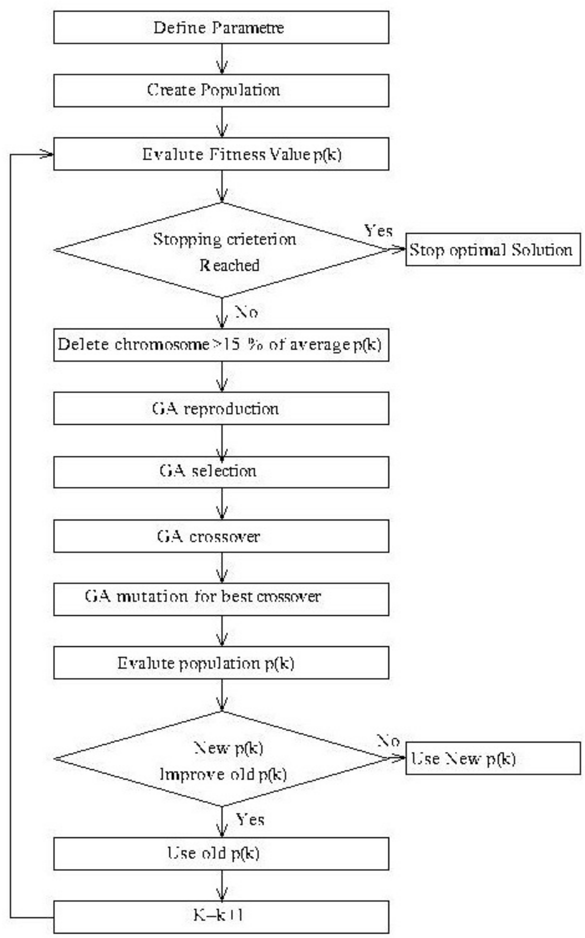

Fig. 2. Flow chart of GA optimization procedure.

4. To repeat Step 3 for the second population member and to check so that the new selected member is not the same as the first member.

4.4. Crossover operator

The probability of crossover pc is the probability of applying the crossover operator to these chromosomes. The remainder of chromosomes will produce offspring chromosomes, identical to their parents. Otherwise, the selected chromosomes to crossover will be crossed to produce two offspring chromosomes by using crossover operator. A new crossover operator is proposed as follows considering a pair of parent chromosomes (P1, P2) as shown below:

P1	1	3	6	8	4	2	5	7	9
P2	8	3	1	5	7	9	6	2	4

The way of crossover implemented has been chosen four central numbers of both parents i.e. (8,4,2,5) in P1 and (5,7,9,6) in P2, but not to exchange it from P1 to P2 and vice versa [13,14,6]. Their string is changed 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 P2 should be lined as 9,6,5,7 in P2. At this stage genes can not be found to exist in more than one position in the resultant chromosomes. The structures of the resultant chromosomes then become:

P1	1	3	6	2	5	8	4	7	9
P2	8	3	1	9	6	5	7	2	4

The mutation operator is used to rearrange the structure of a chromosome. The swap mutation was used, which is simply selecting two genes at random and swapping their contents. The probability of mutating a single gene is usually a small number.

Since it is difficult to assume the total optimum solution of the problem investigated, and it becomes more difficult if number of workstations (machines) increase, the program may be terminated when either the maximum number of generations is reached, or until the propounded limit is attained. The second procedure is applied. As propounded limit the value obtained for the material handling cost of optimal facility layouts presented in benchmark test was used. where the value of C = 4818. Only the results with value equal to this were placed in main database, and presented as optimums in figure 2.

In all experiments the same genetic parameters were used [13,14]. Those genetic parameters were: the probability of crossover pc = 0.6 and probability of mutation pm = 0.001. The percentage of replication of well-performed chromosomes in each generation was R = 5%.

4.5. Mutation operator

The mutation operator is used to rearrange the structure of a chromosome. The swap mutation is used, which is simply selecting two genes at random and swapping their contents. The probability of mutating a single gene is called the probability of mutation, pm, which is usually a small number. Mutation helps to increase the searching power. In order to explain the need of mutation, a case may be considered where reproduction or crossover may not produce a good solution to a problem. During the creation of a generation it is possible that the entire population of strings is missing a vital gene of information that is important for determining the correct or the most nearly optimum solution.

4.6. Stopping criterion

The program is terminated when either the maximum number of generations is reached, or until the population converges.

5. Application of the GA to the layout problem of Bangladesh Cable Shilpha Limited (BCSL), Khulna.

The plant flow of materials between machines of Bangladesh Cable Shilpha Ltd (BCSL) and material handling cost between machines are presented in tables 1 and 2, respectively. The plant configuration layout is 3X3 grid using 9 machines; there are 362880 possible solutions in the solution space e.g. (9!). The stopping criterion for iteration has been obtained using value of fitness C from Eq. 1.

Table 1. Flow of materials between machines

From/To	1	2	3	4	5	6	7	8	9
1		100	3	0	6	35	190	14	12
2			6	8	109	78	1	1	104
3				0	0	17	100	1	31
4					100	1	247	178	1
5						1	10	1	79
6							0	1	0
7								0	0
8									12
9									

The experimental results are shown in Table 3 and expressed in terms of:

1. The material handling cost of the best solution among trials (Best)
2. The number of the trials needed to obtain one of the optimal solutions (#).

In general, an increase in the population solutions since the number of sampling solutions from the solution space is enlarged. The general cost performance for the four different approaches is studied with the sampling solution space used, Fig. 2 shows some of the resulting optimal machine layouts giving a material handling cost of value equal to 4818.

Results obtained by proposed approach are compared with the standard results [14,13,6] and found to have very less variation, and generation sizes can provide better number of iterations, as shown in the Figure 3. Minimum costs of handling is found to be 4818. The reason for such discrepancies of results presented in this paper and the results proposed by models selected for comparison from the literature, concerning number of iterations, is laying mainly in simplicity of the way of crossover implementing in this work comparing to the procedure explained in previous literature as described in section 4.

Table 2. Material handling cost between machines

From/To	1	2	3	4	5	6	7	8	9
1		1	2	3	3	4	2	6	7
2			12	4	7	5	8	6	5
3				5	9	1	1	1	1
4					1	1	1	4	6
5						1	1	1	1
6							1	4	6
7								7	1
8									1
9									

4	8	5
3	9	2
7	1	6

7	1	6
3	9	2
4	8	5

6	2	5
1	9	8
7	3	4

5	2	6
8	9	1
4	3	7

5	8	4
2	9	3
6	1	7

4	3	7
8	9	1
5	2	6

Fig. 3. Some of the optimal facility layouts for BCSL

Table 3. The experimental results for BCSL

Exp.	No.of trials	Proposed approach	No.of trials	M.Adel El-Baz	Mak et al.	PMX (Chan and Tansri)
	#	Best	#	Best	Best	Best
1	4050	5119	200	5039	5233	4939
2	8595	5150	400	4818	5040	5036
3	180	4872	1000	4818	4818	4938
4	405	4818	2000	4818	4818	4818
5	270	4818	5000	4818	4818	4818
Exp.	No.of trials	Proposed approach	No.of trials	M.Adel El-Baz	Mak et al.	PMX (Chan and Tansri)
	#	Best	#	Best	Best	Best
6	360	4818	400	4872	5225	4938
7	2160	4939	800	4818	4927	4992
8	1125	4990	2000	4818	4818	4818
9	765	4818	4000	4818	4818	4818
10	1485	4818	800	4818	5225	4938
11	3105	4818	1600	4818	4927	4992
12	990	4818	4000	4818	4818	4818
13	2160	4818	8000	4818	4818	4818
14	3105	4818	2000	4818	5225	4938
15	225	4818	4000	4818	4818	4927
16	2160	4818	10000	4818	4818	4818
17	3015	4818	4000	4818	4818	4938
18	3240	4818	8000	4818	4818	4862
19	3600	4818	5000	4818	4818	4818
Sum:	40995		63200			

6. Conclusion

The present paper proposes an approach using GAs to solve facility layout problems. This Algorithm may be used as a useful tool to find out an ideal workstations position of BCSL in short time as well as practical significance of saving financials needed for transportation costs in concrete production systems. The proposed GA approach for BCSL produces the optimal machine layout, which minimizes the total material handling cost. The effectiveness of the proposed approach has been examined by using three benchmark problems. The comparison indicates that the proposed approach is efficient and has a high chance of obtaining the best solution for the facility layout problem with less number of iterations. The solutions for the layout problem for BCSL have been calculated in reasonably short time on standard PC equipment. Only demerit of GA presented in this work, is that number of trials needed to obtain first optimum is to some extent larger, still overall number of iterations is much lesser (40995 < 63 200), with same number of experiments.

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Application of Six Sigma Philosophy for Reducing Process Variability: a DMAIC Model

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Abstract

Now-a-day's many leading manufacturing industry have started to practice Six Sigma and Lean manufacturing concepts to boost up their productivity as well as quality of products. In this paper, the Six Sigma approach has been used to reduce process variability of a food processing industry in Bangladesh. DMAIC (Define, Measure, Analyze, Improve, & Control) model has been used to implement the Six Sigma Philosophy. Five phases of the model have been structured step by step respectively. Different tools of Total Quality Management, Statistical Quality Control and Lean Manufacturing concepts likely Quality Function Deployment (QFD), Failure Mode & Effect Analysis (FMEA), Exponentially Weighted Moving Average (EWMA) chart, Multi Criteria Decision Making Technique (Analytical Hierarchy Process), Regression analysis and finally Process Capability Indices have been used in different phases of the DMAIC model. After having practical demonstration in a food manufacturing firm it can be claimed that the paper will make a fruitful impact on advance decision making techniques for reducing different types of industrial wastage.

Keywords: *Six Sigma, DMAIC model, Variation reduction, Lean management.*

1. Introduction

Six Sigma is a systematic data-driven improvement method using cross-functional teams to reduce variation, improve quality, enhance bottom-line balance sheet performance, and improve customer satisfaction [11]. Every process has a mean and a standard deviation. By comparing the process statistics to the specification limits, we estimate a sigma level. A 'sigma level performance' quantifies the relationship between customer specifications and the natural distribution of the process results [6]. As improvements reduce process variation, more standard deviations will fit between the process mean and the specification limit. When Six Sigma performance occurs, 6 process standard deviations will fit between the process mean and any specification limit, and the product measure will fall within specification limits for 99.9997% of samples, resulting in only 3.4 failures per million opportunities, which means this number of occurrences outside the specification limit. In a comparison with traditional 3 sigma level failure number is 66807 per million opportunities. But in Bangladesh the application of Six sigma is inconsiderable yet now. If we see on the production sectors of any kind of industry in this area there shown a huge amount of loses due to higher degree of defects. For this particular work it is focused on a renowned food processing Industry in Bangladesh. If it would be possible to apply six sigma quality control systems, then it could greatly diminish the defects that are generally happened on the production floor. For this reason authors have been interested to work on Lean Six sigma and applied it through DMAIC model in any food processing company in Bangladesh. Pran Agro Limited is one of the renowned food product manufacturers in Bangladesh. Particularly in their ice-pop department the authors noticed four major types of defects which normally occur. Those are leakage, leaving bottles without coding traces, excess/short materials fill up and cap loose sealing.

2. Literature Review

Lean manufacturing and Six Sigma are two very powerful concepts in manufacturing and industrial sectors. They have been applied in various forms and have proven their worth in making businesses more productive over time. For the last few decades we have seen that there occupied a noticeable work in the field of research & methodological study on the basis of lean six sigma concepts. Some works are based on six sigma philosophies, some are based on lean manufacturing & some are based on combination of this two, called lean six sigma. Hung & Sung [5] in their paper applied six sigma concepts to manufacturing processes in the food industry to reduce quality cost. In their research work they have shown a remarkable change after application of six sigma concerns to their field. Furthermore Kwak and Anbari [9] defined the benefits, obstacles and future of six sigma approaches. In passing years, the manufacturing industry has successfully applied the six sigma methodologies to numerous projects. However, due to insufficient data or a misunderstanding of the six sigma methodology, some of the project failed. Besides this, Khalil et.al [7] in their paper captured some of the key concepts in Lean Six Sigma initiatives and how industries were utilizing it to lower production costs while maintaining high quality and speed. In addition of that Ditahardiyani et.al [3] put forward the six sigma methodology and its implementation in a primer packaging process of Cranberry drink. DMAIC approaches have used to analyze and to improve the primer packaging process, which have high variability and defects output. Apart from this, Hekmatpanah et.al [4] in their works they surveyed the six sigma process and its impacts on the organizational productivity. He emphasized on the key concepts, problem solving processes as well as the survey of important fields such as; DMAIC, six sigma, productivity applied program and other advantages of six sigma. There are lots of papers or works on Lean six sigma methodology in the history of literature. The very latest trend in these fields is to combine the techniques and tools from these two methodologies into a new format called “Lean Six Sigma” to improve productivity, quality, and speed. In this paper lean six sigma methodologies have been implemented through DMAIC model in a food processing industry in Bangladesh to reduce process variation. The difference of this work from the others is in terms of tools used in conducting this work and its perspectives. At the primary section of this paper six sigma & lean concepts have introduced with some relevant literature reviews. Then in the later portion all the calculations and analysis for DMAIC model have been discussed. After which some recommendations for the manufacturer and for future works have provided. At last an informative conclusion is drawn which is followed by some references.

3. Research Methodology

Here in this research work, the authors employed DMAIC model for successful implementation of six sigma philosophy. DMAIC, an acronym for Define, Measure, Analyze, Improve, and Control, is a structured problem-solving procedure widely used in quality and process improvement. In the different Phase of DMAIC model different types of Six sigma tools and lean tools such as Quality Function Deployment (QFD), Exponentially Weighted Moving Average (EWMA), Process Centring Index, Regression analysis, Analytical Hierarchy Process (AHP) and Failure Mode & Effect Analysis (FMEA) were employed. For doing this paper work data were taken from a leading food-product manufacturing company in Bangladesh named Pran Agro Ltd. Among various departments of this industry Ice-pop department and their products had been chosen for collecting data. A total of 26 working days data were collected from the quality assurance department. After doing that the authors targeted four types of defects named leakage, leaving bottles without coding, loose sealing, and Short/Excess material filled up.

4. Implementation of DMAIC Model

4.1 Define Phase

The Define phase of a six Sigma DMAIC model is used to identify the product quality characteristics which are critical to customer [2]. For this particular work the authors use a Quality Function Deployment (QFD) structure to indicate the relationship between the defects and the factors that affect these defects.

$=weak relation (3)
#=Moderate relation (5)
@=Strong relation (9)

	Management			Environment			Method										
	Unskilled Operator	Improper Training	Lack of Attention	Humidity	Temperature	Dust	Product Design	Measuring System	Measuring Instrument	Heat Balance	Importance (10)	They Today (10)	Target in Future (10)	Improvement Ratio	Sales Point	Score	Percent Score
Leakage	@	#	$		#		@			@	10	8	9	1.1	1.2	13	36
Without Coding	#	@	@				$		@	$	3	2	3	1.5	1.3	6	16
Loose Sealing	#	@	@	#	@	$	@		@	#	4	3	4	1.3	1.2	6	16
Excess/ Short	$	@	#	#	#	$		@	@	$	8	6	7	1.2	1.2	12	32
Score	580	756	556	240	484	144	516	288	576	548							
Percent Score	13	16	12	5	10	3	11	6	12	12							

Fig 1: QFD model showing the relationship between defects and possible causes

The alternative tools for define phase were SIPOC (supplier, Input, Process, Output, Customer) analysis, Voice of customer analysis etc. In spite of having these ones QFD is chosen because QFD clearly shows the relationship as a tabular form. In the diagram it is seen that unskilled operator & improper training has the highest score. Here importance means is the numbering the defects among 10.

4.2 Measure Phase

In this phase, the measure contains the identification of appearance problems up to each some performance situation [1]. For this research work authors chose to drive this step by the exponentially weighted moving average (EWMA) control chart. Process control charts are chronological graphs of process data that are used to help understand, control, and improve processes – such as infection control or adverse event processes – and that, although based in statistical theory, are easy for practitioners to use and interpret [1]. The EWMA is a statistic for monitoring the process that averages the data in a way that gives less and less weight to data as they are further removed in time. Using the 'QI Macros 2013' extension of 'Microsoft Office Excel 2007' EWMA chart was drawn (shown in fig 2) on experimental data founded in that concerned company floor.

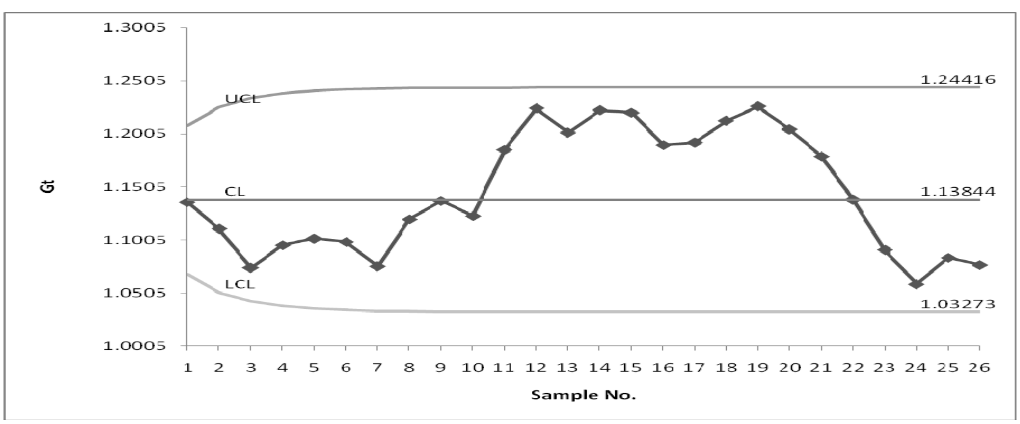


Fig 2: EWMA Curve (using QI Macros)

4.3 Analysis Phase

The analyze phase involves identifying input and output variables that affect each Critical to Customers (CTQs). Three tools named Process Performance Indices, Multi criteria decision making (MCDM) techniques &

Regression analysis have been used to analyze the defects for this research work. At this stage other usable tools are Pareto analysis, Cause-effect diagram, Flow diagram, ANOVA & Brainstorming.

4.3.1 Process Performance Indices

Here in Table 1 summarized on different process performance measuring tools based on statistical quality control concepts.

Table 1: Summary on different Problem relevant Process Performance measures

Problems	**Process Potential Index (C_p)**	**Process Performance Index (C_{pk})**	**Process Centring Index (K)**	**Remarks**
Leakage	0.5396	0.3736	0.3077	Process is not capable. i,e. $C_p < 1$
Without Coding	0.5311	0.4903	0.0769	Process is not capable. i,e. $C_p < 1$
Loose Sealing	0.5396	0.3736	0.3077	Process is not capable. i,e. $C_p < 1$
Excess/Short Material	0.336	0.2584	0.2308	Process is not capable. i,e. $C_p < 1$

4.3.2 Regression Analysis

The study also uses the simple linear regression relationship between the dependent variable Leakage problem and the independent variables like without coding problem, loose sealing problem & excess/short materials as shown is table 2. These relationships help the manufacturer to find out the Leakage problem very easily.

Table 2 The relationship between Leakage & different independent variables

Dependent variables (Y)	**Independent variables (X)**	**Linear equation**
Leakage Problem	Without Coding	Y= 7.294X – 5.47
Leakage Problem	Loose sealing	Y= 27.462X-16.6302
Leakage Problem	Excess/short materials	Y= 243.313X-91.184

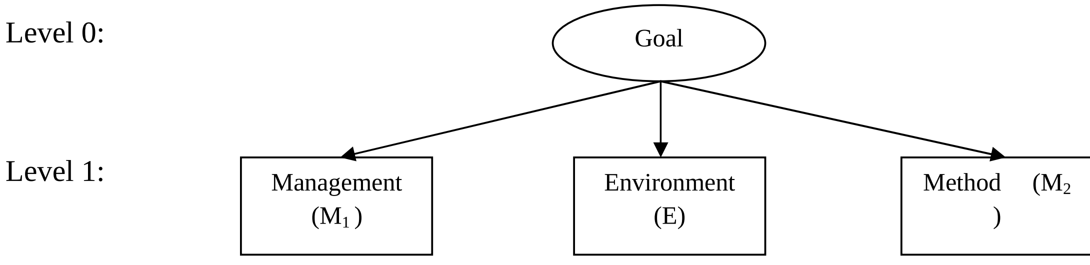
Table 3 The overall relationship with Leakage & others

Dependent variables (Y)	**Independent variables (X)**		
Leakage (Y)	Without Coding (X_1)	Loose Sealing (X_2)	Excess/Short material (X_3)
Overall Relationship	$Y = 0.902 + 0.801X_1 + 0.796X_2 + 0.181X_3$		

Table 2 and 3 illustrates the regression analysis along with the relationships among different quality parameters. Here by using the derived overall relationship as shown in table 3, the relevant personnel could easily find out the actual scenario for future surmise

4.3.3 Analytical Hierarchy Process

The AHP is a measurement method for determining the relative importance or preference of a set of activities in a multiple criteria decision-making (MCDM) problem. It is a systematic approach for selecting alternatives. Based on mathematics and human psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. Analytical Hierarchical Process (AHP) is a decision-making method for prioritizing alternatives when multiple criteria must be considered and allows the decision maker to structure complex problems in the form of a hierarchy, or a set of integrated levels.



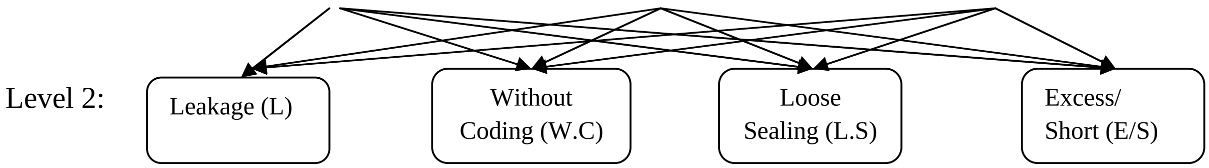


Fig 3: Proposed AHP Model

Table 4: Level of preference weights for AHP model

Level of preference	Definition	Explanation
1	Equally preferred	Two activity contribute equally to the objective
2	Moderately	Experience and judgment slightly favour one activity over another
3	Strong Importance	Experience and judgment strongly or essentially favour one activity over another
4	Extreme Importance	The evidence favouring one activity over another is of the highest degree possible of affirmation
Reciprocals	Reciprocals for inverse comparison	

Table 5: Average Random Index (RI) based on matrix size (adapted by Saaty)

N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RCI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Table 6: Final Evaluation under AHP approach

Attribute	**Attribute & their weight**			**Composite Weight**	**Final Ranking**
	Management (0.56)	Environment (0.12)	Method (0.32)		
Leakage	0.55	0.146	0.16	0.377	2
Without Coding	0.08	0.12	0.07	0.012	4
Loose Sealing	0.13	0.27	0.16	0.156	3
Excess/Short	0.24	0.48	0.61	0.387	1

Here the important information is being given in tables 4, 5 & 6. For successful implementation of AHP techniques, the authors employed the level of preference as in table 5. Then by using the random indices from table 5, the authors concluded the results in table 6. From table 6, it is clear that Excess/Short materials problem for each cant is the main culprit which is followed by leakage problem, loose sealing problem & finally without coding problem sequentially.

4.4 Improvement Phase

The improve phase deals with the activity related to the improvement of the project. Many types of tools can be used for this phase. The goal of this phase is to improve the process to bring it to the performance goal. While this phase involves experiments, often several experiments - it allows discovery and testing of an improved process. For this research work, the tool used is Failure Mode & Effect Analysis (FMEA).

No	Function	Failure	Effects	Sensitivity Rating, S	Causes
1	Damage on the Products	Leakage	Manage 3-5 more cans to damage with the marked one	4	Product design, Improper training, Heat balance, Temperature & Unskilled operator
2		Without Coding	Coding isn't done well on few times, so at that time operation should be retaken	2	Measuring instruments
3		Loose Sealing	Sealing on the cap of the bottle isn't done properly & some of them are damaged after few days	3	Controlling of environmental factors & attention of workers
4		Excess/ Short	Goodwill are damaged gradually; Company can face loss	5	Attitude of worker; Training of worker; Measuring instruments

Occurrence Rating, O	Detection, D	Critical Characteristics	Current Condition	RPN (Risk Priority Number) = S×D×O	Recommended Action	Action Taken
4	3	Y	Product is not well designed, Improper training is provided to the worker	5×3×3= 45	Product should be well designed; Proper training should be provided to the worker.	Both are taken
3	1	N	Measuring instruments are insufficient	2×1×1=4	Modern instruments should be provided	New budget for latest instrument is already taken.
2	2	N	Controlling system of environmental factors isn't very good & lacking in the attention of customers	3×1×2=6	Analytical meters should be replaced by digital meters at various environment related factors.	Analytical meters are replaced by digital meters.
1	5	Y	Lack of attention of workers; Measuring instruments are not well calibrated	4×1×5= 20	Workers should be brainstormed & measuring instruments should be calibrated in the shortest possible time.	Different brainstorming procedures of the workers are undertaken.

Fig 4: Schematic View of targeted Failure Mode & Effect Analysis chart

4.5 Control Phase

The objective of this step is the control the burning issues found from the analysis phase and to maintain or implement proper supervision environment for new improved process. The controlling process could be done based on the experiments of EWMA & FMEA. But, the most important thing for this stage is that to make proper inspection & taking necessary steps. Implementation plan, Process control plan, Standard operating procedures, Communication plan & other up to date tools may be usable to control the process variation.

5. Conclusion & Future Works

The key objective of this study was to reduce process variability by applying Six Sigma philosophy through DMAIC model.The reduction of process variations is a continuous process. To achieve the Six Sigma level for any manufacturing firm is a laborious & time consuming task. Lean and Six Sigma both have been implemented as integrated form in this study to obtain better results and support to each others. The major outcomes of this research work are to reduce cost, reduce time, maximize profits & quality of the products and also increase customer satisfaction. In this study, various Six Sigma and Lean tools such as Failure Mode & Effect Analysis (FMEA), Regression analysis, Quality Function Deployment (QFD), Exponentially Weighted Moving Average chart (EWMA) and also AHP technique of MCDM approach have been used. Other techniques of MCDM approach such as Grey relational analysis (GRA), fuzzy sets may be applied here. Data have been taken over one month only. If more data was taken it would give more precise results. Here only defective items and their causes have been described and have tried to overcome these. Other type of waste such as motion, inventory, transportation etc. also can be solved by this technique. Value process map can be used for the purpose of identification the activity which does not add value. Non value added activity will need to be identified to apply 5S philosophy or elimination of other type of defects. But here non value added activity have not identified although 5S tools have been suggested to evaluate the work place area. The application of Lean Six sigma in the service sectors in Bangladesh is inconsiderable yet now. So there should some steps to implement this philosophy.

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Hazards and Risks Identification in Shipbuilding Industry- A Case Study.

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Abstract

Shipbuilding industry is one of the oldest and the heaviest production industries all over the world. There are several production processes here which result in hazardous waste and pollutants to the environmental safety and health. With over many shipyards, Khulna Shipyard is one of the ship construction and repair yard in Bangladesh renowned as a heavy industrial zone. Production processes are variable and complicated. Different hazards that occur in shipbuilding industries are identified here and risk evaluation is done in structured and systematic way in order to prioritize decisions to reduce risks to a tolerable level. During this study, all processes are investigated in detail and all wastes and residues are described with effects to workers health and safety. This paper includes the identification of potential hazards in the shipbuilding industry (Khulna Shipyard Limited) using the hazard evaluation checklist, determining the risks, preparing hazard evaluation worksheet and deciding corrective actions.

Keywords: hazard evaluation checklist, hazard evaluation worksheet, risk calculator, workers, safety issue..

1. Introduction

Bangladesh has been since 2005 building and exporting ships to owners from Denmark, Mozambique, Germany, The Netherlands and Finland. In September 2008 Bangladesh has been declared as a shipbuilding nation of international standards. Bangladesh is presently contributing to the shipbuilding industries globally through its exported workforce. There are almost 17 shipyards in BANGLADESH. There is a major manpower requirement to process production in shipyard industry under hard working conditions with hazardous material. Most of the processes such as welding, painting, blasting, fiberglass production has direct effect on workers health, i.e. exposure to volatile organic compounds (VOCs), fumes resulting from burning through base metal and from burning the interior and exterior coatings, as well as a significant generation of NOx gases during welding and cutting processes that are often left in place can cause acute and chronic health problems**.**

Production processes of shipyards may be discussed in two main categories: New shipbuilding and ship repair industry. Production methods of these two divisions are similar. Most of them are risky and potentially hazardous..

Shipyard workers tend to be those working in some of the most risky working environments. This not only adds to the problems of their job but actually makes it a work profile full of need for constant caution. Working as a ship yard worker is not as simple or easy as it may seem. Here are with the help of hazard identification checklist, the different types of hazards are identified. Then preparing hazard evaluation worksheet these hazards with respective risk levels and required measures are shown. The risk calculator for each risk was prepared also.

2. Research methodology

A descriptive type investigation was accomplished in a systematic manner on the workers of KHULNA shipyard, Khulna, Bangladesh. In this study, different variables such as age, skill, job type, injury in different body parts, agent of accidents and types of hazards were taken into consideration. Some focus group discussions also arranged to cross-check the information collected through prescribed questionnaires. The details steps of the methodology to accomplish the objectives of the study are stated in the followings:

2.1 Selection of Sample

For the study, it is tried to cover all the active yards of Khulna shipyard. However, due to variation of active yard number and the availability of the different types of employee in the yard, 5 were covered. From each yard 10 categories of employees (generally Ship In In-charge, Yard Supervisor, Forman, Cutter, Fitter, Cutter Helper,

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Fitter Helper, Wire group personnel, Loader and Cleaner are the common categories of work force pattern in each yards) interviewed.

2.2 Sampling Technique

Sample selected in such a way that collected data fulfill the objectives of the study. As the total number of sample were not so big, but considering the limitations and scope of the study, efforts, availability of concurrence for providing information, purposive sampling technique were used in this study.

2.3 Period of Research

Ship building in Bangladesh is not a continuous business & depends on the availability of ship in the yard. The research work was conducted in the field from October-December, 2012 for data collection.

2.4 Research Instruments

In order to collect information, a preliminary questionnaire was prepared keeping the objectives of the study in mind. After a primary visit and informal discussion with some management staffs and workers in order to develop a format with variables of interest, the preliminary questionnaire was modified and finalized.

2.5Procedure of Data Collection:

Data for this study were collected from the respondents through interviews and were made individually in the ship breaking yard during their work and leisure time with the permission of the yard management as well as contractor management.

2.6Techniques of Data Analysis:

Based on the prepared questionnaire, data on the variables were collected and the information were summarized and finally analyzed in accordance with the objectives of the study to identify various hazards, their sources and relative consequences and risk levels.

2.7Interpretation of the Results:

On the basis of the results, interpretations and necessary recommendations were made for the betterment of this sector in terms of both safety and policy issues at the field level.

3. DATA ANALYSIS

In total 100 workers (25 High-skilled, 11 skilled, 38 semi-skilled and 26 un-skilled) were interviewed. After completion of these data, these are feed into tabular format/figures and then analysis is done in the following subsections.

3.1 Identifying hazards with hazard identification checklist

In this paper hazards are identified from gathered data and summarized in a checklist with their respective sources and exposure. The main hazards of Khulna Shipyard is identified and shown below in the checklist.

Hazard Identification Check-list:

Types of Hazards	Source	Task involved (Who is exposed and when?)
1. Working Conditions	1.1.Cramped spaces for working 1.2.Lack of comfortable environment 1.3.Excessive source of falls 1.4.Dull and dirty work area	Most of the workers working on the shipyard
2.Mechanical Hazard 2.1 Crushing 2.2 Knock with metal parts 2.3 being caught in machine 2.4 Injury due to Automatic machine startup 2.5 Fire	2.1 Crushing in metal cutting machine 2.2 unprotected prolonged machine part / tool 2.3 Unprotected and automatic start of machine 2.4 Automatic start of machine 2.5 Unauthorized use of lubricants	1. concerned worker 2. anyone going through the work area or in work 3. worker and anyone going through the work area 4. worker and anyone going through the work area 5. Concerned worker and surrounding area.
3.Physical Hazards: 1.1 Physical injury to limbs 1.2 suffocation, asphyxiation, pressure 1.3 Hearing problem	1.1.Cramped spaces 1.2.Cramped spaces 1.3 -Working near abrasive blasting or jack hammering operations -Heavy equipment or machinery	People working in the shipyard and all concerned near the source of hazard.

(eardrum rupture etc.) 1.4 Extreme temperatures 1.5 Vibration 1.6 Radiation	-Fuel-powered hand tools and power actuated tools -Compressed air 1.4 -Slag, weld splatter, or sparks -Combustible material closer than thirty-five feet (10.7 m) to the hot work 1.5 -Heavy equipment or machinery -power actuated tools 1.6 -x-ray machines and radioactive sources (radiography) used to test pipe welds, bore-holes	
4.Chemical Hazards: 4.1Asbestos fibers, dusts 4.2 Heavy and toxic metals (lead, mercury, cadmium, copper, zinc, etc.) 4.3Welding fumes 4.4Inhalation in confined and d spaces	4.1 & 4.2 - Materials of broken ships. -Fuel oil and Lubricants -Heavy metals like Tin, Lead and chemical constituents of paints and coatings. -Remnants of toxic chemicals in cargo compartment of chemical carriers. Bilge and ballast water 4.3Oil sludge in oil tankers and oil/bulk ore carrier 4.4Solid waste viz. hydrated/solidified cement	The people at working with chemicals, broken ships, and other relevant sources as well as other people not in direct contact with these sources.
5.Biological hazards: 5.1Toxic marine organism 5.2Risk of infectious diseases 5.3Risk of diseases transmitted by pests, rodents, insects and other animals	-Animal guts: fatal contamination -Soil and water contaminated by non-treated manure -Human contamination due to poor personal hygiene -Bacteria, Virus, Parasites	Almost all people of shipyard and surrounding area.
6.Timing Problem (causing fatigue & mental disruption)	6.1.No fixed timing with extreme nature of job 6.2.Erratic time schedule 6.3. Prolonged working hours without rest.	Workers are the actual sufferers.
7. Slips, falls and trips 7.1 fall from several feet 7.2Slipping 7.3.just fall 7.4. Multiple fractures 7.5.head injuries 7.6 traumatic experiences 7.7.amputations 7.8. drowning	7.1 –unconsciousness -misalignment of lifting equipments and tools - lack of PPE 7.2 -lubricants , oils, and other slippery substances -unconsciousness -work area kept unclean 7.3 - Improper orientation of work area. 7.4 All above 7.5 mainly lack of personal protective equipment. 7.6-7.8 Almost all of above points.	Workers on operation as well as people needs to pass through the work area.
8.Fires and explosions 8.1.Fire explosion 8.2.Electrical Explosion 8.3.Short circuits 8.4.Electric shocks	8.1 - Generating excessive heat near lubricant or flammable materials. -naked flames -lack of sufficient fire extinguisher.	Workers working close to fire and electricity.

8.5.Burns	-Lack of maintenance. 8.2 - Improper maintenance of electrical machinery. - Excessive heat generation 8.3 - Improper circuit design & maintenance. 8.4 - unconsciousness - placing conducting materials near the electricity driven machines & circuits - lack of PPE 8.5- exposure to fire/ flame/ electric shocks.	
9.Asbestosis and Mesothelioma 9.1.Asbestosis 9.2.Mesothelioma 9.3.Cancer	-construction material, exposure to asbestos, Mesothelioma causing cancer	Almost all persons of shipyard especially workers.(long term effect)
10. Improper knowledge 10.1. Unawareness of law 10.2. Safety measures 10.3. PPE	10.1. Unawareness of working procedure & safety law 10.2. Safety measures 10.3. Not using PPE	Workers of shipyard.

3.2 Hazard Evaluation Worksheet preparation

After the hazards and relative sources being identified, their consequences (both existing and potential), frequencies and risk levels were identified based on the consequence analysis technique. In this technique, hazard category is grouped as insignificant, minor, major, severe, fatality and multi-fatalities depending on consequences. Risk is also grouped as risk level A (Multi-fatalities, fatality, severe), B (Severe, major, minor) and C(Insignificant, minor consequences). The necessary tables & hazard evaluation worksheet is shown below.

Table 2: Category of consequences

Category	Description	Examples
I	Insignificant	Bruising, Light abrasion etc
II	Minor	'First aid' (normally reversible)
III	Major	Loss of consciousness, burns etc.(3 days off work)
IV	Severe	Serious injury/damage to health(normally reversible)
V	Fatality	Permanent disability ,Loss of sight, amputation, respiratory damage etc (not reversible)
VI	Multi-fatality	To include delayed effects, catastrophic

Table 3: Risk level

Risk Level	
A	Unacceptable risk and cannot be justified on any ground
B	Risk level reduced to ALARP
C	Risk level is broadly acceptable & no further precautions necessary

Table 4: Hazard analysis study reference/ worksheet

HAZARD ANALYSIS STUDY REFERENCE/ WORKSHEET						
Activity no	**Hazardous events**	**Possible causes**	**Consequences**	**Risk level**	**Frequency**	**Control Measures**
1	Poor working conditions.	1.Cramped spaces for working 2. Lack of comfortable environment 3. Fumes from residual materials in tanks	1. damage to physical and mental health 2. discomfort leads to injury 3. can create both health and fire hazards.(major) 4.Falls and slips	**A** **A** B	1 in 10	1.Ventilation in confined spaces must be supplied mechanically 2. supplied-air respirators must be used

		4.Excessive source of falls 5. Dull and dirty work area 6. extreme concentrations of fibers	5. Long term diseases.	B B		
2	Crushing in metal cutting machine	1.Poor Machine tool condition 2. unsafe clamping of machine parts 3. Problem in electric circuit.	1.Serious crash 2.serious injury 3.damage to health	B B B	1 in 10	1.Routine check up of machines 2.Attention to circuits
3	Knock with metal parts	1.Unprotected machine part 2.Extra prolonged portion of machine 3. Lack of efficient storage of metal parts 4.inattention	1. first aid needed, light abrasion 2.lack of consciousness 3. first aid needed, light abrasion 4. first aid needed, light abrasion	B/C B B/C B/C	In 10	1. Be attentive 2. use safety sign 3. cover machine parts
4	Being caught in machine	1.Automatic start of machine 2.Inattention 3.using inappropriate cloth	1.catastrophic 2.serious injury 3.serious injury	A A/B A/B	1 in 1000	1.Be attentive 2. use safety sign 3. use proper clothing
5	Fire	1.sparks at metal contact 2.sparks in machine tool 3. faulty storage & Unauthorized use of lubricants	1.burns 2.burns 3.permanentdisability /catastrophic	B B A	1 in 100	1.be conscious in lubricating 2. lubricant storage should be far from workplace
6	Injury due to Automatic machine startup	1.Automatic start of machines 2.Lack of safety sign	1.Catastrophic 2.Catastrophic	A A	1 in 100	1.use safety sign 2.protect machine switches
7	Physical injury to limbs	1.Cramped spaces 2. Dangerous working environment	1.Permanent disability	A	1 in 10	1.Ventilation in confined spaces must be supplied mechanically 2. supplied-air respirators must be used
8	suffocation, asphyxiation, pressure	1.Cramped spaces 2.extreme concentrations of fibers 3.Welding in confined spaces can yield high concentrations of toxic airborne contaminants 4. Painting	1. permanent disability 2. Delayed effects	A A	1 in 10	1.potentially dangerous spaces must be tested, inspected, and determined as safe for entry by a marine chemist, industrial hygienist, or other qualified person

		operation generating toxic fumes				
9	Hearing problem (eardrum rupture etc.)	1.Working near abrasive blasting or jack hammering operations 2.Heavy equipment or machinery 3.Fuel-powered hand tools and power actuated tools 4.Compressed air	1.Permanent disability 2.Damage to health	A A	1 in 10	1.Proper protection in ear should be taken
10	Extreme temperatures	1. Slag, weld splatter, or sparks 2.Combustible material closer than thirty-five feet to the hot work 3. insufficient ventilation	1.Burns	B	1 in 10	1.Proper coolant , ventilation system should be used 2.Workplace should be organized in such a way that it should keep combustive material apart from heat generating sources
11	Vibration	1.Heavy equipment or machinery 2.power actuated tools	1.Loss of concentration	C	1 in 1000	1.Machinery should provided with proper maintenance 2.Hydraulic powered tools can be used
12	Radiation	1.x-ray machines and radioactive sources (radiography) used to test pipe welds, bore-holes 2.Toxic rays emitted during various operation	1. Permanent disability/ Irreversible disease 2.Include delayed effects	A A	1 in 100	1. Radiation affected areas should be kept apart from work areas. 2. Safety sign should be used. 3. PPE should be properly designed in case of those areas.
13	Asbestos fibers, dusts	1. Materials of broken ships. 2.Fuel oil and Lubricants 3. Heavy metals like Tin, Lead and chemical constituents of paints and coatings. 4. Remnants of toxic chemicals in cargo	1.All have catastrophic long term effects	A	1 in 100	1.potentially dangerous spaces must be tested, inspected, and determined as safe for entry by a marine chemist, industrial hygienist, or other qualified person 2.PPE must be worn

		compartment of chemical carriers. Bilge and ballast water				
14	Heavy and toxic metals (lead, mercury, cadmium, copper, zinc, etc.)	1. Materials of broken ships. 2.Fuel oil and Lubricants 3. Heavy metals like Tin, Lead and chemical constituents of paints and coatings. 4. Remnants of toxic chemicals in cargo compartment of chemical carriers. Bilge and ballast water	All have catastrophic long term effects	A	1 in 100	1.PPE must be worn 2.Proper ventilation should be provided
15	Welding fumes	1. Confined space 2.Oil sludge in oil tankers and oil/bulk ore carrier 3.toxic fume in welding where surfaces are coated with lead- and chromium-based finishes etc 4.fatal levels of nitrogen dioxide	All have catastrophic long term effects as well as permanent disability	A	1 in 1000	1.Ventilation in confined spaces must be supplied mechanically 2. supplied-air respirators must be used
16	Inhalation in confined and enclosed spaces	1.Solid waste viz. hydrated/solidified cement 2. welding & painting fumes 3. Asbestos	Loss of consciousness	B	1 in 10	1.Ventilation in confined spaces must be supplied mechanically 2. supplied-air respirators must be used
17	Toxic marine organism	1.Materials released during ship breaking 2. Asbestos & other marine particle	All have catastrophic long term effects as well as permanent disability	A	1 in 100	1. Affected areas should be kept apart from work areas. 2. Safety sign should be used. 3. PPE should be worn.
18	Risk of infectious diseases	-Animal guts: fatal contamination -Soil and water contaminated by non-treated manure -Human	Insignificant damage	C	1 in 1000	1. Proper measures should be taken to avoid contamination. 2. Workplace should be kept clean.

		contamination due to poor personal hygiene -Bacteria, Virus, Parasites				
19	Timing Problem causing fatigue & mental disruption	1.No fixed timing with extreme nature of job 2.Erratic time schedule 3. Prolonged working hours without rest.	Major & minor fatigue	B	1 in 10	1.A proper scheduling technique should be maintained and followed 2. Work should be properly/ equally delegated among workers.
20	Falls from several feet	1.Inattention 2.slippery passage 3.using improper /extra cloths 4. lack of safety sign 5.misalignment of lifting equipments and tools 6. lack of PPE	1.first aid needed 2. first aid needed, damage to health 3. first aid needed 4.first aid needed, permanent disability	B A/B B B/A	1 in 10	1.Be attentive 2. use safety sign 3. use proper clothing
21	Slipping	1.lubricants , oils, and other slippery substances 2.unconsciousness 3.work area kept unclean	first aid needed, permanent disability	B/A	1 in 10	1.Be attentive 2. use safety sign 3. keep workplace clean
22	just fall	Improper orientation of work area.	first aid needed, serious injury	A/B	1 in 10	1.Be attentive 2. use safety sign 3. use proper clothing
23	multiple fractures	All causes for slips and falls	Loss of limbs/ serious injury	A	1 in 10	1.Using PPE 2. Be attentive during work. 3. Keep extra workers. 4.provide appropriate training
24	head injuries	Mainly lack of personal protective equipment.	serious injury	A	1 in 100	1.Use Helmets 2.Using PPE 3.provide appropriate training
25	traumatic experiences	Almost all of above slips, falls and injury related causes	Delayed effects	A	1 in 100	All like 23
26	amputations	Almost all of above slips, falls and injury related causes	Delayed effects	A	1 in 100	All like 23
27	drowning	Almost all of above slips& falls	Catastrophe	A	1 in 100	1. Workplace should be kept

		related causes				clean. 2. Necessary boundaries and safety signs should be provided.
28	Fire explosion	1. Generating excessive heat near lubricant or flammable materials. 2.naked flames 3. Lack of sufficient fire extinguisher. 4. Lack of maintenance.	1.Burns 2.Death / catastrophe	B A	1 in 10 1 in 100	1. Keeping lubricant or flammable materials apart from excessive heat generating sources. 2.naked flames should be in secured place 3. Providing sufficient fire extinguisher. 4. Maintenance.
29	Electrical Explosion	1. Improper maintenance of electrical machinery. 2. Excessive heat generation	1.Burns/ shocks 2.Death / catastrophe	B A	1 in 100	1. Maintenance of circuits and electrical equipments. 2. Providing sufficient fire extinguisher. 3. using non conducting material in PPE 4.Skilled operator should only be allowed
30	Short circuits	Improper circuit design & maintenance.	1.Catastrophe	A	1 in 100	As 29
31	Electric shocks	1.lack of consciousness 2.placing conducting materials near the electricity driven machines & circuits 3. lack of PPE	1.Burns 2.Major & Minor shocks 3.Death	B B A	1 in 10 1 in 100	As 29
32	Burns	Exposure to fire/ flame/ electric shocks.	burns	B	1 in 10	As 28 & 29
33	Asbestosis, Mesothelioma & Cancer	-construction material, exposure to asbestos, Mesothelioma causing cancer	Permanent disability	A	1 in 100	1.PPE should be worn by all 2. PPE should be perfectly designed using proper material.
34	Unawareness of law	Unawareness of working procedure & safety law	Major , minor & severe losses	A/B	1 in 10	1.Introducing mandatory training courses on safety & respective rules

35	Lack of Safety measures	Lack of Safety measures of management	Major , minor & severe losses	A/B	1 in 10	1.Introducing safety measures in workplace strongly 2.Strenthening the safety management team
36	Not using PPE	Not using PPE	severe losses	A	1 in 10	1.Using sufficient amount of PPE 2.Following & impelling workers to follow safety laws

The risk levels given here were determined using RISK CALCULATOR concept. The risk level for activity 1 and activity 2 with their respective subcomponents are shown in different risk calculators below.

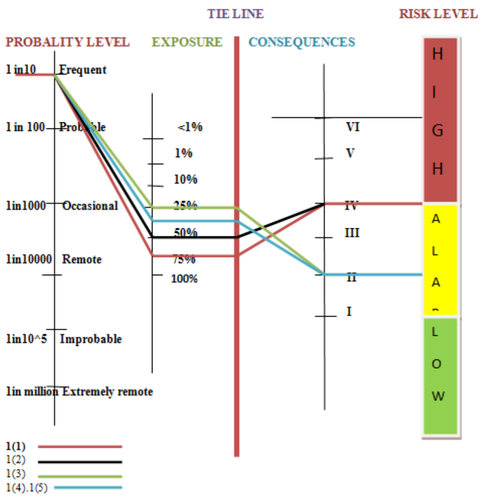

Fig 1: Risk calculator for hazard 1

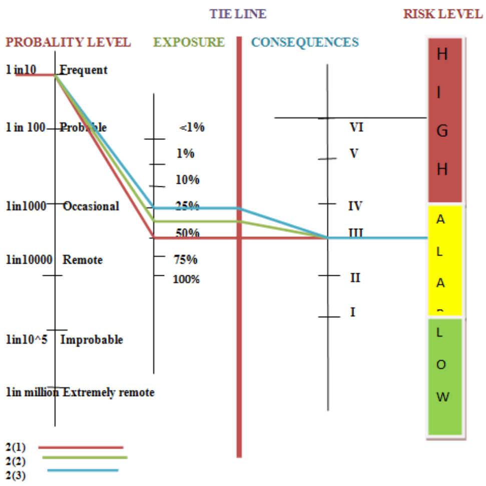

Fig 2: Risk calculator for Hazard 2

Where, respective numbering means-

1(1). Damage to physical and mental health
1(2). Discomfort leads to injury
1(3). Can create both health and fire hazards.(major)
1(4). Falls and slips
1(5). Long term diseases.

2(1).Serious crash
2(2). Serious injury
2(3).damage to health

By preparing such calculators for all hazardous events risk level is determined which is already shown in Table 4 in column no 5.

4.0 Risk reduction measures and Recommendations:

The accidents or hazardous events with their risk levels are shown in the topic above. Certain control measures are shown there also. These are some common measures that can easily be practiced and accident probability decreases. It is shown that almost all hazardous events possess high risk levels with a great frequency which is totally undesirable. By detailed analysis of risk preventive measures and from detailed discussion with qualified workers and management of Khulna shipyard it is found that almost 32% of them believe that the accidents can be minimized by ensuring the use of PPE, 27% mentioned awareness campaign on occupational safety and health issues. Training can play vital role to reduce accident expressed by the 24% respondents. Rest 8% do not have any idea about any measures to prevent or to minimize accident or may be they would not like to mention anything.

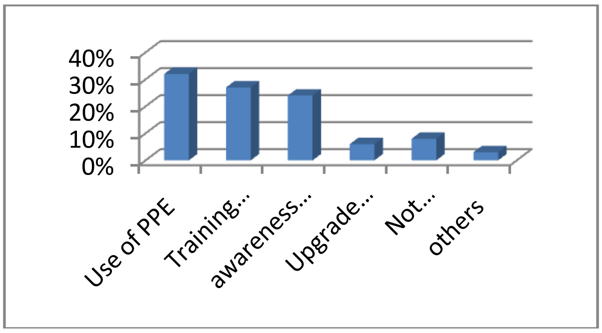

Fig3: Measures of hazard prevention (by interview and questionnaire)

Here the figure shows the percentage of people vote for suggestion along Y axis with respective preventive measure in along X axis.

Khulna Shipyard can follow some recommendations for decreasing their probability of hazardous events as well as risks. Some precautions are mandatory.

1. The first and foremost task is to implementing safety rules and conducting primary trainings to workers as well as all persons of shipyard.
2. Personal protective equipment should be provided and should be ‘declared’ as mandatory in workplace.
3. Safety sign is must in risky areas.
4. Means of escape should be kept clear at all times.
5. Roadways quays, yards where persons or vehicles move or are stationed should be so constructed and maintained as to be safe for the traffic that they have to carry.
6. A suitable housekeeping program as proper material handling and storage equipment, scrap removal etc. should be designed.
7. Necessary fences and guards should be provided where falls generally happen.
8. Sufficient secure storage areas should be provided for flammable liquids, solids and gases as LPG.
9. “No smoking” notices should be prominently displayed in all places containing readily combustive or flammable material.
10. Suitably protected electrical installations should be used.
11. Color codes and symbols may be used.
12. Unauthorized entry should be prevented.
13. OSHA safety rules should be followed.
14. Arrange the workplace layout to minimize noise exposure to workers.
15. If possible replace noisy parts with quieter alternatives.
16. Radiation exposed area should be detected and adequate protective equipment should be used.
17. Regular medical checkup to workers should be arranged.
18. Light should ensure safe working, prevent glare.

11 Background of the study

This job has been taken into account mainly considering the accidents involved in the Khulna Shipyard. Khulna shipyard is easily reachable for anyone resides in Khulna. As we all authors live in Khulna, it is much more convenient to us about studying it. Convenient related researches also made before by some members of IEM department on related topics which influenced us in proceeding our research work.

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Implementation of Production Control Tools in Garments Manufacturing Process Focusing Printing Section.

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Abstract

Traditional printing works in maximum garment industries are facing different problems like low productivity, longer production lead time, high rework and rejection, low flexibility, lower quality product, high non-value added work etc. In this study these different problems were identified by using numerous effective production control tools like process analysis, layout of work station, motion and time study, work standardization etc. The encouraging results after implementing these tools give the way to go forward and thrust to reach at the end point. Some key benefits of this implementation are reduction of excess motion and non-value added work by 50%, decreasing of sample rejection level by 70%, reduction of work level for repairing works by 80%. As a result total processing time for final output is decreased. After the implementation of these tools effectively the result shows the significant improvement of the production than before.

Keywords: *Production control tools, process analysis, motion study, Layout, Time study.*

1. Introduction

In this paper study was conducted in the printing section under a garment manufacturing company. From textile industry fabric comes to printing section for being the output of sewing section. So, printing section plays a vital role for apparel industries. Printing section involve different types of critical work like expose work, color mixing according to recipe, die work, drying and curing work etc. This study introduces general procedures for promoting improvement and production layout as a means of production design.

Background

Due to the increasing labor wage in developed countries, the apparel manufacturing has been migrating from the high wage developed world to low wage developing countries. Garment industries in developing countries are more focused on sourcing of raw material and minimizing delivery cost than labor productivity because of the availability of cheap labor. Due to this, labor productivity is lower in developing countries than in the developed ones.Now the worry is about labor productivity and making production flexible; because the fashion industry is highly volatile and if the orders are not fulfilled on time, the fear for losing business is real.In some cases it has been observed that, in developing countries the garment industries are run as family business lacking skilled personnel as well as capital to implement new technologies for improving productivity and flexibility. Because of this, industries have been running in a traditional way for years and are rigid to change. They don't have much confidence and will towards innovation over old processes. Now the time has come to struggle with global market demand and niche market in garment industries if they want to run it further.The best way to cope with all these challenges is the implementation of production control tools. This will serve our purpose of flexibility and save a lot of money by reducing production lead time, reducing the inventory, increasing productivity, training operators for multiple works, and by reducing rework.

2. Process analysis

Processes are units of divided work which form a series of work. Purposes of process analysis are given below [1]:

(i) To clearly define the order of the processes.
(ii) To clearly define the manufacturing method.
(iii) To make further improvements in each process.
(iv) To provide basic information on improving the performance.
(v) To provide basic information on production design.
(vi) To provide teaching materials for workers and sub-contractor.

For process analysis here a special sign is used (Fig.1).

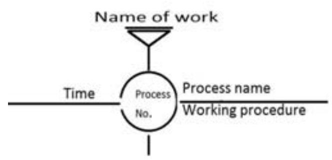

Fig.1. Sign used for process analysis.

Process analysis diagram is shown in figure 2. At first work begin with expose work. Expose is the work to produce die which is the vital equipment of printing work. Process 1 includes adjustment of art design which is sent from buyer. After completing adjustment of design a film is produced with the help of printer which is process 2. In process 3 die is made with combining film and frame with pressing mechanism. After expose work, color related work is carried out. Color composition is one of the most important tasks for printing work. In process 4 color composition work is done according to color pattern. Additional work 5 and 6 are needed for further processing. Gum and tape are sent everywhere of working bed where printing will be carried out. Cutting part is then set on working bed with the help of gum and tape. Inprocess 7 the main value added work is carried out with combining the output of process 3 and process 6.After process 7, decision making stage is come out. In this stage the color on cutting fabric is examined with buyer requirement. If it seems that the color is perfect than it goes for further processing as primary sample and if not then the process 4, 5, 6 would be carried out according to the way described earlier. After getting primary sample, it sends for curing operation which is process 8. After final inspection, final sample is come out in process 9. After getting final sample it sent to buyer for approval. Buyer can reject final sample in two ways, one for misalignment as well as error of design adjustment and another is for error in color mixing. It will be awkward for company if buyer reject final sample for error in design adjustment. Because then the whole process from 1 to 9 would be carried out according to the way described earlier. If buyer reject final sample for the reason of color mixing then process 4 to 9 would be carried out. If buyer approve final sample then it goes for bulk production. In process analysis time study has performed for 72 fabrics for sampling wok and 250 fabrics for bulk production. So, after process analysis it can be said that the process of design adjustment is more sensitive than any other process. Hence more attention should give for design adjustment to reduce sample rejection rate. With proper concerning on design adjustment and color activity, it is shown that the sample rejection rate can be reduced up to 70%.

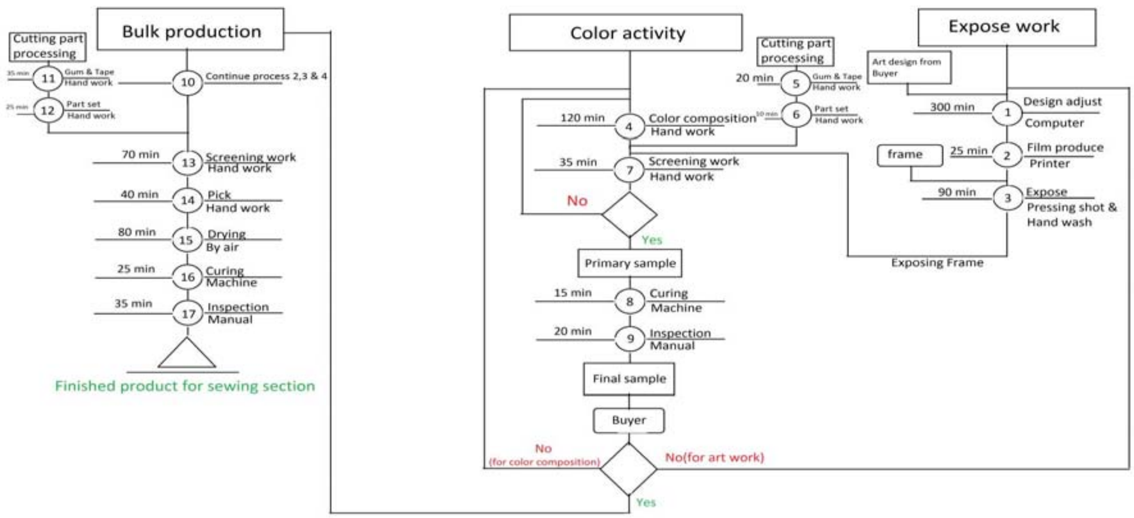

Fig.2. Process analysis.

3. Layout

In developing a layout for an operations system we seek the optimum allocation of space to the components of the production process [7].The need for layout planning arises both in the process of designing new facilities and in redesigning existing facilities.Layout refers to the configuration of departments, work centers, and equipment, with particular emphasis on movement of work (customers and materials) through the system [6].

Building layout

During observation of different process of printing section it is noticed that the orientations of work stations are not good enough. For these reason excess motion and extra work are needed [2]. Types of existing work station on different floor (Fig.3) are given below:

In ground floor only screening work of all over printing is carried out. First floor consist design adjustment room of piece by piece and all over printing. It also consist an expose room for sampling work of both types of printing but used only for the bulk production of piece by piece printing. A cutting work of all over printing output and repair work of piece by piece printing are carried out on first floor. Second floor consist expose room of all over printing. And also bulk production, curing and inspection of piece by piece printing are carried out there. In third floor only bulk production of piece by piece printing is carried out. In fourth floor sampling work of both type of printing and bulk production of piece by piece printing are carried out.

After completing capacity analysis [7] of each floor we propose a new layout besides the existence layout of workstations for each floor of 5 stored building. Types of workstation on different floor in proposed layout (Fig.3) are given below:

In ground floor, expose room and screening work of all over printing both will come together. Because of sufficient space curing, inspection, repair work of piece by piece printing and also cutting work of all over printing will come together on first floor. In second and third floor only bulk production of piece by piece printing will be carried out. Fourth floor will be accomplished with design room and sampling work of both type of printing. Fourth floor also consist an expose room which will be used for sampling work of both type of printing but only for the bulk production of piece by piece printing.

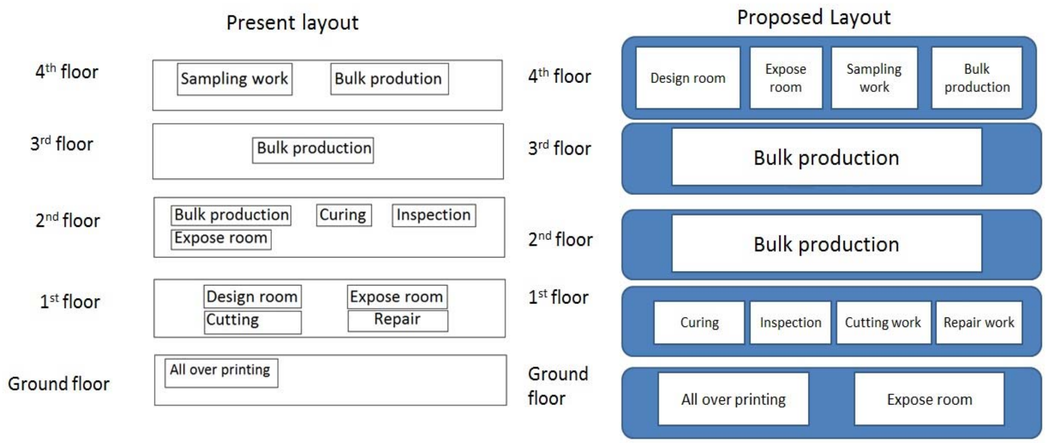

Fig.3. Layout of workstation in different floor.

The results after implementing the proposedlayout are given below:

(i) It minimizes the effort of workers to carry the exposed die for sampling work.
(ii) It remedies the difficulties for workers of lifting exposed die.
(iii) It reduces extra motions and forms linear flow of material by eliminating circular flow.

It is shown that the proposed layout causes reduction of non-value added work by reducing extra motion, transportation distance, idle time. It also increases worker reliability, smooth material flow.

Curing process layout

In curing process for existing layout operators require extra motion for picking and disposing fabrics from working table because of backward movement [2]. Some operators are waiting beside the input table during idle time. Input and output box are not efficiently distributed. More operators required for this process.It is shown that a smooth production flow is achieved with minimum interruptions after implementing the suggested layout [3] for curing process. It also causes better working condition, less processing time and fewer workers to accomplish the task.
The existing and the proposed layoutfor curing process (Fig.4) are given below:

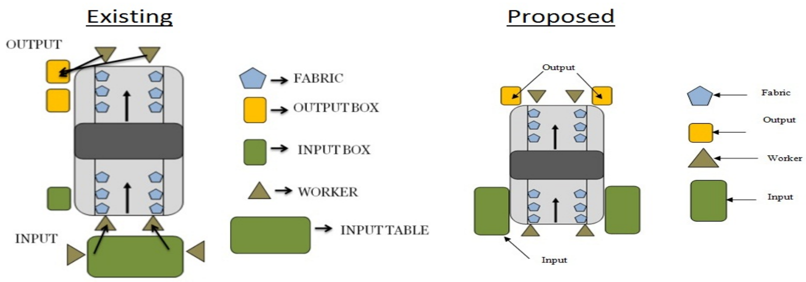

Fig.4. Existing and proposed layout of curing process.

Inspection system layout

In existing layout of inspection involved larger processing time. Works cannot be distributed properly among workers because of incorrect layout of inspection system. Extra workers are needed for the inspection system. Because of communication gap it causes less flexibility for workers [4]. The existing and the proposed layout for inspection system (Fig.5) are given below:

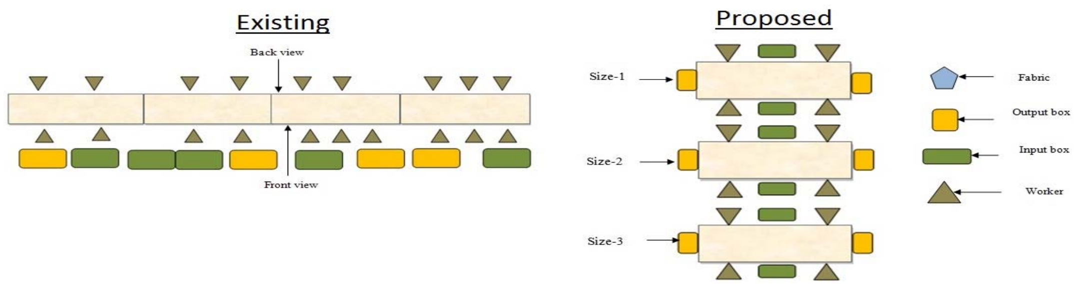

Fig.5. Existing and proposed layout of inspection system.

By implementing suggested layout for inspection system it is shown that work can be easily distributed among worker and it also reduce the number of worker needed to accomplish the inspection work. It also increases reliability by reducing communication gap among worker.
The improvement of the existing layout of work station, curing and inspection system causes reduction of non-value added work by 50%.

4. Work study

Work study is a generic term for those techniques, method study and work measurement which are used in the examination of human work in all its contexts. And which lead systematically to the investigation of all the factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement. Work study forms the basis for work system design. The purpose of work design is to identify the most effective means of achieving necessary function [9].

Transportation

The traditional transportation systems for drying included the following steps:

(i) First one person separates the fabric from table which is attached with table by gum.
(ii) Another person brings a stick which is used to carry the fabric.
(iii) Then a person put the fabric on the stick to carry in the drying area.
(iv) Then the Fabric stays in drying area more than 30 minutes. The drying time is varying due to some reasons such as weather, air circulation system, color combination etc.
(v) Then another person takes the sticks with fabric from drying area and delivers the fabric for inspection.

There are some problems in traditional transportation system. The Problems are given below [3]:

(i) Need extra times to separate fabric from table.
(ii) Need lot of equipment to carry the fabric.
(iii) Need extra workers
(iv) More waiting time
(v) Not proper utilization of man, equipment and time.
(vi) Material flow is not smooth

These difficulties can be eliminated by using conveyor system instead of traditional transportation system. Conveyor system will also increase production rate as well as overall efficiency [8].
The designed conveyor for drying (Fig.6) andthe working procedures of that conveyor [8] (Fig.7) are given below:

(i) A U shaped conveyor system will be established upon the working bed.
(ii) U shaped conveyor will consists of lot of hanker to carry the fabric.
(iii) After completing the printing of fabric a worker will take the fabric from bed and will put it on hanker of the U shaped conveyor.
(iv) Then hanker will goes to the drying area according to the path of conveyor system.
(v) Then another empty hanker will come upon the bed and after that same procedure will be repeated.

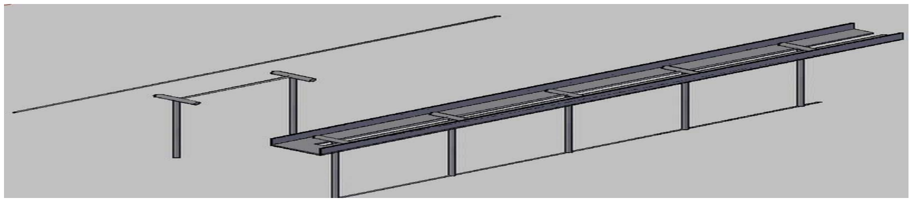

Fig.6. Designed conveyor for drying process.

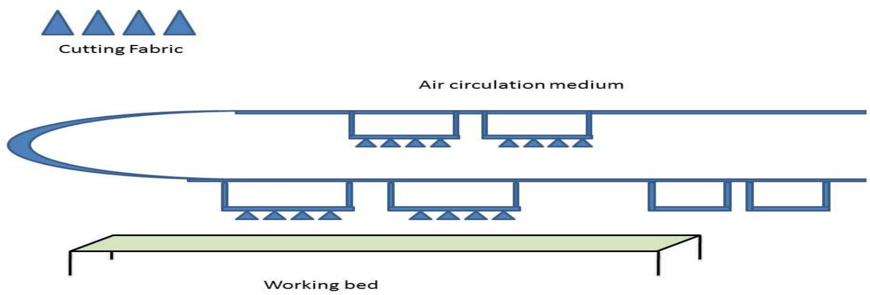

Fig.7. Working procedure of designed conveyor

Delivery section

After the drying section the fabric goes to the inspection section. In this section the fabric inspected by workers to maintain the quality and find out the defects. If find any disorder of the color or printing problem or another defects then the fabric goes to repairing section to repair the defects. And the good product goes to delivery section to deliver the output toward sewing section.
The procedures followed for deliver the output are given below:

- (i) After completing the inspection the fabric put on a basket according to their size.
- (ii) Then the baskets are sent to the delivery section.
- (iii) In delivery section a worker transfer all the fabric into a sack.
- (iv) Then a worker tied the bundle
- (v) Then it stored to deliver for sewing section.

Problems involved in traditional delivery system of final output are[3]:
(i) It needs extra time to transfer the fabric from basket.
(ii) It need extra worker to transfer the fabric from basket and one worker in idle.
(iii) When a worker tied the bundle the quality of the fabric may be hampered.
(iv) Face lot of waiting time to deliver the sewing section.

These problems can be eliminated by introducing a lift system which will carry the final output for sewing section just after the inspection stage. By introducing lift system for deliver the output reduce the time needed for transportation and also reduce the number worker needed to accomplish the task. By the utilization of gravity it also increases flexibility for worker [5].

5. Repair work:

Repair work means doing the job over again, because it wasn’t right the first time.Set up procedure of the fabric has identified as the main cause for repair work. The steps involved to set a fabric on working table are given below:

- (i) At first a worker sweeps the working bed by gum.
- (ii) Then a worker distributes the Tape.
- (iii) Then a worker distributes the fabric.
- (iv) Then a worker attached the tape and fabric on the table.

After two or three cycle of printing, it is necessary to clean the table for next cycle. In this situation it produces a lot of dirt due to gum and tape. When it is cleaned it may be present in the air with small amount which may be fall in the fabric in next cycle and then it causes poor printing quality. For these reason repairs work is needed to improve the printing quality of the fabric. It is shown that using of wax instead of gum and tape on working table causes reduction of repair work by 80%.

6.Summary and conclusion

The research consists of conducting time and motion study of printing operations. By doing this, printing operations will be standardized and production targets for each operation will be fixed. Secondly, working condition, space utilization increases and also processing time, number of workers decreases by the implication of new layout. In the research the unit layout has been implemented to increase the productivity. Similarly, the sitting operations have been converted into standing operations for the better movement of operators in between the machines, from the perspective of work balancing and uniform work load distribution. Finally, flexibility in production is achieved by the reduction of work in progress and complexity in material flow.

7. Recommendation for Future Research

In this research, only the printing operations are standardized due to time limitation. But this work can be extended forotheroperations like stitching, storing etc.This will minimize the duplication of work and it is easier to calculate standard time of new style by reallocation of some operations over existing. In this research conveyer system with hanger has been suggested for drying process, but it is necessary to be reviewed some other way also which will be profitable for long period. It is also important to be reviewed some other material instead of wax for table to reduce repair work more effectively.

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Paper ID: IE-21

An Efficient Supply Chain in Apparel Industry

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Abstract

A supply chain is a sequences of processes and flows that take place within and between different stages and combine to fill a customer need for a product. The apparel industry has, like most other industries quickly started using the Internet to gain improvemeoments in the efficiency and effectiveness of operations and marketing. In this paper, a proposed supply chain model has been developed which can save most unnecessary cost of the apparel supply chain over the traditional supply chain. In this paper, it has moreover been analyzed that 35% efficiency improved after implementation of proposed model in apparel supply chain.

Keywords: *supply chain, network, efficiency, apparel industry.*

1. Introduction

One of the main challenges of today's apparel manufacturing industry is to be efficient and contribute to high effectiveness, i.e. customer satisfaction .In the competitive market, Information is ever more available through e-business, customer relationship management (CRM) and supply- chain management (SCM) solutions, making it possible to serve buyers individually with customized goods [1].

Operation manager is strictly monitored to achieve factory plan efficiency in order to match the shipment date as well as the company profit goal in garments industry. Practically, there is a gap generated between plan and actual efficiency in account of some inappropriate processing, which will be discussed in the next chapter echelon wise of the supply chain in a typical garment's manufacturing industry. The main reason is to magnify the inefficiency level; involving uneducated people for long times in garments manufacturing industry. Some of the people are leading mid- level management among unqualified manpower. Garments industry now a days looking for establishing industrial engineering section for finding out the actual reasons and take possible action to overtake such as kind of issues, which greatly bring an effect in efficiency. The efficiency is therein described as a compound evaluation of quality, delivery, cost, and overall capability that is not only planned and reviewed in the relationship but also a measure of the relationship. Thus, in this research, an initiative has been taken to improve efficiency of garments manufacturing organization. Textile and apparel supply chain in the U.S. consists of about 22,000 companies and employs about 675,000 people analyzed by U.S. Census Bureau (2004a). U.S. apparel industry has been in a transition over the last 20 years. Imports from lower wage countries and retail consolidation forced U.S. manufacturers to look for other ways to remain competitive: quality and flexibility. Physical proximity and advances in information and manufacturing technologies enabled U.S. manufacturers to accept retailer orders closer to the season and replenish their stocks frequently during the season. However, retailers continue to source more and more of their merchandise from overseas with the cost of having to make risky inventory decisions. However, buyers are looking to buy the high quality garments with low or competitive cost with the delivery status must be on time. That is meant, the buyer is demanding to follow QQD in their manufacturer. It can be illustrated that Q for “Quantity”; Q for Quality and finally D for just time “Delivery”. As efficiency can be defined that it is quantity matrix. So, in this context, buyers will place order to the manufacturer who can meet the QQD and who can show proof that his supply chain is efficient in order to deliver their products to the buyer on time. Only considering co-efficient supply chain buyers are placing the orders to the low cost countries rather than US market. In this research, an apparel supply chain model as well as smooth supply chain network has been developed to retain in the competitive market.

1.1 Objective of the research

- To identify the actual cause of lower efficiency in apparel manufacturing organization.
- To improve efficiency of the selected garments manufacturing organization by implementing the proposed chain model.

2. Literature review

“Supply Chain Management” was revealed in the late 1980s, and then it was exposed to all in 1990s [2]. Before of that time „Supply Chain Management was used as different terms like- “logistics” and “operations management” in the business fields. Once up on a time, supply chain management was considered just like a concept. Implementation of this concept was very difficult as there were some necessary components in the total chain to connect with each other. The focal part of the barrier to full supply chain management was the cost of communication and coordination among the many independent suppliers in each supply chain. An entire supply chain covers the area from the creation of raw materials to the delivery of the finished consumer goods. So, many supply chains are involved in the entire supply chain of a product up to the ultimate delivery stage. This is why; it was difficult to link up actively all the supply chain points considered [3]. But day by day companies are being interested to implement the supply chain concept in their business for three environmental changes. First, development of the communication technology has made easier the process to communicate between members of the supply chain. Second, new management models have been developed that are being used by the supply chain members to simplify the coordination of tasks. Third, for the development of highly trained work-force, it has become easier to assume the responsibility, make decisions quickly and take required actions to coordinate the supply chain. These three changes are encouraging the companies to take the challenges in the competitive market through the utilization of supply chain management concept. In this paper, developed a proposed supply chain model for apparel manufacturing industry which can save the time and cost of the communication through whole apparel supply chain.

Time-based management and the relationship between speed of operations and efficiency has been one of the key issues in operations management literature during the 1980s and 1990s and he has also described how time has become one of the most important sources of competitive advantage in manufacturing industries [4].The background for “Japan’s secret weapon” or “lean thinking” by illustrating how the competitive advantage of Japanese manufacturing industry evolved from low labor costs—through scale-based strategy, focused factory and flexible manufacturing—to time-based competitive advantage in order to expedite the supply chain efficiency premeditated [5] . Uncertainty and the nature of the forecasting problem have a considerable impact on the supply chain structure. The first step in devising an effective supply chain is to consider the nature of the demand for the products. If products are classified on the basis of their demand patterns, Many recent texts emphasize that the product, manufacturing process and supply chain structure need to be considered together to create a capability for mass customization; different industries require different approaches for customization considered [7].

3. Industrial Practice

Garments manufacturing organization is looking for enhancing efficiency in their internal supply chain echelon i.e. cutting, sewing and finishing. The inefficiency of apparel supply chain is started from cutting section. This is the key echelon of apparel supply chain. Cutting department receive input from store, they keep it on the cutting floor for “Relax”. After keeping on relax the fabric about 6 hours, cutting people keep it on the cutting table and ready for cutting. The cutting departments have the capacity of supplying input into sewing section, but maximum time they cannot feed input due to improper flow of material which is caused by the in-efficiency. Consequently, sewing department fall on pressure, they have to complete the 5 days production within 3 days because of the delay of the cutting section. In this case, shipment date become sturdy to meet and the company cannot keep the buyers commitments. It greatly hampers the company's reputation. For example :

Order confirming date on 30th June
Shipment date on 15th august
Total lead time :47 days
Order quantity :9800 pieces
Required fabric : 2814 kgs
Embellishment status: Embroidery
Production target : 100 pcs /hour
Working hours : 8
Allocated line : 02

For meeting this shipment sewing should complete 4000 pieces per day. But if the cutting department delays at least 6 hours to send input into sewing department, the shipment cannot be met. If the working hour is 8 hours, then the production manager takes decision about overtime for production and meeting the shipment date. It enhances the product cost whereas the amount of profit is being reduced in order to pay for overtime of workers.

After receiving the input from cutting department, input has to be re-cut and the shipment date cannot be met. Before entering the input into sewing line quality was not checked. So, after the production of a major quantity, quality related problem of cutting department is occurred. At that time sewing department is bound to discontinue production of that particular line and send information into cutting department. The cutting department ensures inputs quality again and send it to sewing department for starting the production process. It takes time that obstructs the production and shipment being tight. Also when operator and quality section of the line make defective product check it out and resend the defective item to the respective operator. The operator takes time to make the correction of this product. For this reason in this process the bottleneck may be happened which limits the total production and target of line and also to make the shipment delayed.

For delay of production from the sewing and cutting departments, finishing department hindrance delay by default. So, shipment cannot be done on time. Inventory is created in the finishing section in spite of having the capacity to make finishing on time they cannot complete timely because of problem faced by predecessor department. In the finishing section, they receive finished goods from sewing section and they also do not check it out on the account of hammering on them to meet shipment on time. So after finishing they make packaging the finished goods where some product remains unchecked. When the buyer checks the lot and unfortunately if the unchecked product is being disqualified then full lot can be re-checked. This news is very pedantic for company. The above mentioned reason can cause for decreasing efficiency in apparel chain.

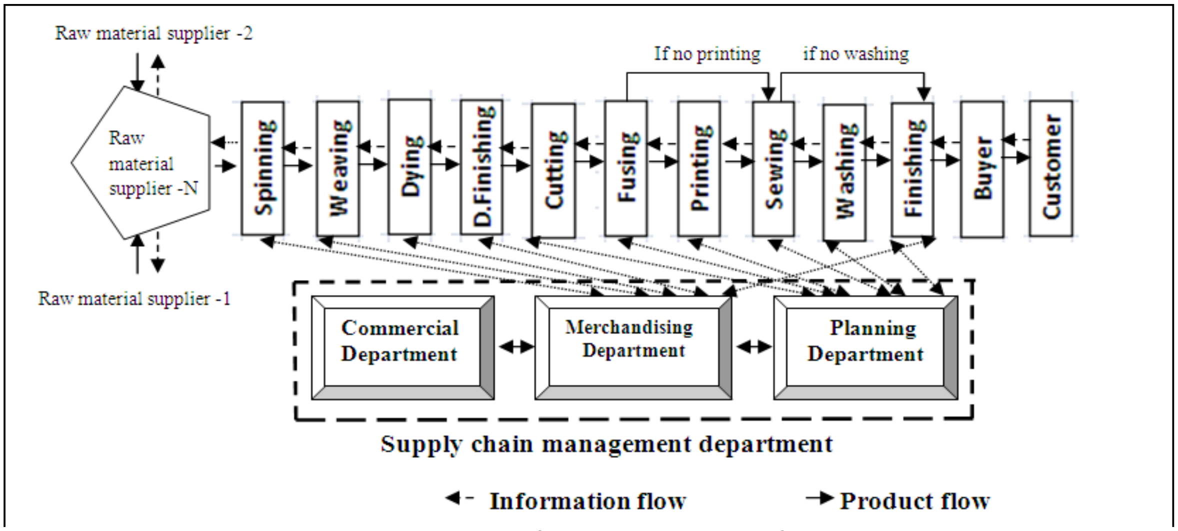
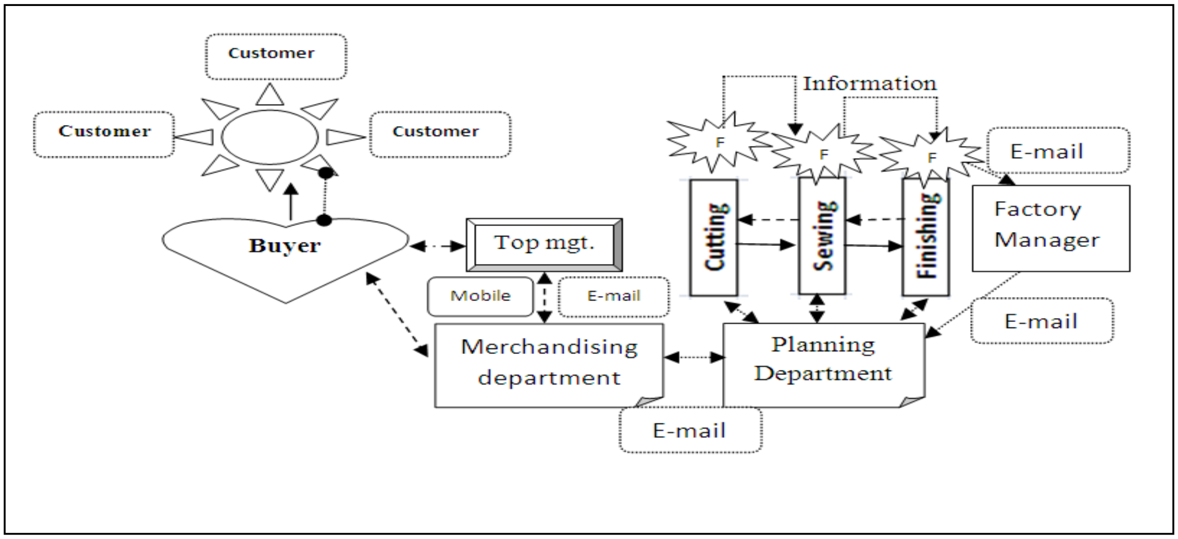


Fig.1 Supply chain of a typical apparel manufacturer



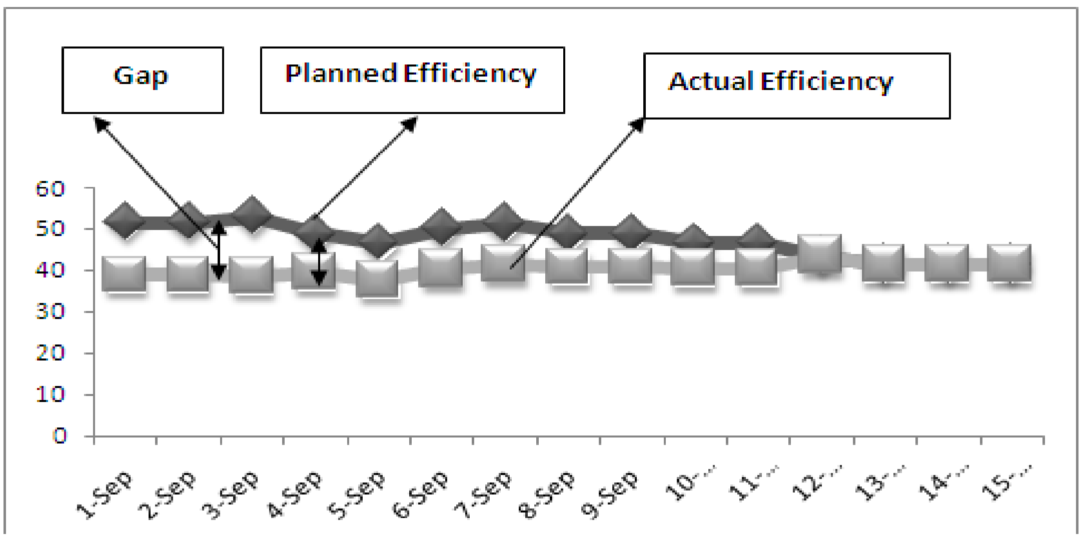


Fig. 3: Date vs. Efficiency in Cutting

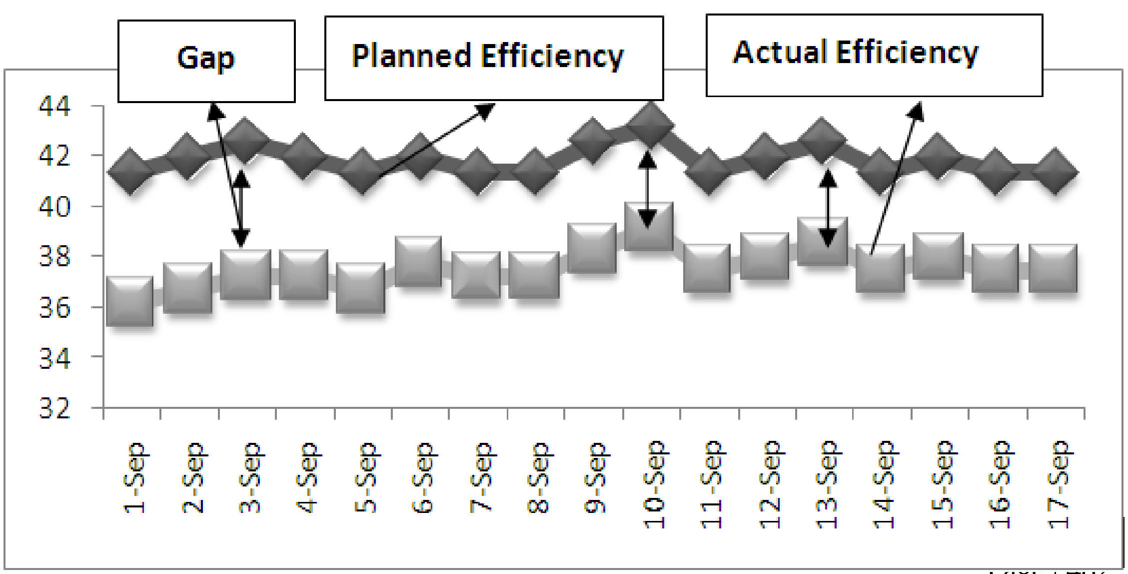


Fig.4 : Date vs. Efficiency-Sewing

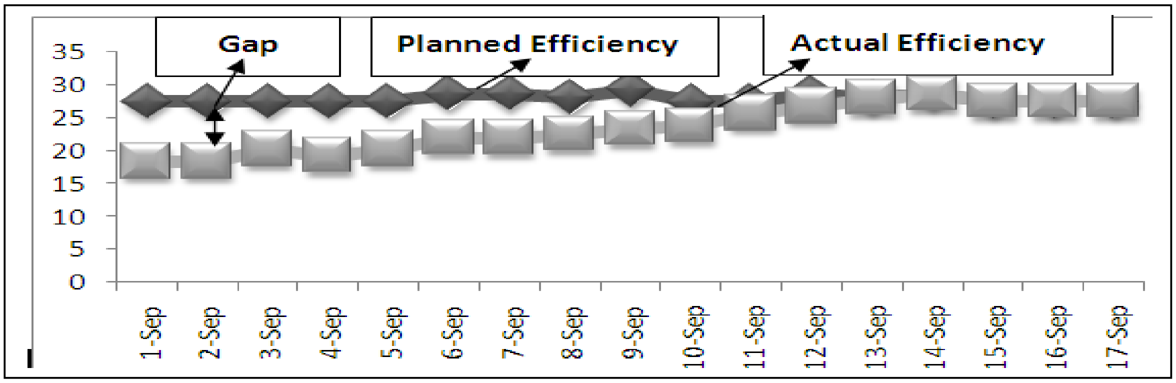


Fig. 5 : Date vs. Efficiency-Sewing

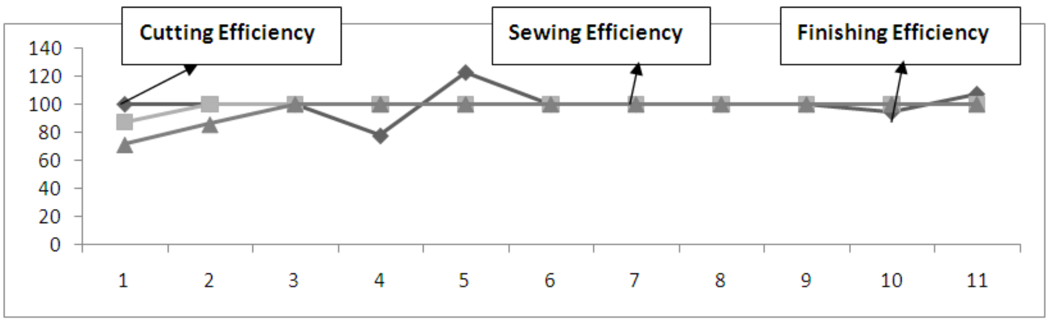


Fig. 6: Improved Efficiency of Apparel Supply chain

4. Results & Discussions

Apparel manufacturing organization is harassed to make the downy supply chain in order to deliver garments to the buyer on time as well as gain the profit margin by reducing unnecessary waste or from the chain. Pragmatically, we have shown from the figure 3, 4 & 5, supply chain department cannot reach their goals. Figure 4 depicted that there was a huge gap formed between plan and actual efficiency of cutting section. The fallout of efficiency of the cutting department alarming to the supply- chain department that shipment will not be met on time whereas sewing line was waited for the inputs which also ensured that plan productivity target was nil as input was not available on time. It was the colossal waste in the apparel supply chain which greatly an impact on efficiency. Figure 4&5 has further depicted the scenario of the efficacy gap for sewing and finishing section. It was clear that owner of the apparel manufacturing organization in a dilemma to take a decision, whether can be met delivery date; they have to decide for the air shipment. Resulting in, this leads to massive cost for managing the supply chain. However, this practice eventually affected on overall chain profitability, which is the core objectives of the supply chain. It was too sturdy to analyze the whole supply chain inefficiency and strived to mitigate the delivery cost as well as improving the efficiency level of apparel supply chain and co-ordinate with all the chain members. In this research, we have developed a supply- chain model shown in figure 2 in order to overcome the inefficiency. This model has described that the decision making system while the proficient supply chain was being impeded, and it will ensure about the saving of air cost because of information visibility among the chain partners. The anticipated chain model has been developed in order to make the smooth supply chain. The outcome has shown moreover, in table 1 and figure 6. The efficacy level was very near to the acknowledged plan efficiency in the three echelons in the apparel supply chains. The result was illustrated in table 1 that shipment date for a typical style was October 9, where the order quantity was 9600 pieces for a specific buyer. It has shown that 98% work completed on October 8. The supply -chain department can take a decision without any troubles to inform shipping line to confirm the delivery for sending garments to the buyer on time.

5. Conclusions

Efficiency is the major points in any manufacturing organization in order to stay alive in competitive market. In this research, to make the efficient supply chain in apparel manufacturing industry was giant challenge. The study has been analyzed the real conditions of apparel supply chain while inefficient supply chain. Implementing the proposed apparel supply chain model was more challenging job in the typical apparel manufacturing organization as the middle management put down antique idea regarding the efficiency of the organization. It apparently seemed that the gap between the plan and actual efficiency was vast but from the figure 6 it was clarified that due to make efficient supply chain in a typical apparel manufacturing organization ultimately there were no adverse effect on efficiency in the three key tier of the chain gradually. After implementation of proposed supply chain model in the reputed apparel industry in Bangladesh, the revenue figure has been increased and objective of the chain was being achieved. An essence of the philosophy has been implemented between three branches of the chain and has received immense success. This paper showed vital model for making smooth apparel supply chain which improves efficiency of the company, maximize overall profitability for overall value chain in apparel manufacturer, reduces cost of manufacturing and finally helps to meet the on time delivery of products to the respected customer. See appendix A, B and C for analysis of the effect of efficiency for cutting, sewing and finishing respectably. The top management must be sympathetic before implementing such kind of proposed supply chain model in apparel manufacturing organization. Future work can be done by making efficient entire apparel supply chain shown in figure 2 in the textile and apparel industries.

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Simulation and Optimization of Natural Gas Processing Plant

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Abstract

Natural gas (NG) is naturally generated gas mixture lying under the earth and collected from gas well directly. Natural gas emits little amount of pollutant when it burns and is buried around the world widely. Because of these properties, NG is receiving attention as low-carbon, eco-friendly alternative fuels. It is the major energy source of our country for both domestic and industrial operations. Natural Gas processing plant converts gas reservoir's raw natural gases to produce sales gas, which is highly demanded commodity in the market. Sales gas specification typically required processed gas with small amount of water to avoid pipelines corrosion, avoid hydrates formation in the gas and for their immediate industry consumption. The plant is equips with gas dehydration system facilities to absorb water from raw gas and most of the gas dehydration processes are using tri-ethylene glycol (TEG) process unit. This article presents a generalized methodology of a natural gas process plant simulation and optimization taking a typical gas process plant in Bangladesh as an example. In this study, a steady-state simulation of the process plant was performed using Aspen HYSYS. The work aims in achieving two main objectives, which are carrying out plant simulation model using Aspen HYSYS software and reasonable optimizing of gas dehydration system.

Keywords: *Natural gas plant, Simulation, Hysys, Process optimization, Separation.*

1. Introduction

The last 35 years have seen a remarkable growth in the contribution of gas to the world's total primary energy demand [1].The primary use of natural gas (NG) is as a fuel; it can also be a source of hydrocarbons for petrochemical feed stocks [2]. Its clean burning and ability to meet stringent environmental requirements have raised the demand for natural gas [3]. Much of the world's gas reserves are in offshore fields [4]. Natural gas is the gas obtained from natural underground reservoirs either as free gas or gas associated with crude oil. It generally contains large amounts of methane (CH_4) along with decreasing amounts of other hydrocarbons. Impurities such as H_2S, N_2, and CO_2 are often found with the gas. It also generally comes saturated with water vapor. The principal market for natural gas is achieved via transmission lines, which distribute it to different consuming centers, such as industrial, commercial and domestic. Field processing operations are thus enforced to treat the natural gas in order to meet the requirements and specifications set by the gas transmission companies. The main objective is to simply obtain the natural gas as a main product free from impurities [6]. There are quite a few treating processes available for removal of acid gases from natural gas, including Chemical solvents, Physical solvents, Adsorption Processes Hybrid solvents and Physical separation [5]. In addition, it should be recognized that field processing units are economically justified by the increased liquid product (NGL) recovery above that obtained by conventional separation. Different techniques are used for dehydration plant. Absorption (Glycol dehydration process) is one of the easy and vigorously used processes. In this process, a hygroscopic liquid is used to contact the wet gas to remove water vapor from it. Triethylene glycol (TEG) is the most common solvent used [6]. Process simulation has become an essential tool for operators and engineering firms in the oil & gas industry. Simulators can better support process design, debottlenecking and optimization when used to their full potential. Aspen HYSYS is the market-leading process modeling and simulation solution with a proven track record of providing substantial economic benefits throughout the process engineering lifecycle. It brings the power of process simulation and optimization to the engineering desktop, and delivers a unique combination of modeling technology and ease of use [7].

In order to reduce the operating costs of a plant, much effort is put to find the optimal design condition of the process though optimization studies. Optimization has many applications in chemical, mineral processing, oil and gas, petroleum, pharmaceuticals and related industries. Not surprisingly, it has attracted the interest and attention from many chemical engineers for several decades. Optimization of chemical and related processes requires a process modeling and optimization along with control characterizes the area of process systems engineering (PSE), important in chemical engineering with a wide range of applications. In this simulation work, use of Triethylene glycol (TEG) has been investigated for a variety of cases using a process simulation program HYSYS in steady state.

2. Effect of impurities found in natural gas

Field processing operations of natural gas, which is classified as a part of gas engineering, generally include the following:

1. Removal of water vapor, dehydration
2. Removal of acidic gases (H_2S and CO_2)
3. Separation of heavy hydrocarbons

The effect each of these impurities has on the gas industry, as end user, is briefly outlined.

Table 1. Effect of natural gas impurities [6]

Water vapor	H_2S and CO_2	Liquid Hydrocarbons
It is a common impurity. It is not objectionable as such ➢ Liquid water accelerates corrosion. ➢ Solid hydrates, made up of water and hydrocarbons, plug valves, fittings in pipelines, and so forth	Both gases are harmful specially H_2S which is toxic if burned. It gives SO_2 and SO_3 which are nuisance to consumers ➢ Both gases are corrosive in the presence of water. ➢ CO_2 contributes a lower heating value to gas	Their presence is undesirable in the gas used as fuel ➢ The liquid form is objectionable to burners designed for gas fuel ➢ For pipelines it is a serious problem to handle two-phase flow; liquid and gas

3. TEG process

Most natural gas producers use Triethylene glycol (TEG) to remove water from the natural gas stream in order to meet the pipeline quality standards. This process is required to prevent hydrates formation at low temperatures or corrosion problems due to the presence of carbon dioxide or hydrogen sulfide (regularly found in natural gas). Dehydration, or water vapor removal, is accomplished by reducing the inlet water dew point (temperature at which vapor begins to condense into a liquid) to the outlet dew point temperature which will contain a specified amount of water. Absorption of water vapor in the TEG is the common method. The wet gas is brought into contact with dry glycol in an absorber. Water vapor is absorbed in the glycol and consequently, its dew point reduces. The wet rich glycol then flows from the absorber to a regeneration system in which the entrained gas is separated and fractionated in a column and reboiler. The heating allows boiling off the absorbed water vapor and the water dry lean glycol is cooled (via heat exchange) and pumped back to the absorber [8].

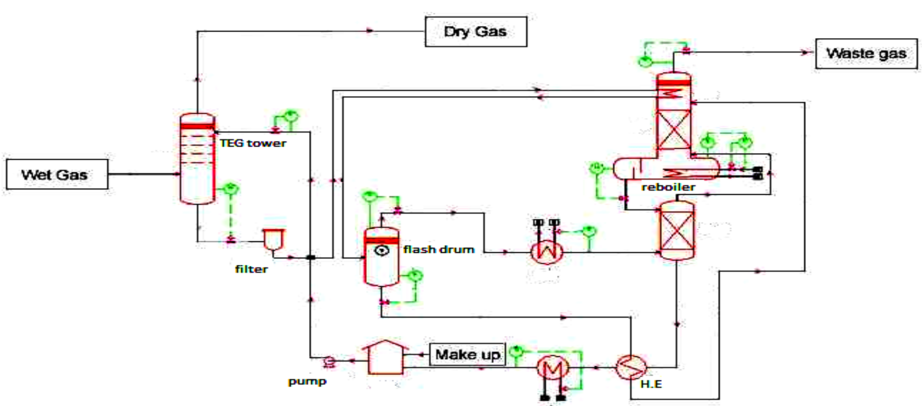

Fig. 1. Schematic diagram of a TEG dehydration type NG plant.

4. Simulation of gas processing plant

The simulation model is developed on Aspentech HYSYS 3.2.The type of fluid package selected is peng-robinson Package. TEG used as an aqueous absorbent to absorb water from gas streams. Before entering the contactor, the gas is passed through an inlet separator where entrained droplets of liquid are removed from the gas stream. Specification of feed gas is shown in figure 2.

Stream Name	well
Vapour / Phase Fraction	0.9949
Temperature [C]	86.67
Pressure [kPa]	2.925e+004
Molar Flow [kgmole/h]	1096
Mass Flow [kg/h]	1.873e+004
Std Ideal Liq Vol Flow [m3/h]	59.74
Molar Enthalpy [kJ/kgmole]	-7.925e+004
Molar Entropy [kJ/kgmole-C]	139.4
Heat Flow [kJ/h]	-8.683e+007
Liq Vol Flow @Std Cond [m3/h]	<empty>
Fluid Package	Basis-1

	Mole Fractions
Nitrogen	0.003674
CO2	0.004865
H2S	0.000000
Methane	0.947609
Ethane	0.025319
Propane	0.004269
i-Butane	0.001191
n-Butane	0.000596
i-Pentane	0.000298
n-Pentane	0.000199
n-Hexane	0.000796
n-Heptane	0.000497
n-Octane	0.000298
n-Nonane	0.000298
n-Decane	0.000895
TEGlycol	0.000000
H2O	0.009193

Fig. 2. Conditions and compositions of raw gas coming from well.

In simulating the processing plant, natural gas with condensate and water is drawn from one well. The gas composition of this field is used. The industrial data are obtained for the simulation. Then the gas pressure is reduced and is passed through a water bath heater H-101 to heat the gas to prevent hydrate formation. Then the outlet streams of the heaters are passed through pressure reduction manifold VLV-101 to the inlet two phase separators (V-101) and then the TEG tower inlet scrubber. The pressure control valve (VLV-101) controls the pressure of the separator (V-101). The vapor phase (stream 8) from the separator goes to the T-101 scrubber and then is passed through the bottom of dehydration unit (TEG contactor) to dehydrate the gas. Lean TEGlycol enters from the top of the contactor (stream 33). The water is absorbed from gas by glycol and water free gas is then allowed to gas/glycol heat exchanger (E-202) to get heat from the hotter glycol. The gas then goes to fuel gas scrubber (V-104) for the final separation of gas-liquid before going to sales line. The rich glycol from T-101 contactor goes to the energy exchange pump (stream 17) and pressure dropped remarkably. Here VLV-100 denotes the pump as a pressure reduction device. Then the rich glycol goes to reflux condenser (E-206), then to glycol flash separator V-204 (another three phase separator) to remove condensate from gas. To be preheated the rich glycol (stream 24) enter into a Plate and Frame exchanger and then to the TEG reboiler through packed bed still column. The glycol heated here upto about 400 ^{o}F at almost atmospheric pressure. Water vaporized from glycol and from the top of the reboiler (stream 24) it goes out to V-206 via cooling system. The lean glycol circulates from the reboiler to E-201 (stream 28) for necessary cooling and then pumped by P-102 to TEG contactor via E-202 and E-205 where it's cooled to desire. The liquid consist condensate plus water from the bottom of V-101 goes to three phase separator V-102 and it's separated as water (stream API), condensate (stream 38) and gas (stream 36). Inlet of V-102 is the mixer of different stream of hydrocarbon liquid MIX-103. Fuel gas is collected from TEE-101 (stream 15), V-102 (stream 36) and V-204 (stream 21). Then it's gathered at MIX-105 and the buffered at V-103 for further distribution.

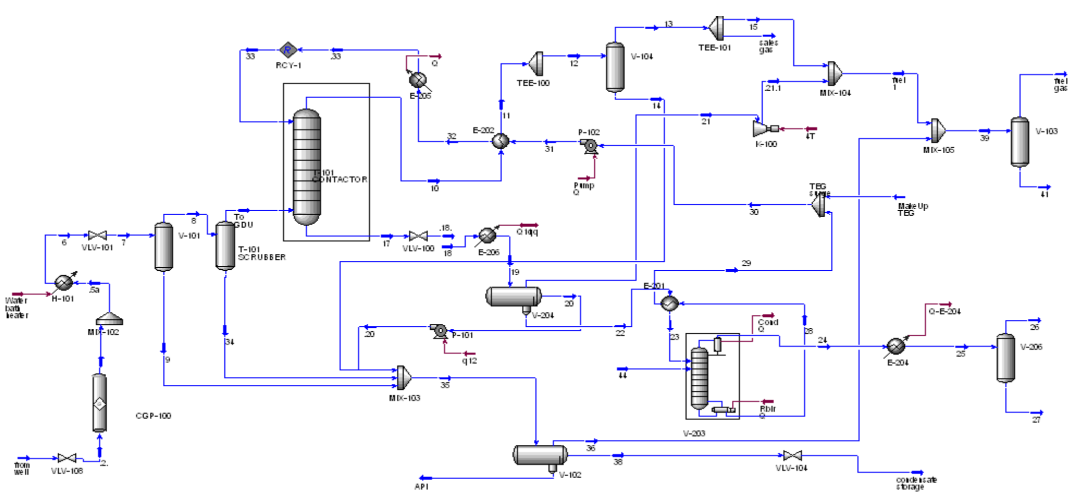

Fig. 3. Simulation model of natural gas processing plant.

5. Results and Discussions

The effect of process parameters have been studied in a typical gas processing plant in Bangladesh. Sweet natural gas is feed to the contactor designed for 20 MMSCFD and the operating pressure was 1010 Psig. Glycol circulation rates have been tested in different inlet gas temperatures and reboiler operating conditions.

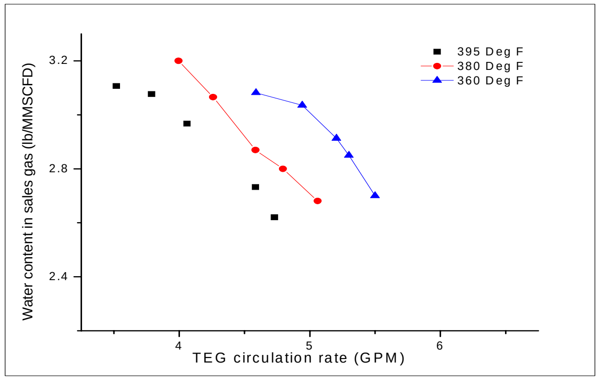

Fig. 4. Water content VS circulation rates and reboiler Temperature
(Contactor Inlet Gas Temperature fixed at 90 ^{o}F)

The result clearly shows the optimum operating temperature of TEG reboiler. Lower dew points have been resulted TEG reboiler is operated at 395 ^{o}F. The optimum circulation rates under the operating conditions are also evident in the result. It is certain that under the design condition, lowest dew point refers the corresponding circulation rate somewhere between 4.5 to 5.5 GPM.

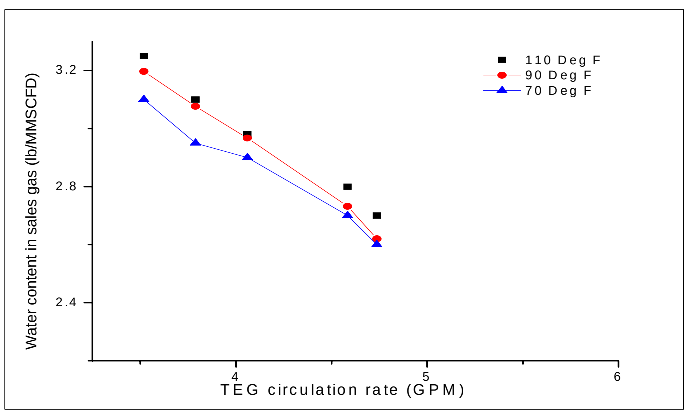

Fig. 5. Water content VS circulation rates for different inlet gas temperature.
(Re-boiler Operating Temperature 395 ^{o}F)

Another graph has been plotted based on the inlet gas temperatures of the contactor. The results clearly show that lower inlet gas temperature to the contactor requires less amount of TEG circulation. However it will be clearer if there were another graph representing the experimental results under 70 ^{o}F but due to the raw gas temperature, composition and hydrate formation, the results are limited to the value of 70 ^{o}F. Flow direction and settling time are directly related to the water content in the wet gas from the high pressure two-phase separator (V-101). The following graph contains results on two different equilibrium conditions. Initially the high pressure separation was designed to handle 20 MMSCFD of sweet natural gas with and operating pressure of 1010 psig. Later a contactor (T-101) inlet scrubber has been installed to increase the settling time (time in V-101 plus time in inlet scrubber) and flow direction of the inlet fluid. The results confirm that initially HP separator outlet gas stream's water content and after inlet scrubber water content came down as well as in the sales gas water content (lb/MMSCF) decreased. As the inlet water content decreases due to the equilibrium condition, lower dew points have been observed in same TEG circulation rates.

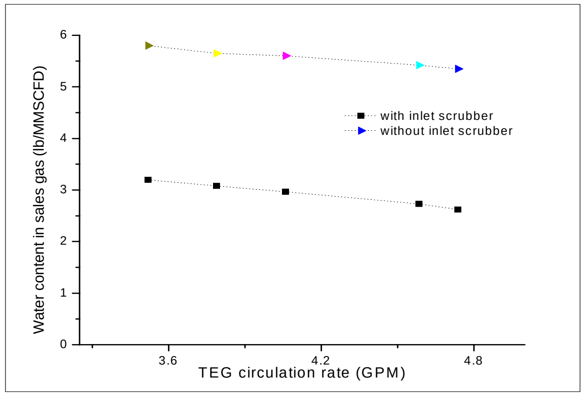

Fig. 6. Water content VS circulation rates in different settling time.

Stripping gas flow rate is actually a parameter in the stripping column of TEG regeneration system, which is a function with the reboiler efficiency.

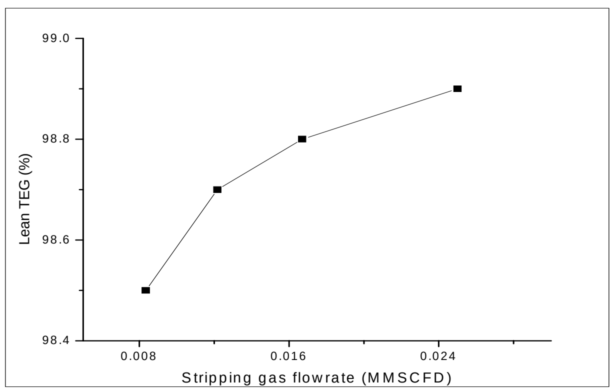

Fig. 7. Water Removal Efficiency VS Stripping Gas Flow Rate.

It was tested different stripping rate conditions of the reboiler and found the water removal efficiency from the rich glycol at given circulation rates. Increasing the stripping gas flowrate in the TEG reboiler, purity of Lean glycol can be increased to a certain limit. As countercurrent absorption in contactor is directly dependent on the quality of the lean TEG fed to the contactor, higher efficiency of water removal (≥ 99%) is one of the main areas of concern in optimization of this process.

	Mole Fractions
Nitrogen	0.003707
CO2	0.004900
H2S	0.000000
Methane	0.956841
Ethane	0.025543
Propane	0.004301
i-Butane	0.001199
n-Butane	0.000599
i-Pentane	0.000299
n-Pentane	0.000199
n-Hexane	0.000784
n-Heptane	0.000475
n-Octane	0.000266
n-Nonane	0.000234
n-Decane	0.000558
TEGlycol	0.000000
H2O	0.000097

Fig. 8. Composition of sales gas before fuel gas scrubber.

Some equipment in this process plant can be removed without hampering product quality. Process parameters must be maintained well. Considering more safety they are installed. Here it was supposed to eliminate Fuel Gas Scrubber (V-104) and Air/ Glycol Exchanger (E-205). Stream 11 at the outlet of TEG contactor to the sales gas line, there contains very negligible amount of water, even it shows no Liquid phase in the conditions tab. So V-104 which was used for further gas/liquid separation can be eliminated. Composition of stream 11 is given above Figure 8.

Stream Name	32
Vapour / Phase Fraction	0.0000
Temperature [F]	120.0
Pressure [psig]	1045

Stream Name	33
Vapour / Phase Fraction	0.0000
Temperature [F]	115.0
Pressure [psig]	1040

Fig. 9. Inlet and outlet condition of air/glycol cooler.

Air/ glycol exchanger (E-205) decreasing the temperature of TEG from 120 ^{o}F to 115 ^{o}F only to maintain the TEG contactor tower inlet temperature (Fig. 9). This 5 ^{o}F temperature can be easily reduced by either E-202 (gas/glycol heat exchanger) or E-201 (glycol/glycol PFE heat exchanger) by little amount of higher overdesign. The process conditions of E-205 inlet (stream nr 32) and E-205 outlet (stream nr 33) is showing below.

6. Conclusion

In this paper a simulation model of natural gas processing plant is developed using the process simulator HYSYS. Properties and conditions of different unit processes were optimized. For the plant equipment optimization also done to make more cost effective. Process optimizes the operating conditions that maximize the overall profit for the process with reduction of loss, cost and modification in present plant equipment. Experimental results are based on certain operating conditions, however it provides the trend of the data and any proactive action could be taken following the results on the experimental conditions. Experiments to determine effect of one parameter were carried out keeping the other ones fixed based on the optimum operative conditions.

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Implementation of Lean Philosophy and Improvement of Sigma Level in Cutting Section according to DMAIC approach

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Abstract

Manufacturing industries like Readymade Garments (RMG) manufacturer are interested in improving their products and process by reducing the variation. Because of global competitiveness, most of the Bangladeshi RMG industries are striving to achieve overall operational excellence in their business. Six sigma is a most powerful methodology for any manufacturing or service organizations and its significance is growing vigorously. Six sigma is a highly disciplined process that focuses on developing and delivering near-perfect products and services. In many organizations, six sigma means a business management process that shows tangible business results to the bottom line by continuous improvement and variation reduction. Six sigma processes is to reduce process variation, so that it will result in no more than 3.4 defects per million opportunities (DPMO). An 'opportunity' is defined as a chance for nonconformance or not meeting the customer requirements. So the objective is to establish the right strategy for never ending continuous process improvement. Six Sigma improves the process performance of the critical operational process, leading to better utilization of resources, decreases variations & maintains consistent quality of the process output. The DMAIC (define-measure-analyze-improve-control) approach has been followed in this paper to solve an underlying problem of reducing process variation and the associated high defect rate in Readymade Garments (RMG) sector and the critical operational process is taken in cutting section.

Keywords: *Six Sigma, DMAIC, Lean, Defects Per Million Opportunity (DPMO), Critical To Quality (CTQ), Voice of customer (VOC).*

1. Introduction

Organizations searching for the ways to improve their production and management processes in order to remain competitive in the market. These requirements push the organization towards the reduction of production cost, enhance productivity and improve product quality. Therefore, to deal with these target organizations must utilize all the available resources efficiently and effectively in order to provide their customers with high quality products at a low price. This is the main theme of six sigma strategy used to improve profitability, to drive out waste, to reduce quality costs & improve the effectiveness and efficiency of all operational processes that meet or exceed customers' needs & expectations. This paper discusses the implementation of six sigma methodology in one process in a readymade garments company. The six sigma Define-Measure-Analyze-Improve-Control (DMAIC) approach has been used to achieve the result. This paper focuses the step-by-step methodology of six sigma implementation in a manufacturing process for improving the quality level by reducing variation. This project is selected by Pareto analysis. Project charter, Voice of customer (VOC), Cost of Poor Quality (COPQ) etc has been done in define phase. As-Is-Process map, SIPOC diagram, Critical To Quality (CTQ) requirement, data collection and measurement, capability analysis etc has been done in measure phase. FMEA, Fishbone diagram, regression analysis etc has been done in analyze phase. 5'S, Kaizen, cycle time reduction etc has been done in improve phase. Control chart, award and various sustaining programs has been done in control phase.

2. Six sigma methodology

2.1Define:

Define phase indicates the goals of the improvement activity. The most important goals are obtained from customers for many areas. At the operations level industrial level, a goal might be to increase the throughput of a production department and reducing the number of defectives.

2.1.1Voice of Customer (VOC)

To drive improvement through continuous improvement projects, it is imperative for practitioners to determine first what is important to the customers who are affected by the process. The objective of VOC is to list the key customer needs in their language. And translate these needs into specific items called critical-to-quality requirements (CTQs).

2.1.2 Project charter

- Our current defect rate is 8.25%. Only scissoring problem is responsible for 5.10%. If we reduce 2% of that 5.10%, then it becomes at 3.10%. That means we can increase our revenue approximately 50 person's working hour per month as well as approximately BDT. 505000 per month.
- Problem/opportunity statement.
  - Current defect rate in cutting department is 8.25% [Too high].
- Goal. Reduce defect percentage by (5.10-3.10) 2% within 6 month (By July, 2012)

2.2 Measure

It is the second step of DMAIC and a key transitional step of the six sigma road. It measures the existing system. Establish a reliable matrix to monitor the progress towards goals defined at the previous step. Data collection from cutting section respectively for various types of defects that shown in table: 2 **[**Sample taken randomly 2000 piece from 10 batches]

DPMO Calculation			
Opportunities	2000	**DPMO**	82,500
Defects	165	**% Defects**	8.25
		% Yield	91.75
		Sigma	2.89

Table: 1

In this paper the main concerned area is cutting section. The defect of cutting section is divided by two segments and the concerned area has been narrowed to the internal defects From DPMO Calculation with respect to the table: 1 it have seen that the current sigma level is 2.89 where defects percentage is 8.25 with respect to the opportunities 2000.

Bat ch No .	Chec ked Piec e	Fab ric stai n	Oil ma rks	H ol e	Cola r Shad ing	Fore ign fiber	Bro ken stitc h	Ski p stit ch	Cu t stit ch	Une ven	Nee dle dam age	Shadin g proble m	Embel ishme n proble m	Scisso ring	Defec tive Piece
1	200	2	1			1	1		2			1		11	19
2	200			3	2		1	1	1					9	17
3	200	1									3		2	12	18
4	200		1		1	3				2	1		1	8	17
5	200		1				1	1		2				10	15
6	200			1				1			1		1	13	17
7	200	2			2				1			2		7	14
8	200	1		3									1	13	18
9	200		2			1	1			1				9	14
10	200			1					2	2			1	10	16
	2000	6	5	8	5	5	4	3	6	7	5	3	6	102	165

Table: 2

3.3Analysis

Analyze the system to identify ways to eliminate the gap between the current performance of the system or process and the desired goal. Begin by determining the current baseline. Use exploratory and descriptive data analysis to understand the data. Use statistical tools to guide the analysis

3.3.1 Pareto analysis

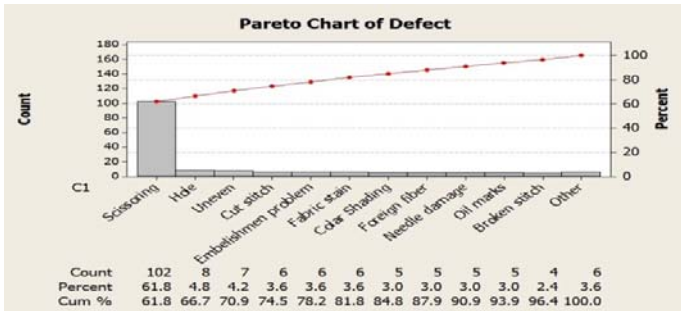


Figure: 1 Pareto analysis

Pareto analysis is a formal technique useful where many possible courses of action are competing for attention. From this analysis it has been seen that the main area for defective product is Scissoring. . From this current data it has been seen that the main area of defective is scissoring and it contributes 61.8 percent of defect from total defects.

3.3.3 Cause and Effect Diagram:

Pareto analysis shows the cause of defect with it level but not identifies the factor behind this defect. The fishbone diagram identifies many possible causes for an effect or problem. It can be used to structure a brainstorming session. In this paper the main concerned area of defective is scissoring. This type of defective is responsible for deviation of measurement from standard during cutting. So for this deviation a cause and effect diagram is drawn bellow-

Man

Machine

Lack of skill

No standardization

No standardization

Knife life cycle

Deviation of measurement from standard

Lay transfer

Lay Parallelism

Cutting

Cut panel

Method

Measurement

Fig: 2 Causes and Effect Diagram

3.4 Improve:

In improvement stage, be creative in finding new ways to do things better, cheaper, or faster. Use project management and other planning and management tools to implement the new approach. Use statistical methods to validate the improvement. So the project team needs to develop ideas to remove root causes, test solutions, and standardize solution/measure result.

3.4.1 **Standard Operating Procedure (SOP) implementation.**

Standard operating procedures (SOP) are a detailed explanation of how a policy is to be implemented. The details in an SOP standardize the process and provide step-by-step how-to instructions that enable anyone within your operation to perform the task in a consistent manner.

The SOP document serves as an instructional resource that allows employees to act without asking for directions, reassurance, or guidance. The step-by-step written procedure can also help hold employees accountable because employee expectations are documented and their actions can be measured against the SOP.

Grasp the cutter handle by one hand & puss the lay by other hand	Set the cutter edge to the line of the marker.	Press the cutter handle and run the cutter according marker line
		
Puss the marker carefully during turning the cutter	Separate the cutted lay in a distinct area	Take the cutted lay to resize according to marker line
		
Resize the lay according to marker line	Store the off-cut in a specific place	Take away the cut panel in a specified location
		

Fig: 3 Standard Operating Procedure (SOP)

3.4.2 Action plan to improve the process:

Based on the cause effect diagram, Pareto analysis and Standard operating procedures (SOP) action plan has been set to improve the situation and implement the plan.

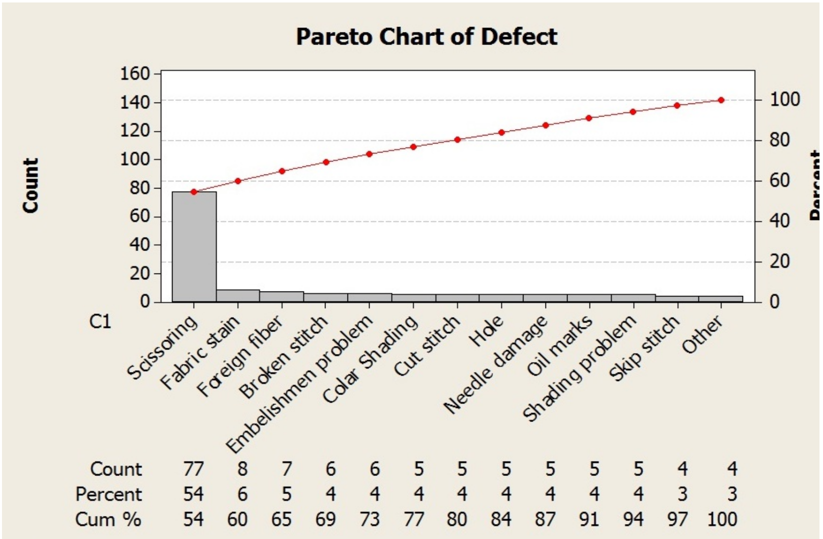
Categories	Causes	Effects	Actions
Man	Lack of skill	**Measurement Variation during cutting.**	a. Standard Operating Procedure (SOP) making b. Visual Management System establishment c. 5'S implementation.
	Lack of motivation		a. Incentive system development b. Support and encouragement c. Job empowerment.
Machine	Knife life cycle		a. Knife life time standardization b. Precession requirement according to buyer c. Knife storing system.
Method	Visual Management System	**Measurement Variation during cutting.**	a. Poster making b. Photo and symbol attaching. c. 5'S map development. d. 5'S slogan development.
	Clamping method		a. Standard Operating Procedure (SOP) making b. 5'S implementation. c. On the job training.
Measurement	Lay parallelism		a. Visual measurement techniques b. Developing a check list.
	Marker		a. Visual measurement techniques b. Developing a check list.

Table: 3 Action plan

Based on the cause effect diagram and Action plan and SOP, the operators are trained in all aspects of their job and after taking the remedial action we have checked the defects and again calculate the sigma level. Our maximum pain area was Scissoring. After implementation of this methodology we able to reduce the Scissoring problem.

Batch No.	Checked Piece	Fabric stain	Oil marks	Hole	Colar Shading	Foreign fiber	Broken stitch	Skip stitch	Cut stitch	Uneven	Needle damage	Shading problem	Embelishmen problem	Scissoring	Defective Piece
1	200		1			1	1		1		2	1		8	15
2	200	1					1	1						9	12
3	200	1		2	1						1		1	7	13
4	200		1		1	3				2	1		1	8	17
5	200		1		1		1	1		1				10	15
6	200	2		1			2				1	2	1	5	14
7	200				2			2	1			2		7	14
8	200	1		1		1							2	8	13
9	200		2				1		1	1				9	14
10	200	3		1		2			2				1	6	15
	2000	8	5	5	5	7	6	4	5	4	5	5	6	77	142

Table: 4 Result analyses



DPMO Calculation	
Opportunities	2000
Defects	142
DPMO	71,000
% Defects	7.10
% Yield	92.90
Sigma	2.97

Table: 5 Result analysis for sigma

Figure: 4 Pareto analyses after improvement

3.5 Control

This is about holding the gains which have been achieved by the project team. Implementing all improvement measures during the improve phase, periodic reviews of various solutions and strict adherence on the process yield is carried out. Once the improvement has been made and results documented, continue to measure the performance of the process routinely, adjusting its operation. Institutionalize the improved system by modifying compensation and incentive systems, policies, procedures, budgets, operating instructions and other management systems. Without control efforts, the improved process may well revert to its previous state. There is various ways to sustain the improvement like Awards and Bonus Program When an employee identifies is doing well in this DMAIC process he/she should rewarded with a bonus check. In some cases the bonus check is a fixed amount. In other programs the bonus may be a small percentage of the potential direct cost but may be large effect for overall development. Creating such environment that is consistent with the desired system and improving production process & equipment to sustain the improvement.

Discussion and recommendations

3.1 Discussion:

Six Sigma provides a great opportunity to become business leaders with the strategy, methods, tools and techniques to their organizations. Six Sigma as a powerful business strategy for achieving and sustaining operational effectiveness, producing significant savings to the bottom line and thereby achieving organizational excellence. If implemented properly with total commitment & focus, Six Sigma can put industries at the forefront of the global competition. Implementation of six sigma methodology has resulted in large financial savings for the company. Due to reduction in measurement variation as well as reduction in rejection and rework, the approximately savings from this project was $75750 per annum.

3.2 Recommendations

The Sigma level achieved after implementation of DMAIC Six Sigma methodology can be further improved by considering every small and large defective area that are not considered in this paper & new performance standards can be realized. It can be incorporate other various types' tool and also algorithm to this work to increase the reliability of the acquired result. So it can be integrated effectively in every company for maintaining & further improving the improved performances.

Conclusion

This case study has demonstrated that the integration of Lean-Six Sigma can be an effective and useful approach to eliminating inefficiencies and inconsistencies in garments industries. The researchers highlighted a number of questions regarding the implementation of DMAIC. The main thing of this paper is to reduce the defects rate and also reduce fault opportunities in the final garments; we have worked in every department to reduce these opportunities and gave a solution in the form of preventive action in the cutting section of this garments industry.

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Effect of external magnetic field on drilled hole quality during drilling operation

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Abstract

The improvement of the machinability of mild steel during drilling operation can be achieved by considering the optimized cutting conditions. This study aims to investigate the magnetic field effect on drilled hole quality in terms of surface quality, behavior of the chips and the circularity of the drilled hole. The comparison has been made between the machinability responses for both normal drilling and drilling with applying magnetic field. Magnetic field of unlike poles is applied to the both sides of the work piece using electromagnets during drilling process. The strength of the magnetic field is constant during the experiment by ensuring a constant current through the magnetic winding. Same cutting condition is used for both magnetic cutting and non magnetic cutting. The results show a better quality of the drilled surface, less serrated chips and more accuracy in the circularity of the hole when external magnetic field is applied compared to that obtained during cutting without using magnetic field.

Keywords: *Machinability, magnetic field, drilling, surface roughness, circularity etc..*

1. Introduction

The quality of drilled hole on a work piece is defined by several machinability factors among which the circularity of the hole, roughness of the inside surface are the two most important ones. The objective of the current study is to investigate the effect of applying strong magnetic field on the machinability responses. The first study of the effect of magnetic field on the machining process was performed by Bagchi and Ghosh [1,2]. They investigated the effect of EMF created by a magnetic field on the wear characteristics of cutting HSS tools while machining mild steel. An improvement of the tool life was found in their study. Pal and Gupta [3] investigated the effect of an alternating magnetic field on the wear behavior of HSS drills in drilling gray cast iron and malleable cast iron under dry cutting condition. The magnetic field was applied on both the work piece and tool in case of gray cast iron whereas for malleable cast iron the magnetic coil was kept over the work piece so that the field lines are mainly applied on the tool. Satisfactory result was obtained for improvement of tool life. More significant explanation of the above phenomenon was given by Muju and Ghosh [4-,5], when conducting tool wear experiments. Mansori et al [6] studied the magnetic field effect on the tool wear and the feed force during drilling a mild steel work piece. A considerable decrease in tool wear and feed force has been observed during the experiment. The effect of magnetic field on surface roughness of the finished work piece during the turning process of mild steel has been studied by Anayet U Patwari et al. [7]. The authors observed a decrease in the surface roughness due and significant improvement of tool life to the application of magnetic field. Serene [8] in her study investigated the effect of magnetic field on the accuracy of the drilled hole with respect to change in the strength of the magnetic field and the polarity of the magnetic field. It has been shown in her study that the magnetic field creates a damping effect on the drill bit which reduces the tool vibration and hence improves the tolerance. The exposed length of the drill bit was considered as another variable whose vibration affects the tolerance of the drill hole. In the current study, the accuracy and quality of the drilled hole was identified by its circularity and surface roughness. To find out the change in vibration nature of the drill bit during drilling process, when external magnetic field is applied, chip morphology was done.

2. Experimental Details

The work piece used in the experiment was mild steel. The diameter of the drill bit is 11 mm. The constant speed of 900 rpm of the spindle was kept constant throughout the experiment. controlled experiment was done, considering without magnet and with magnet. A total of four holes were drilled on the work piece for each condition. The feed used in the experiment was 20 mm/min. The experimental set up is shown in figure 1.

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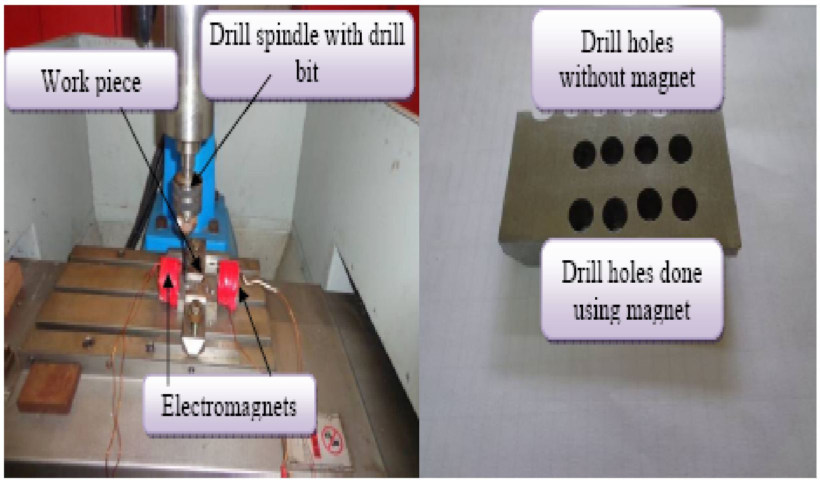


Fig. 1: (a) Experimental setup, **(b)** Work piece with drilled holes on it

200 V a.c.from the main line is converted to 12 V d.c using a transformer and an a.c. to d.c. converter circuit which is kept constant to ensure a constant current through the magnetic winding around the iron core of rectangular cross section. Two magnets are attached on both sides of the work piece.

The vertical pictures of the holes are then taken to process them using developed code by Anayet U Patwari et.al [9] in order to find out the circularity of the holes. The holes are cut in the middle to take the microscopic picture of the surface using Kruss metallurgical optical microscope. The surface is then processed using image processing technique developed by Anyet U Patwari et al [10]. The whole process sequence of the digital image processing (DIP) technique for a certain sample of surface is given below.

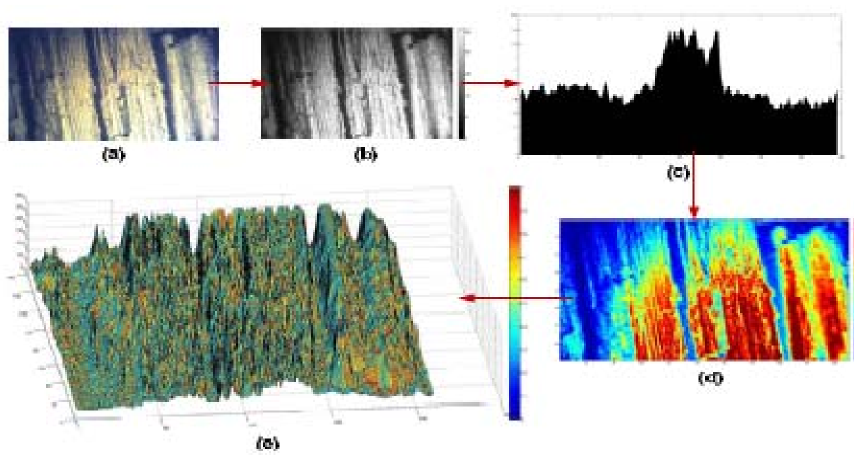


Fig. 2: (a) 10X zoom RGB microphotograph, (b) grayscale, (c) profile plot, (d) 2-D colored contour plot, (e) 3-D colored contour plot

In order to investigate the chips formed during drilling process, they are first collected for each condition, i.e. magnetic cutting and non magnetic cutting, and mounted using a mixture of resin and hardener. The mixture was stirred for about one minute and left to solidify. The solidified mixture is called mounting. The next step is to grind the mounting surface to reveal the chip to the surface. In order to remove the scratches on the surface, the mounting is then polished using alumina. Finally 2% nitol solution is applied to the surface. Then the mounting is ready to be viewed under the microscope to capture the structure of the chip. Figure 3 illustrates the mounting of the chips and the microscope used for viewing the surface roughness and the cross section of the chips.

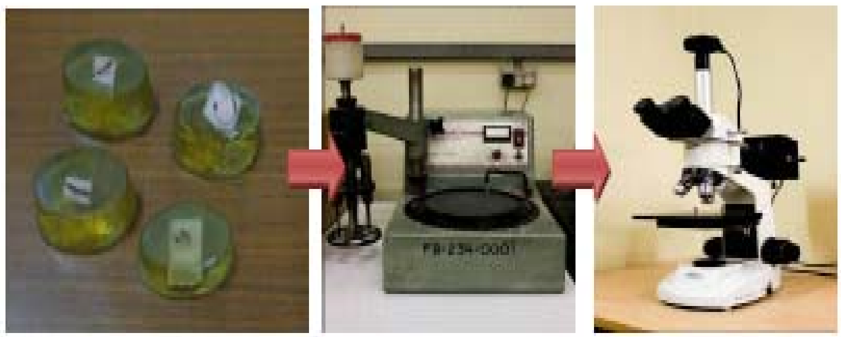


Fig. 3: (a) samples of mounted chips (b) polishing wheel (c) Optical microscope

3. Result and Discussion

Surface roughness

The surface quality of the drill hole shows significant improvement when external magnetic field is applied compared to the case when no magnet is used during drilling process. The following figure shown in Figure 4 illustrates the samples of the surface pictures taken by the optical microscope which are then processed by image processing software to get the exact value.

Fig. 4: (a) Inside surface of the drilled hole machined without magnet, (b) surface of the drilled hole machined with magnet

The exact values of the surface roughness of all four drill holes are given in the following table.

Table 1. Roughness of the inside surface of the drill holes

Drill hole number	Surface roughness(With magnet)/µm	Surface roughness(Without magnet)/ µm
1	0.422	0.594
2	0.482	0.558
3	0.423	0.480
4	0.465	0.493

The 3D contour profile of the surface for the first set of samples for both magnetic and non magnetic are shown in Figure 5. From the contour diagram it has been observed that the surface roughness improved in magnetic cutting compared to non magnetic cutting.

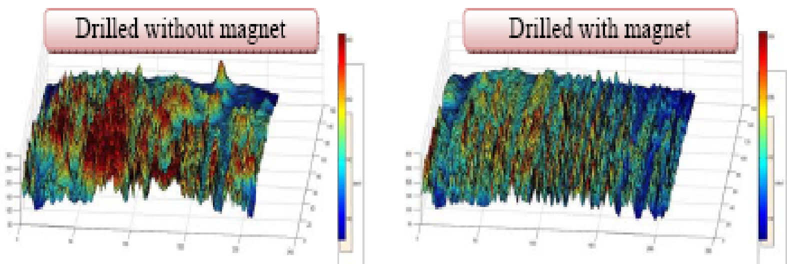


Fig. 5: 3-D contour diagram of the surfaces for the first set of samples

Circularity

The samples pictures of the circularity of the holes as processed by the MATLAB developed code are given below.

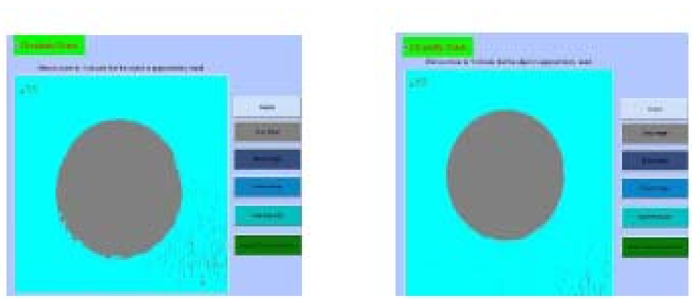
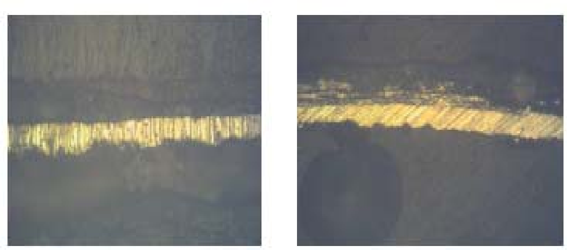


Fig. 5: sample picture of the circularity of the drill hole; (a) drill hole with magnet, (b) drill hole without magnet

In the circularity check, the index 1 means the hole is completely circular. Lower the value of the circularity index indicates less circularity of the drilled hole shape. From the circularity test it is clear that external magnetic field causes the drill bit to produce a almost uniform circular hole compared to non-magnetic cutting.

Chip morphology

The behavior of the chips during drilling process indicates the vibration characteristics of the drill bit. The chips for magnetic cutting are more continuous than that produced during non magnetic cutting. The following figure 6 shows the microscopic view of the chips.



(a) Non-Magnet cutting (b) Magnetic cutting

Fig. 6: Cross section view of chip formed at different cutting condition

From the figure, it is clearly visible that the serration behavior of chips greatly decreased due to the application of magnetic field and the tooth of serrated chip is larger in case of non magnetic cutting. This phenomenon is a clear indication of change in vibration characteristic of the system in different condition.

4. Conclusions

From the current experiment, it is obvious that the presence of magnetic field during drilling process can improve the quality of the drilled hole in terms of the decrease in the surface roughness of the inside of the drilled hole and circularity of the hole. From the results it found that significant improvement can be achieved in the surface quality of the drilled hole by applying magnet externally. The holes become more circular by the magnetic field. This is due the decrease in the vibration of the drill bit. It results in the in-line movement of the drill bit. This phenomenon is also supported by the reduction of the serration behavior of the chips and the tooth size of the cross section of the chips.

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Advanced Functionalization of Textiles by Nanofinishing: A Review

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Abstract

This paper reviews the applications of nanotechnology in terms of nanofinishing in textile products. Textiles appearance, handle, performance and texture can be modified by finishing process to be suitable for the end uses. Functional finishing process involves surface modification by both mechanical and chemical techniques, which can be applied on traditional textile materials to incorporate new functionalities and value addition. Nanofinishing is concerned with control and processing technologies in the sub nanometer range and so must play a vital role in the fabrication of extremely precise and fine parts. Finishes can be emulsified into nano-micelles, made into nano-sols or wrapped in nanocapsules that can adhere to textile substrates more evenly. The possibility of applications of nanoparticles in different forms and applying methods are discussed in this paper in order to implement advanced functionalization. Developments of anti-static textiles, ultraviolet (UV) resistant textiles, self cleaning textiles, antibacterial textiles by nanofinishing process are also discussed.

Keywords: *Nanofinishing, Nano-particles, Nanotechnology, Textiles, Surface.*

1. Introduction

Influenced by constantly evolving consumer lifestyles within the last two decades, textile industry globally adopted a forward-looking approach to create new conceptual textile systems for the 21st century, based on so called knowledge-based textile materials. This strategy aims the development of futuristic human-friendly textile products which would redefine the role of textiles and expand the capabilities to affect human life by efficiently fulfilling advanced expectations of modern lifestyle. Nevertheless, in addition to conventional technologies, novel specific technologies are needed to create knowledge-based textile materials with new advanced functionalities and environmental responsiveness [1]. Nanotechnology is the engineering of functional systems at the molecular scale. With the advent of this technology, today nanofibers, nanocomposite, nano-particles and intelligent garments are developing in the market.

Especially a new area has developed in the area of textile finishing called "Nanofinishing". Nanofinishing is a finishing process with nanotechnology to functionally or protectively build more unique or better qualities to textiles as a result of their novel and fascinating properties, and applications of nanomaterials superior to their conventional counterparts [2]. The first commercial application of nanotechnology became available in terms of nanofinishing. Nanofinishing is introduced on the textile materials in a controlled and ordered way while chemical finishing is done randomly. Demands for functionality and intelligence of wearable textiles increasing and pose lot of challenges in product development [3, 4, 5, and 6]. The technology can be used for desired textile attributes, such as fabric softness, durability, breath ability and in developing advanced performance characteristics in fibers, yarns and fabrics. Growing awareness of health and hygiene has increased the demand for bioactive or antimicrobial and UV-protecting textiles.

Nanotechnology has real commercial potential for the textile industry, because conventional methods have no permanent effects and lose their functions after laundering or wearing. In addition, normal finishing can affect air and moisture transfer of the fabric. On the other hand, treating textiles with nanomaterials is a method to improve its properties, which making them longer durable, nicer colours etc. Fiber provides large surface area for a given weight or volume of fabric. The synergy between nanotechnology and textile industry uses this property of large interfacial area and a drastic change in energetic is experienced by macromolecules or super molecular clusters in the vicinity of a fiber when changing from a wet state to a dry state [7]. Nanotechnology can also be used in the opposite manner to increase the ability of textiles, particularly synthetics, to absorb dyes. Until now most polypropylenes have resisted dyeing, so they were deemed unsuitable for consumer goods like clothing, table cloths, or floor and window coverings. A new technique being developed is to add nanosized particles of dye friendly clay to raw polypropylene stock before it is extruded into fibers. The resultant composite material can absorb dyes without weakening the fabric.

2. Different structures of nano-particles

Structures with three dimensions in the nano-scale are known as nano-partilces. Since atoms and molecules belongs different behavior than those of bulk materials, so nanofinishing by nano-particles develop innovative and advanced functional properties in the treated textile materials. The whiskers get hooked on the fibers to alter the fabric property. It makes the fabric stain, water and wrinkle resistant, but keeps the fabric breathable and soft. The three dimensional molecular nano-net covers the core fiber completely. It can inject linen property into a synthetic fiber, as a result wicks body moisture fast, dries quickly and gives the cooling effect. Nano sheet wraps the fiber completely to cover it and alter its property, which enhance the fabric robustness and color fastness.

3. Nano-particle Application Methods

There are various application methods for textile nano particle, such as sol-gel techniques, plasma polymerisation, pad-dry-cure method, dip coating, foulard process, chemical vapor deposition (CVD), electro spraying process, layer-by-layer deposition method etc. First of all nano-particle is synthesized and then applied on of these methods. Some of them are described below.

3.1 Electrospraying process:

The nano-particles such as metal oxides or fluorocarbon can be deposited onto the textile surface by using an electro spraying process. The electro spraying process has a conventional configuration consisting of a charged syringe fed with polymer solution and a grounded collector plate. When a liquid or emulsion is subjected to an electric field of several kilovolts produced by a high-voltage power supply, the droplet at the capillary tip of the syringe, which is kept in place by the surface tension of the liquid, is also charged and overcomes the forces of surface tension resulting in elongation of the droplet into a conical shape. Further increase in the attractive force of the electric field by means of increased voltage produces a charged jet of liquid that is channeled to the ground [8].

3.2 Layer-by-layer deposition method

Layer-by-Layer deposition is a thin film fabrication technique. The films are formed by depositing alternating layers of oppositely charged materials. The dissociation of certain materials in solution form into their nano-size cationic and anionic groups of molecules which is utilized to alternatively and repeatedly deposit nano-scale layers of the nano ionic components of the materials. This repeated cationic anionic assembly deposition of nano particles of certain polymeric components on a substrate can exhibit significantly improved functionalities of the end-product. For example, deposition of silver in nano format on a cotton fabric provides satisfactory antimicrobial and wound-healing features [9].

3.3 Sol-gel process

It is a process for making very small particle 20 to 40 nm. A liquid precursor of the particle is dissolved in a solvent, usually alcohol, water is added and then acid or base. The mixture is coated or cast. The precursor then decomposes to form the fine ceramic particles. If the particle concentration is high enough, the mixture gels. The gel is dried, and then heated at high temperature to sinter the ceramic, giving the desired ceramic film or fiber. During this drying and sintering process, shrinkage occurs through loss of solvent and air, and this shrinkage must be carefully controlled to avoid cracking.

3.4 Wet chemical/Dip coating

Continuous dip coating is an easy and popular way of creating very thin films onto textile substrates. It is also known as impregnation or saturation method. In this method, the substrate is immersed for a certain time (known as dwell time) in a tank which contains coating polymer and then material is squeezed out by passing though nip rollers or a set of doctor blades to give a fixed net pick up of the resin [10].

4. Antistatic Textiles

Static electricity can cause many processing problems for textile materials, especially those made from hydrophobic synthetic fibers. In most dry textile processes, fibers and fabrics move at high speeds over various surfaces which can generate electrostatic charging from frictional forces. This electrical charge can cause fibers and yarns to repel each other, leading to ballooning. Fabrics and nonwovens are also affected by static charges, causing materials handling problems. As synthetic fibers provide poor anti-static properties, research work concerning the improvement of the anti-static properties of textiles by using nanotechnology were conducted. It was determined that nanosized titanium dioxide [11], zinc oxide whiskers [12], nano antimony-doped tin oxide (ATO) [13] and silane nanosol [14] could impart anti-static properties to synthetic fibers. TiO_2, ZnO and ATO provide anti-static effects because they are electrically conductive materials. Such material helps to effectively dissipate the static charge which is accumulated on the fabric. On the other hand, silane nanosol improves anti-static properties, as the silane gel particles on fiber absorb water and moisture in the air by amino and hydroxyl groups and bound water [15].

5. UV-protective Finish

An overexposure to UV radiation can cause sunburn and some forms of skin cancer. In humans, prolonged exposure to solar UV radiation may result in acute and chronic health effects on the skin, eye, and immune system. However the most deadly form - malignant melanoma - is mostly caused by the indirect DNA damage (free radicals and oxidative stress). This can be seen from the absence of a UV-signature mutation in 92% of all melanoma (10). Previously organic and in organic UV absorbers were coated on the textile material they prevent UV radiation effectively but they are less durable. As UV blockers usually certain semiconductor oxides such as TiO_2, ZnO, SiO_2, and Al_2O_3 can be used. Among these semiconductor oxides, TiO_2 and ZnO are commonly used. Through study showed that nanosized titanium dioxide and zinc oxide are more efficient at absorbing and scattering UV radiation [6, 16].

6. Self Cleaning Effects for Textiles

One of the most common ways to use nanotechnology in the textile industry is to create stain and water resistance. To do this, the fabrics are embedded with billions of tiny fibers, called “nanowhiskers”, which are waterproof and increase the density of the fabric. The nanowhiskers can repel stains because they form a cushion of air around each cotton fiber. When something is spilled on the surface of the fabric, the miniature whiskers actually cohesively prop up the liquid drops, allowing the liquid drops to roll off. This treatment lasts, for about 50 home wash cycles before its effectiveness is lost [17]. The best known example with regard to a water and soil-repellent finish is the lotus-effect. On the basis of lotus leaf concept scientist developed a new concept “Self cleaning textile” the textile surface which can be cleaned by itself without using any laundering action. Self cleaning surface possess a water contact angle greater than 150° and a very low roll off angle. Water through these surfaces easily rolls off and completely cleans the surface in the process. Self cleaning fabrics not only repellant to water but are also resist stains, dirt, and odor and are antimicrobial as well. Self cleaning textiles can be developed by using photo catalysts, using microwaves, using carbon nano tubes, and using silver nano-particles [18]. We know that wet ability strongly depends on two properties the surface free energy and the surface roughness. Surface free energy is an intrinsic property of the material that can be controlled by chemical modification, such as fluorination and other hydrophobic coatings.

7. Antimicrobial Effects for Textiles

Neither natural nor synthetic textile fibers are resistant to bacterial or pathogenic fungi. The nano-particles of silver (Ag), TiO2 and zinc oxide (ZnO) exhibit high antibacterial activity [19, 20, 21, and 22]. Nano-silver particles are widely applied to socks in order to prohibit the growth of bacteria. In addition, nano-silver can be applied to a range of other healthcare products such as dressings for burns, scald, skin donor and recipient sites. Because of photo catalytic feature, nano TiO2 are proved to show antibacterial property. Several papers have reported the use of the photo catalytic property of TiO2 for developing antibacterial textiles [23]. On the other hand, zinc oxide is also a photo catalyst, and the photo catalysis mechanism is similar to that of titanium dioxide; only the band gap is different from nano TiO2. Nano ZnO provides effective photo catalytic properties once it is illuminated by light, and so it was employed to impart antibacterial properties to textiles [24].

8. Commercially Available Products

Nano-Tex^{TM} has developed wrinkle resistant fabric, stain resistant, anti-static and UV protection fabrics [25-27]. Scholler® company's products include soft shells technology for functional stretch multi-layer fabrics: dynamic climate controlled extremely air-permeable, light and water and wind resistant clothing and gloves [28-30]. On the other hand Bugatti has developed jacket with a nanosphere finish, which has the moisture management features [31]. Ski jacketes for developing grime-resistant, windproof, waterproof, and breathable fabrics have been developed by another company named Franz-Ziener [32]. Institute for soldier nanotechnologies (ISN) develop textile materials for soldiers: light weight, strong, abrasion/wear resistant, durable, impact energy absorbent, temperature controlled water proof, improved camouflage, and embedded with multipurpose micro/nano sensors [33-34]. Nano- Plem' technology is claimed by Toray, Japan. This imparts water- repellant characteristics and color resilience to nylon and polyester fabrics, and Terylene/ wool blends. Mincor TX TT, a nanofinish from BASF, is a composite material consisting of nanoparticles embedded in a carrier matrix. This finish may provide solution for the fabrics like polyester awning, sunshades, flags and sails that are generally required to remain continuously in outdoor environment; therefore these cannot be cleaned in washing machine. Synthetic fibers can be made soft and comfortable like cotton. Nano- TouchTM fabric technology is known to permanently graft an outer layer of cotton- like properties around a synthetic fiber core.

8. Conclusion

The impact of nanotechnology in the textile finishing area has brought up innovative finishes as well as new application techniques. Particular attention has been paid in making chemical finishing more controllable and more thorough. Nanofinishes being developed for textile substrates are at their infantile stage. Nano finishing can replace traditional finishing technique of textile products and readymade clothing with products of superior quality and lower production costs. A wide variety of clothing and apparel from Levi, Adidas, Nike and home furnishings are commercially available that now comprise some form of nanotechnology, especially antimicrobial and stain- and wrinkle-resistant clothing. Bangladeshi textile industry yet not taken any initiative to established nanofinished based industry due to lack of resource person. Furthermore, this technology is not so cost effective but has many other advantages like low weight, longevity, durability etc. In future, one can expect to see many more developments in textiles based on nanotechnology.

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Characterization of Calcined Sugarcane Bagasse Ash and Sugarcane Waste Ash for Industrial Use

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Abstract

The utilization of waste material provides a satisfactory solution to some of the environmental concerns and problems associated with waste management. In this study sugarcane bagasse ash and sugarcane waste were calcined at 400^{0}C, 600^{0}C, 800^{0}C and 1000^{0}C temperature for 2hours.These samples has been chemically and physically characterized in order to evaluate the possibility of their use in metallurgical and materials industry. XRF analysis for chemical composition of the samples, XRD analysis for determination of composition and presence of crystalline material as well as physical properties has been studied. Carbon content has been determined by elemental analyzer. Bagasse ash is an industrial waste that mainly consists of high amount of silica (SiO_2) and carbon materials. Calcium, magnesium and potassium oxide presents as main minor compound. As temperature increases, the sugarcane bagasse ash (SCBA) and sugarcane waste ash (SCWA) color changes from black to grey and white which indicates that the carbon content present in the SCBA and SCWA were reasonably reduced. The ignition loss of SCBA and SCWA was significantly reduced with increasing temperature. Particle size analysis indicates sample fineness was improved with increasing temperature.
Keywords: *Bagasse ash, sugarcane waste ash, calcination, particle size*

1. Introduction

A large amount of industrial waste is producing day by day in Bangladesh. In present special attention has been devoted to the waste minimization practices, pollution prevention, and sustainable development as applied to the material field.

Sugar industry lays an immense importance in agro-based economy of Bangladesh. Sugar cane, the only raw material of this industry is the main cash-crop of north Bengal of our country. Sugarcane is produced in 2.05% land of the country and it contributes 5.52% to agricultural GDP [1]. There are 15 sugar mills in Bangladesh and the bagasse is the major by-product of these mills. Some amount of the by-product is used as fuel for boiler in the millhouse. Mostly this is either under-utilized or unutilized as a source of heat energy. It is creating waste management problem, specially in the sugar milling sites.

Sugarcane bagasse (SCB) which is a voluminous by-product in the sugar mills when juice is extracted from the cane. It is, however, generally used as a fuel to fire furnaces in the same sugar mill that yields about 8-10% ashes containing high amounts of un-burnt matter, silicon, aluminum, iron and calcium oxides. But the ashes obtained directly from the mill are not reactive because of these are burnt under uncontrolled conditions and at very high temperatures. Ganesan et al [2] stated that 1 ton of sugarcane generates 280 kg of bagasse, and that based on economics as well as environmental related issues, enormous efforts have been directed worldwide towards bagasse management issues i.e. of utilization, storage and disposal.

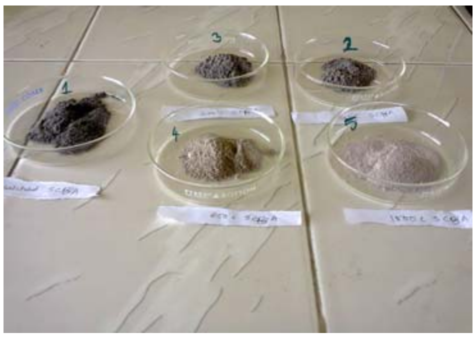
The ash, therefore, becomes an industrial waste and poses disposal problems. It's utilization as an adsorbent as well as mineral admixture in cement and concrete has been examined [3]. Recently, the use of agriculture solid waste materials as pozzolans in the manufacture of blended mortars and concrete has been the focus of research [4,5, 6]. ASTMC618 [7] classified SCBA as N pozzolan and adapted for use in making cement [8, 9]. According to Sing et al [10], the ash produced by controlled burning of agro waste materials below 700°C transforms silica content of the ash in to amorphous silica and can be used as a pozzolanic material. SCBA has proved to be a viable by-product for admixture in cement, with its intrinsic characteristic such as high content of silica in the form of quartz [3]. However, the high carbon content is an obstacle for its use in cement/mortars.

Therefore it would be valuable if the unburned carbon in SCBA could be removed and used for other applications.

In the present study, the collected SCBA and SCW are fired at different temperatures and the calcined SCBA and SCWA are characterized in order to use in the metallurgical and materials industry.

2. Materials and methods

SCBA and SCW were collected from Joypurhat Sugar Mill, Joypurhat, Bangladesh. Sugarcane waste was dried, crushed and then sieved on passing 250 microns. Both SCBA and SCW samples has been calcined at 400°C, 600°C ,800°C and 1000°C temperature for 2hours under controlled condition. At the end of each process, the ash was taken out of the furnace and cooled to room temperature. After cooling, the ash was stored for characterization. In this condition the grey and grey white colour (Fig.1) of the SCBA and SCWA indicated as complete burning.



(A)

(B)

Figure1. (1)Uncalcined bagasse ash (A) and Sugarcane waste (B) and calcined at different temperature (2) 400^0C (3) 600^0C (4)800^0C and (5) 1000^0C

The samples were determined by X-ray fluorescence Spectrometer (XRF) method following the procedures of Goto & Tatsumi [11] using Rigaku ZSX Primus XRF machine equipped with an end window 4.kW R^H-anode X-ray tube. The phase composition of the uncalcined and calcined samples were determined by the XRD analysis of the sample with Bruker X-ray Diffractometer model operating with a CuKα radiation source (Kα=1.5406 A_O). Particle size was determined by sieve analyzer using various sizes of sieve. The percentages of CHNS were carried out by an Elemental Analyzer of model EA 1108 according to the ASTM D3176-84 standard test procedures. The loss of ignition was determined by the mass loss of these samples after heating at 1000^0 C.

3. Results and Discussion

3.1. Chemical Analysis

The chemical compositions of the bagasse ash and sugarcane waste are given in Table 1 and Table 2. It can be seen that the bagasse ash waste powder contains a large amount of silicon oxide and this amount increase with increasing temperature. Chemical composition of SCBA confirmed to be a good pozzolana since the sum of SiO_2, Al_2O_3 and Fe2O3 is 70.10% for raw material and 73.13% when sample calcined at 1000^0C, thus meeting the requirement of 70% minimum recommended by ASTM C618[7]. From Table1 and Table 2 it shows that loss of ignition was significantly decreased with increasing temperature. So, organic matter percentages were low for calcined SCBA and SCWA.

Table 3 and Table 4 shows the percentages of carbon, nitrogen, hydrogen and sulphur of SCBA and SCWA. The percentage of carbon indicates that raw bagasse ash decrease 63% when sample calcined at 400^0C and 97% decrease when calcined at 1000^0C. Carbon percentage of sugarcane waste also significantly reduced when sample calcined at different temperature. According to Corderio et al [12] states that carbon and volatile compounds present in the SCBA are considerably removed at higher calcinations temperature.

"Table1. Chemical compositions of uncalcined and calcined bagasse ash (SCBA)"

Oxides/wt%	Raw SCBA	400^0C	600^0C	800^0C	1000^0C
SiO_2	60.75	62.55	61.93	62.57	62.40
Al_2O_3	4.14	4.31	4.44	4.70	5.02

Na_2O	0.77	0.66	0.74	0.86	0.83
MgO	2.39	2.20	2.43	2.34	2.27
P_2O_5	3.39	3.37	3.42	3.40	3.46
SO_3	1.81	1.70	1.73	1.71	1.79
K_2O	14.63	14.37	14.25	13.86	13.40
CaO	4.48	3.56	3.71	3.49	3.69
Fe_2O_3	5.27	4.88	5.01	4.87	5.71
LOI(1000^0C)	5.24	4.17	3.34	1.27	0.37

"Table 2. Chemical compositions of uncalcined and calcined sugarcane waste (SCW)"

Oxides/wt%	Raw SCW	400^0 C	600^0 C	800^0 C	1000^0 C
SiO_2	15.61	18.62	20.39	20.59	23.20
Al_2O_3	3.22	4.06	4.75	4.99	5.28
Na_2O	0.10	0.27	0.25	0.37	0.52
MgO	1.38	1.97	2.02	2.07	2.10
P_2O_5	10.82	12.87	14.16	14.07	14.63
SO_3	11.95	8.72	8.38	8.93	6.71
K_2O	6.48	5.45	5.42	5.06	4.52
CaO	40.24	40.22	38.64	37.48	36.78
Fe_2O_3	7.32	5.52	3.98	4.34	4.39
LOI(at1000^0C)	77.6	39.7	20.33	2.06	0.77

Table 3. Ultimate analysis of uncalcined and calcined bagasse ash

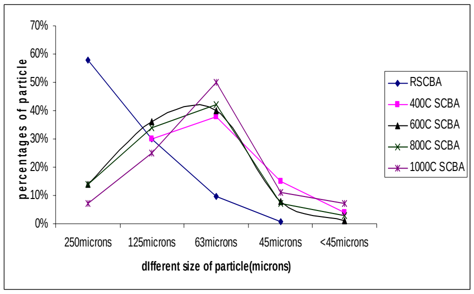
	N%	C%	H%	S%
Raw SCBA	5.85	1.60	0.63	0.319
Calcined at 400°C	1.86	0.58	0.3	0.222
Calcined at 600°C	1.57	0.53	0.24	0.177
Calcined at 800°C	3.22	0.13	0.238	0.203
Calcined at 1000°C	3.94	0.037	0.214	0.275

Table 4. Ultimate analysis of uncalcined and calcined SCWA

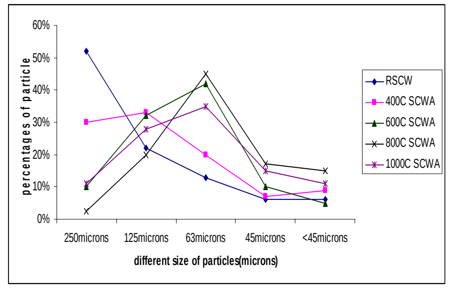
	N%	C%	H%	S%
Raw Sugarcane waste	3.85	38.05	5.43	0.802
Calcined at 400°C	6.63	28.84	1.93	0.803
Calcined at 600°C	3.93	5.41	0.71	2.085
Calcined at 800°C	6.37	0.621	0.28	1.366
Calcined at1000°C	2.07	0.116	0.18	1.533

3.2 Particle size analysis

Figure 2 shows particle size distribution of raw and calcined sample. Particle size was determined by sieve analyzer using various sizes of sieve, the bulk of the retained sample on five consecutive sieves corresponding to 250µm, 125µm,63µm,45µm and <45 µm size fractions (Figure2) respectively. Most fine particle found at 63 µm size and at 800^0C temperature we found most fine size for SCWA and at 1000^0C temperature, found fine particle for SCBA. So, it could be helpful for several metallurgical industries.



(a)



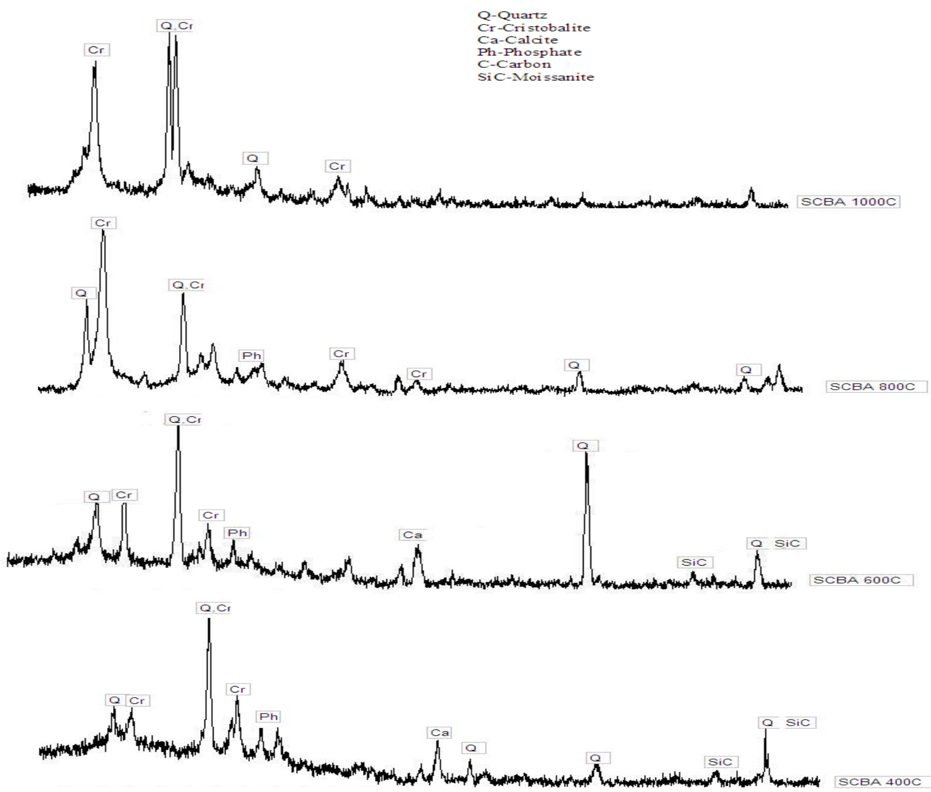
(b)

Figure2. Particle size distribution of the sample of uncalcined and calcined SCBA (a) and SCWA (b)"

3.3 Phase analysis

The XRD patterns (Fig.3) show a remarkable difference between calcined and uncalcined bagasse ash, which suggests that phase transformation has take place. For bagasse ash (Fig. 3), silica is the primary component with small amounts of calcium and other compounds. The peak observed from the uncalcined SCBA and 400°C and 600°C calcined SCBA samples indicates the amorphous nature of silica. For the SCBA 800°C (Fig.3), some sharp and intense peak starts to show up, this may be due to the recrystallisation of amorphous silica to crystalline with temperature and this implies that the crystallanity increases as temperature increases. At 1000°C, the bagasse ash becomes highly crystalline (Cristobalite is the main phase) as evident from sharp reflection peaks.

In uncalcined SCW (Fig. 3), silica and carbon are the primary component with small amounts of calcium, anorthite and other compounds. For the SCWA 800°C and 1000°C, (Fig.4), some sharp peak of crystobalite and anorthite starts to show up and more quartz phase has been observed, this indicates that the crystallanity increases as temperature increases.



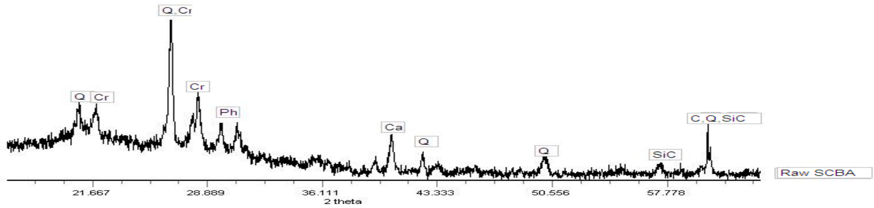


Figure3. XRD analysis for uncalcined and calcined SCBA (Q-quartz, Cr-cristobalite, Ca-calcite Ph-phosphate, C-carbon, SiC- moissanite)

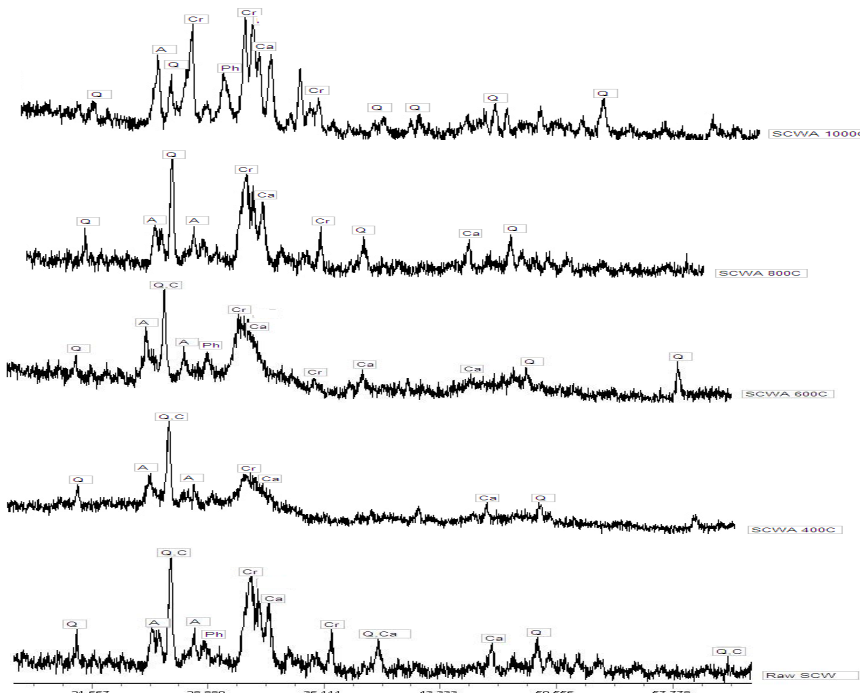


Figure4. XRD analysis for uncalcined and calcined SCWA (Q-quartz, Cr-cristobalite, Ca-calcite, Ph-phosphate, C-carbon, A-anorthite)

4. Conclusion

From the analysis of the results given above, the followings conclusions can be made:

1) The XRD results showed that bagasse ash and sugarcane waste ash structure have been changed from amorphous nature (400°C to 800°C) to crystalline materials (1000°C).

2) As temperature increases, the bagasse ash and waste ash colour changes from black to grey and white which indicates that the carbon content present in the samples were reasonably reduced. Carbon percentage obtained from elemental analyzer also confirmed minimization of carbon content.

3) Also with fine particle size characteristics, implies that these calcined samples can be used as facing sand molding during casting operations.

5. Acknowledgement

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Smart Textiles- New Possibilities in Textile Engineering

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Abstract

In the twenty-first century, product development has progressed tremendously in every field of engineering and technology. Textiles are not lagging behind on the race of such development. Smart textiles are the most exciting innovation in the field of textiles and clothing. Smart textiles can sense and analyze the signals and response in an intelligent way and the response can be electrical, thermal, mechanical, chemical, magnetic or from other source. The extent of intelligence can be divided into three subgroups such as passive smart textiles, active smart textiles and very smart textiles. In smart textiles basically five functions can be distinguished, they are sensors, data processing, actuators, storage and communication. But it must be compatible with the function of clothing such as comfort, durability, resistant to regular textile maintenance processes and so on. Now it is not seen only in the Hollywood movie, it is not limited in our fantasy; it comes in our practical life with tremendous possibility. It is now widely used in various fields like healthcare and safety clothing, fire fighting clothing, intelligence clothing, military clothing, e-textiles, bio-medical application, sports clothing, protective clothing, space exploring activities and so on. So it can also be called the next generation clothing. This study aims to present the overview of smart textiles, its types and functions. Current smart textiles products and their applications as well as market overview of smart textiles have also been discussed.

Keywords: *Textiles, Clothing, Smart textiles, Interactive textiles, Sensors.*

1. Introduction

The term “smart textiles” is derived from intelligent or smart materials. The concept “smart material” was for the first time defined in Japan in 1989. The first textile material, in retroaction, was labeled as a “smart textile” was silk thread having a shape memory.

What does it mean exactly, ‘smart textiles’? [1] Textiles that are able to sense stimuli from the environment, to react to them and adapt to them by integration of functionalities in the textile structure. The stimulus as well as the response can have an electrical, thermal, chemical, magnetic or other origin. Advanced materials, such as breathing, fire resistant or ultra strong fabrics, are according to this definition not considered as intelligent, no matter how high technological they might be. The first applications of smart textiles can be found in clothing.

Smart clothing is defined as a new garment feature which can provide interactive reactions by sensing signals, processing information, and actuating the responses [2]. Similar terminology such as interactive clothing, intelligent clothing, smart garment, and smart apparel is used interchangeably representing for this type of clothing.

Smart textiles are materials and structures [3] of textiles which can sense and react via an active control mechanism for the environmental conditions called stimuli. They are capable of showing significant change in their mechanical properties (such as shape, color and stiffness), or their thermal, capital, or electromagnetic properties, in a handy manner in response to the stimuli. They are systems composed different apparatuses and materials such as sensors, actuators, electronic devices together [4]. Good examples are fabric and dyes that will change their color with changes in P^H[3], clothes made of conductive polymers which give light when they get electromagnetic signals, fabrics which regulate the surface temperature of garments in order to achieve physiological comfort.

2. Types of Smart Textiles

According to the manner of reaction, smart textiles can be divided into three subgroups [1]: Passive smart textiles can only sense the environment, they are sensors; Active smart textiles can sense the stimuli from the environment and also react to them, besides the sensor function, they also have an actuator function; Finally, very smart textiles take a step further, having the gift to adapt their behavior to the circumstances.

3. Functions of Smart Textiles

Basically, five functions can be distinguished in an intelligent suit, namely: Sensors, Data processing, Actuators, Storage and Communication. They all have a clear role, although not all intelligent suits will contain all functions. The functions may be quite apparent, or may be an intrinsic property of the material or structure. They all require appropriate materials and structures, and they must be compatible with the function of clothing: comfortable, durable, resistant to regular textile maintenance processes and so on.

3.1 Sensors

The basis of a sensor is that it transforms a signal into another signal that can be read and understood by a predefined reader, which can be a real device or a person. As for real devices, ultimately most signals are being transformed into electric ones.

Textile materials cover a large surface area of the body. Consequently, they are an excellent measuring tool. Bio signals that are mentioned in literature are: temperature; biopotentials: cardiogram, myography; acoustic: heart, lungs, digestion, joints; ultrasound: blood flow; motion: respiration; humidity: sweat; pressure: blood.

It will be clear to the reader that this list is not exhaustive. A lot of work needs to be done on finding the right parameters for measuring certain body functions, as well as on developing appropriate algorithms for interpretation of the data.

Suits are available already for measuring heart and respiration rate, temperature, motion, humidity, but they mainly use conventional sensors integrated in a cloth. Some examples are already available of real textile sensors for heart and respiration rate and motion, with quite satisfactory results [5].

3.2 Data Processing

Data processing is one of the components that are required only when active processing is necessary. The main bottleneck at present is the interpretation of the data. Textile sensors could provide a huge number of data, but what do they mean? Problems are: large variations of signals between patients, complex analysis of stationary and time dependent signals, lack of objective standard values, lack of understanding of complex interrelationships between parameters.

Apart from this, the textile material in itself does not have any computing power at all. Pieces of electronics are still necessary. However, they are available in miniaturized and even in a flexible form. They are embedded in water proof materials, but durability is still limited.

Research is going on to fix the active components on fibers [6]. Many practical problems need to be overcome before real computing fibers will be on the market: fastness to washing, deformation, interconnections, etc.

3.3 Actuators

Actuators respond to an impulse resulting from the sensor function, possibly after data processing. Actuators make things move, they release substances, make noise, and many others. Shape memory materials are the best-known examples in this area. Shape memory alloys exist in the form of threads. Because of its ability to react to a temperature change, a shape memory material can be used as an actuator and links up perfectly with the requirements imposed to smart textiles.

Until now, few textile applications of shape memory alloys are known. The Italian firm, Corpo Nove, in co-operation with d'Appolonia, developed the Oricalco Smart Shirt [7].

3.4 Storage

Smart suit often need some storage capacity. Storage of data or energy is most common, sensing, data processing, actuation, communication; they usually need energy, mostly electrical power. Efficient energy management will consist of an appropriate combination of energy supply and energy storage capacity. Sources of energy that are available to a garment are for instance body hear (Infineon [8]), mechanical motion (elastic from deformation of the fabrics, kinetic from body motion), radiation (solar energy [9]), etc.

3.5 Communication

For intelligence textiles, communication has many faces: communication may be required within one element of a suit, between the individual elements within the suit, from the wearer to the suit to pass instructions, from the suit to the wearer or his environment to pass information.

Within the suit, communication is currently realized by either optical fibers [10], either conductive yarns [11]. Communication with the wearer is possible for instance by the following technologies: for the development of a flexible textile screen, the use of optical fibers is obvious as well. France Telecom [12] has managed to realize some prototypes (a sweater and a backpack).

4. Fibertronics

Smart textiles are made by embedding computing and digital components into fabrics. The main aim of smart textiles, also known as electronic textile, is the integration of electronic components. The science of embedding the substances is known as fibertronics [13].

Just as in classical electronics, the construction of electronic capabilities on textile fibers requires the use of conducting and semi-conducting materials such as a conductive textile. There are a number of commercial fibers today that include metallic fibers mixed with textile fibers to form conducting fibers that can be woven or sewn. However, because both metals and classical semiconductors are stiff material, they are not very suitable for textile fiber applications, since fibers are subjected to much stretch and bending during use. One of the most important issue of E-textiles is that the fibers should be made so that it can washable as the clothes should be washed when it is dirty and the electrical components in it should be a insulator at the time of washing.

A new class of electronic materials that are more suitable for e-textiles is the class of organic electronics materials, because they can be conducting, semiconducting, and designed as inks and plastics.

Some of the most advanced functions that have been demonstrated in the lab include:

- Organic fiber transistors [14, 15]: the first textile fiber transistor that is completely compatible with textile manufacturing and that contains no metals at all.
- Organic solar cells on fibers [16].

5. Applications

Smart textiles are on the world market since the late 80’s. Their application is getting wider and wider since then. These days, it is not hard to get self-cleaning carpets, shape memory and environment-responsive textiles [3], temperature regulating suit and shoes [17]. They are on applications in geo textiles, bio medical textiles, sports, protective clothing’s, casual clothing’s especially for winter wears.

5.1 Gore – Tex Smart Fabric, Jacket

The Gore-Tex is the first truly smart fabric designed by Gore Company in the year 1978. It has the capability of letting water and moisture flow in one direction and not in the other; this property makes it waterproof, windproof and breathable [18].

The fabric membrane has pore density of 10 billion pores per square inch. Since the diameter of the pores is on the microscopic level, they are 20000 thousand times smaller than a water droplet [18]. Because of this GORE-TEX fabric membrane is waterproof from the outside. The pore diameters are about 700 times larger than a water vapor molecule; they allow perspiration and water vapor to escape from the inside. On the fabric surface, an oil-hating substance uses in preventing the penetration of body oils. It also repels insects that can affect the membrane. There is lamination between high-performance fabrics that are extremely breathable.

5.2Wearable Motherboard

Georgia Tech was the pioneering institute for the development of SFIT that integrates electronics. During a project funded by the US Naval Department in 1996, they have developed a "Wearable Motherboard" (GTWM commercial name is Smart shirt) [19, 20], which was manufactured for use in combat conditions. The garment uses optical fibres to detect bullet wounds and special sensors that interconnect in order to monitor vital signs during combat conditions. Medical sensing devices that are attached to the body plug into the computerised shirt, creating a flexible motherboard. The GTWM is woven so that plastic optical fibres and other special threads are integrated into the structure of the fabric. The GTWM identifies the exact location of the physical problem or injury and transmits the information in seconds. This helps to determine who needs immediate attention within the first hour of combat, which is often the most critical during battle.

Furthermore, the types of sensors used can be varied depending on the wearer's needs. Therefore, it can be customised for each user. For example, a fire-fighter could have a sensor that monitors oxygen or hazardous gas levels. Other sensors monitor respiration rate and body temperature, etc.

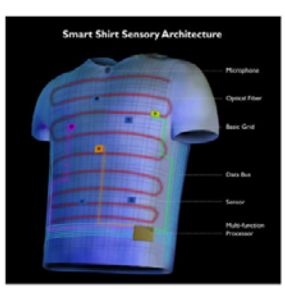

Fig.1. Left: The GTMW of the Georgia Tech, Right: The Smart Shirt by Sensatex [21]
The smart shirt could be used in a large variety of fields and the Sensatex Company currently manufacture it for commercial applications such as: medical monitoring, disease monitoring, infant monitoring, athletics, military uses.

5.3 Smart Running Shoes

Adidas's smart shoes commenced to the market in 2004 and it was the first smart shoe. It consists of a microprocessor, electric motor and sensor into the actual material. The shoe allows the wearer in the running methodology. It adjusts its cushioning dependent on what surface the wearers are travelling over and how they run or walk [22].

- The sensor reads 20,000 readings in a second, with the aid of a 20MHz processor.
- It able to do 10,000 calculations in a second.
- The small motor in the heel changes the tension of a metal cord to assist the wearer.
- It has shock absorption mechanism for an appropriate style of the runner's, etc.

The latest smart Nike brand running shoes come to the customer's recently. It uses a special sensor that tracks the wears' running by doing a lot of interactive activities. It communicates with information technology tools. It sends the running condition, speed, total distance run and other data to personal iPod. The transmitted data can automatically upload and post a status report on Face book [23].

5.4 Biosensor Underwear

The University of California San Diego's Laboratory [24] for Nanobioelectronics has demonstrated a method for direct screen-printing of biological sensors onto clothing [25]. By printing the sensors on the elastic bands in men's underwear, the researchers ensure the sensors maintain tight contact with the skin. The sensing electrodes detect hydrogen peroxide and enzyme NADH, which are associated with numerous biomedical processes. Testing indicated the sensors could withstand the mechanical stress of a wearer's daily activity (flexing and stretching) with minimal effect on the measurements.

5.5 Smart Bra

One of the best examples for improving comfort thanks to electronics is an Australian invention: the Smart Bra. Wallace et. al at the University of Wollongong, have developed a bra that will change its properties in response to breast movement. This bra will provide better support to active women when they are in action [26]. The Smart bra will tighten and loosen its straps, or stiffen and relax its cups to restrict breast motion, preventing breast pain and sag. The conductive polymer coated fabrics will be used in the manufacture of the Smart bra. The fabrics can alter their elasticity in response to information about how much strain they are under. The smart bra will be capable of instantly tightening and loosening its straps or stiffening cups when it detects excessive movement.

5.6 Motion Detecting Pants

Recently the research teams in Virginia Polytechnic Institute and State University in Blacksburg coordinately have developed a pair of pants. The special feature of the developed smart fabric is to sense the movement, speed, the rotation and location of the wearer. It reports to the stored data about the details of the movement to the computer by the wireless signal. These smart and interactive pants work through a loom that helps sew the wires and fabric together [27].

5.7 NASA Aero Gel Jacket

Aero gel materials are the best insulation material for smart clothes. Due to their very low density, weight and often translucent appearance, aero gels are often called solid smoke [NASA Spinoff for 2001]. Their flexible nature making blankets, thin sheets, beads, and molded parts. Their products are not bulky and heavy. When thermal insulation needed like in the design of 2001 NASA jacket, they are highly preferred.

5.8 The Sensory Baby Vest

At the ITV Denkendorf, an interdisciplinary team of researchers has been developing a special vest for babies [28]. The sensory baby vest is equipped with sensors that enable the constant monitoring of vital functions such as heart, lungs, skin and body temperature which can be used in the early detection and monitoring of heart and circulatory illness. It is hoped to use this vest to prevent cot death and other life-threatening situations in babies. The sensors are attached in a way that they do not pinch or disturb the baby when it is sleeping.

5.9 Intelligent Garment for Fire Fighters

The Denmark originated company called VIKING designed the new brand fire fighters jacket in 2009. The thermal sensors integrate with the interior and exterior layers of the coat so as to control the temperature near the fire-fighter and inside of the coat close to the body. The sensors connected to two LED displays, on the sleeve and one on the back.

The LED display on the upper left shoulder indicates critical situations. The LED display on the lower sleeve indicates hazardous heat levels in and outside the turnout gear. The power supply batteries are rechargeable and removable. The microelectronics chips are washable. They can with stand up to 25 cycles. The display gives flash of light slowly at critical and hazardous outside temperature of 250ºC. it becomes rapid at 350ºC, and slow flashing at 50ºC and at 67ºC the display light flashes rapidly because the inside of the coat near the skin reaches 79ºC is the critical situation [29].

5.10 Fashion

There have been a number of commercially available and prototype garments manufactured that use smart textile technology. The range of functions of these garments has been diverse; some enable control of integrated music players (i.e. MP3 Players), some are meant to display emotion, some are purely demonstrate the capabilities and potential uses of smart textile garments.

In 2000 Philips and Levi Strauss launched their ICD+ jacket [30] which combined a remote-controlled mobile phone and an MP3 player and, on removal of all the electronic devices, was washable. The ICD+ jacket was apparently the first wearable device to be marked to consumers, although it was only available in Europe.

Canesis, in conjunction with Australian Wool Innovations [31] developed electrically warmed wool socks through the use of conductive yarns and wool, aimed at the hiking/ walking market and expected to go on sale in late 2004 or early 2005. They are battery powered and suitable for those who worked in very cold environments or for people who suffer from poor circulation, as the amount of heat generated by socks was to equal the rate of heat lost [32] through the foot.

Eleksen’s touch-sensitive fabric was employed in the wireless keyboard introduced in 2006 by G-Tech, and in 2007 it launched an iPod control business suit [33] for sale in a major department store. Fibertronic, launched the iPod control system for the new RedWire DLX jeans, to be launched by Levi’s in 2007, and Burton Snowboards has added Fibretronic’s PTT (push to talk) technology to its Audex range of jackets and packs.

6. Market Overview

According to a US report published by Venture Development Corporation (VDC) [34], the smart fabric and interactive textile (smart textile) market totaled $248 million in 2004 and $304 million in 2005, with expectations that it would grow to $ 642 million in 2008, with a yield of a compound annual growth rate of 27%.

The global market was worth more than $2.5 billion in revenue in 2012 and is expected to cross $8 billion in 2018, growing at a healthy CAGR of 17.7% from 2013 to 2018. In terms of products, wrist-wear accounted for the largest market revenue in 2012, with total revenue of the most established wearable electronic products - wrist-watches and wrist-bands combined, crossing $850 million.

Among application sectors, consumer applications accounted for the largest market share, with revenue crossing $2 billion, as of 2012. However, that of enterprise and industrial application is expected to grow at the highest CAGR (more than 21%), during the forecast period of 2013 to 2018. North America, with U.S. accounting for more than 80% of the market is the single largest revenue base for this global market, and is expected to maintain its dominance during the forecast period as well. However, the market in Asia–Pacific, with China leading the way, is likely to grow at the highest CAGR during the next five years [35].

Smart textiles is now limited in the developed countries. It will be the next generation’s textile. So, there will be possibility of developing countries to earn huge profit. But they need more research and funding as well as technologies to implement this innovation.

6.1 Market Segmentation

This industry is classified based on following application segments: Consumer Products, Military & Homeland Defense/Public Safety Applications, Computing, Biomedical, Vehicle Safety & Comfort, Others (Logistics & Supply Chain Management, and Signage, among others). Major geographies areas include North America, Asia Pacific, Europe, and Rest of the World [36].

6.2 Major Players

Some of the major players dominating this industry are E. I. Du Pont De Nemours and Company, Intelligent Clothing Ltd., Interactive Wear AG, International Fashion Machines Inc., Kimberly-Clark Health Care, Milliken & Company, Noble Biomaterials Inc., Outlast Technologies Inc, QinetiQ North America, Royal Philips Electronics N.V., Toray Industries Inc, and others [36].

7. Conclusion

Smart textiles are the most exciting innovation in the field of textile engineering. The development of smart textiles reaches far beyond imagination; some stories may seem science fiction. The economic value and impact of smart textiles is gigantic. The advent of smart textiles makes it possible to being the traditional textile sector to a level of high-technological industry. Moreover, it appears that this is only possible by intense co-operation between people from various backgrounds and disciplines such as microelectronics, computer science, material science, polymer science, biotechnology, etc. Also more research needs to make it more convenient in our practical life.

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Analysis and Treatment of Waste Water of Textile Dyeing Industry: A Study on Bulbul Textile, Kushtia, Bangladesh.

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Abstract

Textile waste water generation by large and small scale textile industries at Kushtia District in Bangladesh has been posing a serious environmental problem over the last two decades. The study was conducted as a local environmental issue to analyze and treatment of textile waste water runoff from the specific industrial source to the nearby River Gorai through a main drain of the municipality of Kumarkhali Upazilla at Kushtia district in Bangladesh. Standard methods to measure TDS, TSS, BOD_5, spectrophotometer to measure COD, Cr^{6+}, SO_4^{2-}, turbidity and pH meter to measure turbidity and pH respectively were used whereas coagulation and filtration method were used to treat the waste water. The pH, color, turbidity, BOD_5, COD, TDS, TSS, SO_4^{2-}, Cr^{6+} were 8.14, 5170 Pt-Co, 452 NTU, 233 mg/L, 381 mg/L, 2601 mg/L, 408.6061 mg/L, 751.35 mg/L and 0.2 mg/L in the month of June and 8,5050 Pt-Co, 449.29 NTU, 213.948 mg/L, 372 mg/L, 2540 mg/L, 400 mg/L, 750 mg/L, and 0.2 mg/L in the month of July during the year of 2012. Ferrous Sulfate as a coagulant for chemical treatment together with sand bed filtration achieved removal efficiency for pH by16.68%, turbidity by 97.31%, color by 99.09%, TDS by 29.18%, TSS by 80.19%, COD by 82.66%, SO_4^{2-} by 1.46% Cr^{6+} by 75% and BOD_5 by 83.37%.

Key words: *Textile waste water, turbidity, TDS, coagulation, filtration.*

1. Introduction

The nature of the Characterization and Treatment of the waste water of the Bulbul textile Industry indicates the pollution level and optimum dose directly or indirectly of all the textile industries situated in Kumarkhali Upazilla like this industry. Besides, the scope of the analysis and treatment of textile waste water is increase of awareness to the owners of the industries as well as people of the municipality about environmental pollution, designing common effluent treatment plant etc. Kumarkhali is an important centre of the Bangladesh Handloom Board; about one hundred automated textile manufacturing units are located here. Main exports of kumarkhali Upazilla is Textile products [1]. Bulbul textile is one of the large industries of kumarkhali Upazilla among all industries situated in kumarkhali Upazilla which discharge waste water. Textile industries in Bangladesh are denoted as the red colored industries because of serious environmental pollution [2]. It is reported that textile effluent is very low in terms of LC50 and exhibits very high toxicity with acute toxicity unit (ATU) levels between 22 and 960. Dye baths surfactants and fibers could have high levels of BOD, COD, color, toxicity, surfactants, fibers, turbidity and contain heavy metals [4]. The result of a textile waste water process aims at the destruction of the waste water color by means of coagulation/flocculation techniques using Ferrous Sulfate or lime [5]. Due to the use of various chemicals and auxiliaries in the processing of textiles, large volume of waste water with numerous pollutants is discharged every day. They have strong rules regarding these types of industries including the preset up of Effluent Treatment Plant (ETP) with the given time period to get the Environmental Clearance Certificate which is mandatory to get utility connections like gas, water etc [3]. The first step to investigate the problem of the waste water discharged by the industry was done by using a Dissolved Oxygen Meter, pH meter, Thermometer, Dissolved oxygen bottle etc especially based on standard methods. On the other hand, as a first footprint on this specific research in such a study area in Bangladesh, the treatment phase has been done by using Ferrous sulfate as coagulant for chemical treatment. Actually the Dissolved oxygen of the waste water has been found 0.3 mg/L and 0.4 mg/L as well. To treat the waste water, the

Ferrous sulfate has been used as 600 mg/L approximately. The principle result of waste water characterization shows that except pH, all the parameters like color, turbidity, Total Dissolved solid, Total Suspended Solid, chromium as a heavy metal, sulfate, Biological Oxygen Demand, Chemical Oxygen Demand have been exceeded the standard limit of Department of Environment, Government of Bangladesh. As the waste water is less concentrated comparing to the newly developed textile industrial waste water in Dhaka city [3], it takes less amount of chemical for treatment. Besides using sand bed filtration for the Ferrous sulfate coagulated water has been shown good performance in its efficiency.

2. Materials and Methods

The overall methodology consists consequently like topic selection, conceptualization, study area selection, primary data collection, secondary data collection, data processing and preparation of a conference paper. In Characterization phase, Turbidity meter, Color meter and pH meter are used for measuring turbidity and color and pH respectively. Besides for measuring Total Dissolved Solid, Total Suspended Solid, Biological Oxygen Demand, Chemical Oxygen Demand, Standard methods (APHA, AWWA, and WEF, 1995) was used. Sampling design was based on purposive sampling in this research work. In treatment phase, Jar test method for Ferrous sulfate coagulation was used and here Rapid Sand Filtration methods was used to treat the textile waste water. On the other hand, computer software like Microsoft office was used for preparation the graph and data processing.

3. Results and Discussion:

The pH level of the Bulbul textile was found below 9 where the DoE standard was 9 in pH level. It has been expressed in the Fig. 1. The Total Suspended Solid was 408mg/L and 400mg/L for the month of June and July which has been exceeded the limit of DoE where the DoE standard of Bangladesh was 100mg/L. Fig. 2. here represents the TSS analysis. Total Dissolved Solid was 2601 mg/L and 2540 mg/L for the month of June and July respectively which has shown that TDS has been exceeded DoE standard. Fig. 3. represents the TDS analysis. Turbidity of the waste water of Bulbul textile was 452.5 NTU and 449.29 NTU for the month of June and July in 2012 respectively that shows the over limit. On the other hand, drain and river waste water shows the turbidity that does not exceed the limit of DoE standard (Fig. 3.). The range of color, BOD, COD, Chromium and sulfate of the bulbul textile waste water were 5170 Pt-Co, 233.508 mg/L, 381 mg/L, 0.2 mg/L and 751.35 mg/L for the month of June 2012 respectively and 5050 Pt-Co, 213.948 mg/L, 372 mg/L, 0.2 mg/L and 750 mg/L for the month of July 2012 respectively. The analysis of Turbidity, Color , BOD, COD, Chromium and sulfate for all sources like Bulbul textile, Drain and River have been shown in the Fig. 4. –Fig. 9. respectively. In the phase of treatment option, the optimum dose has been detected as 700mg/L for Ferrous sulfate in terms of turbidity, color and pH. Optimum dose of Ferrous sulfate has turned the color, turbidity and pH that are2200 Pt-Co, 102 NTU and 6.82 respectively where the raw textile waste water was approximately 450.29 NTU in turbidity, 5100 Pt-Co in color and 8 at pH. All of the has been shown in Fig. 10, Fig. 11. and Fig. 12. for turbidity, color and pH respectively. The subsequently reduction of the range pH, turbidity, color and filtration rate have been shown in the Table 1. after functioning of Sand Bed Filtration.

Table 1. Functioning of Sand Bed Filtration

Parameter	2+2 inch (fine sand, brick aggregate)	4+4 inch (fine sand, brick aggregate)	6+6 inch (fine sand, brick aggregate)
pH	6.75	6.73	6.74
Turbidity (NTU)	45	19.9	12.1
Color (Pt-Co)	121	63	46
Filtration rate (Liter.m^2/hr)	676.33	559.059	475.15

Bangladesh Environmental protection agency also supported demands for their proper monitoring in the textile effluents in the Country. Textile Effluents are high in BOD due to fiber residues and suspended solids. They can contaminate water with oil and grease, and waxes, while some may contain heavy metal such as chromium, lead, copper and mercury [6]. The effluent characterization of effluent of Bulbul textile Industry has shown that except pH, all of the parameters like TDS, TSS, BOD, COD, turbidity, chromium and color have exceeded the limit of DoE standard. Comparison of parameters among influent, filtrated waste water after coagulation of Ferrous sulfate with DoE standard has been shown in the Table 2.

Table 2. Comparison of parameters among influent ,Filtrated water after coagulation of ferrous sulfate with DoE Standard

parameter	Influent(mg/L)	DoE standard (mg/L)	Filtrated water after coagulation of $FeSO_4$(mg/L)	Removal Efficiency(percentage)
TDS (mg/L)	2570	2100	1820	29.18
TSS (mg/L)	404.335	100	80	80.19
COD(mg/L)	375	200	65	82.66
BOD_5(mg/L)	221	150	37	83.37
SO_4^-(mg/L)	750.675	400	740	1.46
Cr^{6+}(mg/L)	0.2	0.1	0.05	75

The relationship of the parameters has been interpreted that by increasing TDS and TSS, the BOD and COD will be increased. Turbidity acts as an indicator that the more the range of turbidity, the more the range of TDS, TSS, COD, BOD and color will be. Ferrous sulfate was chosen as an optimum coagulant for removal because of the lowest required coagulant dose, minimum settled sludge volume and maximum de-colorization [7]. In this research work, the removal efficiency for TDS, TSS, COD, BOD, Sulfate and Chromium are 29.18, 80.19, 82.66, 83.37, 1.46 and 75 percent. Besides the removal efficiency of color, turbidity and pH are 99.09 percent, 97.31 percent and 16.48 percent respectively. Sand bed filtration has been shown that sequential increase of sand and brick aggregate layer has increased the treatment efficiency which has been shown in Table 1. Some parameters like oil and grease have not been measured due to lack of lab facilities. Although the range of all parameters has been lessened and reached under the limit of DoE standard, sulfate has not been lessened here. Here, efficiency of removal has not been shown for two or more coagulant except Ferrous sulfate. Theoretically it has been shown that as the waste water has high value of its parameters, the environment has been degraded due to its toxicity. Besides waste water treatment by Ferrous sulfate coagulation and sand bed filtration has been done as a first research work in Kushtia district to understand about the pollution intensity and optimum chemical dosing. Practically, no Effluent treatment Plant has been set up still now though the Kumarkhali Upazilla has many large and small scale textile industries. As the industries require Environmental Clearance Certificate to export their textile product, it needs to set up Effluent treatment plant.

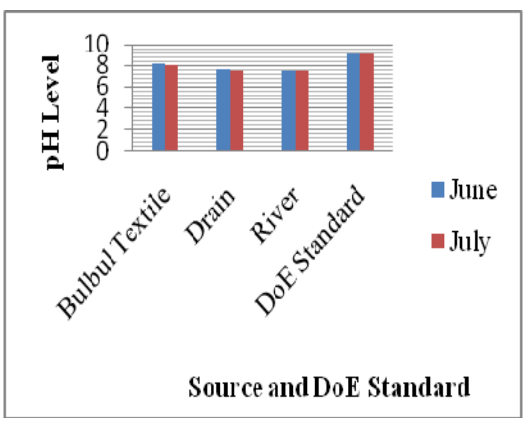

Fig. 1. pH Analysis

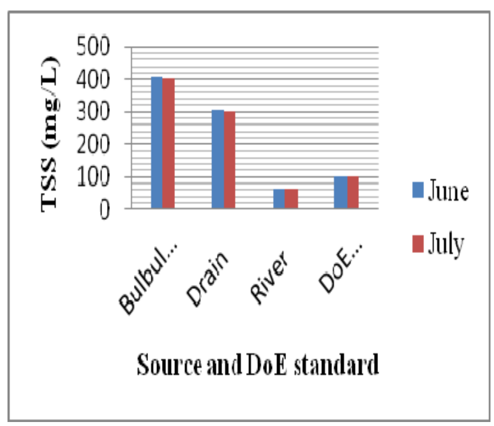

Fig. 2. Total Suspended Solid Analysis

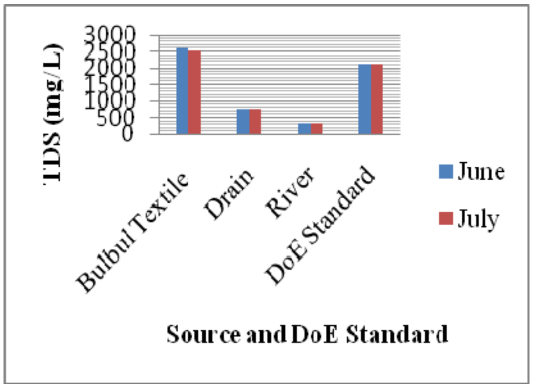

Fig. 3. Total Dissolved Solid Analysis

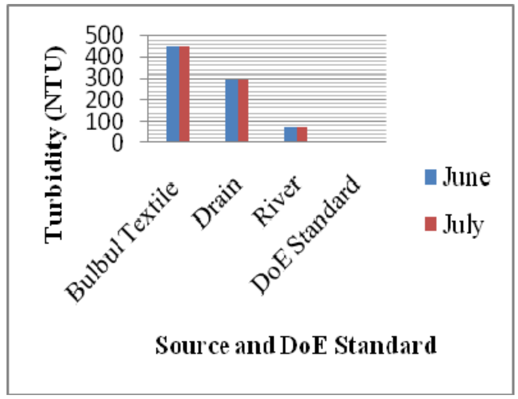

Fig. 4. Turbidity Analysis

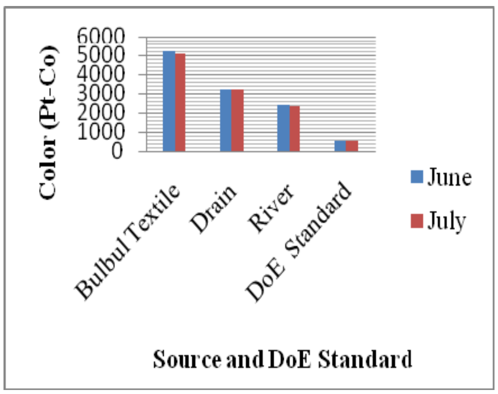

Fig. 5. Color Analysis

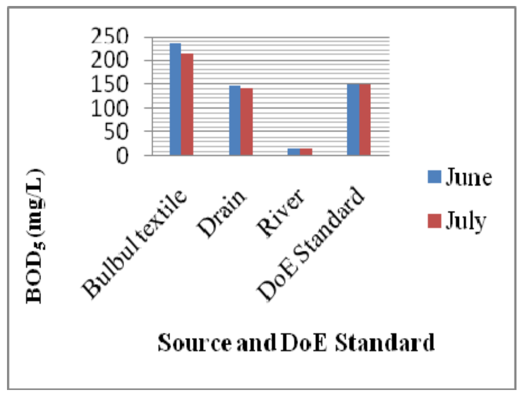

Fig. 6. Biological Oxygen Demand Analysis

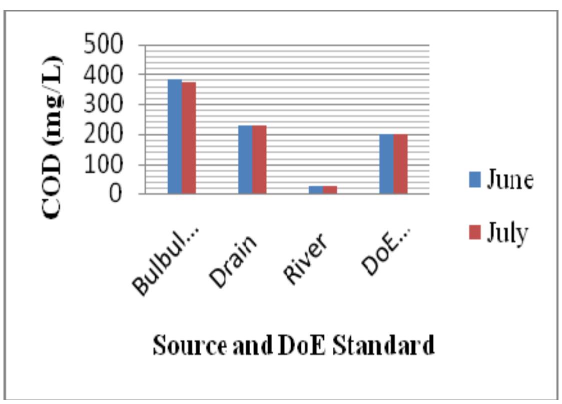

Fig. 7. Chemical Oxygen Demand Analysis

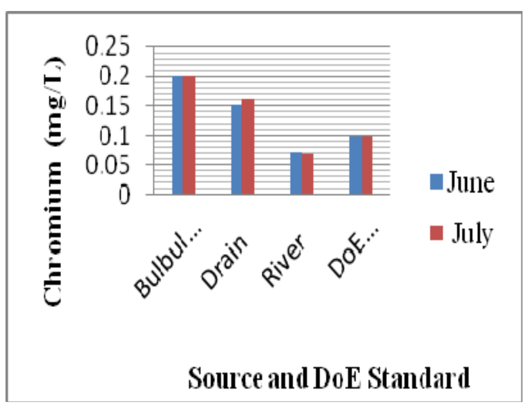

Fig. 8. Chromium Analysis

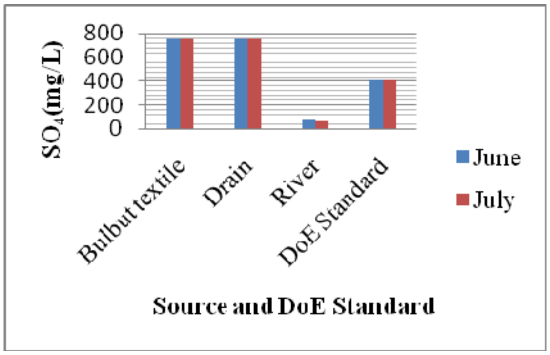

Fig. 9. Sulfate Analysis

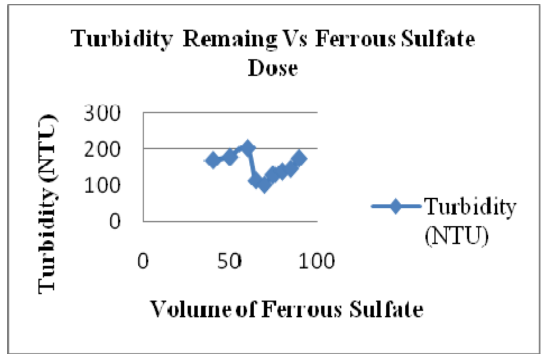

Fig. 10. Turbidity Remaining Vs $FeS0_4$ dose

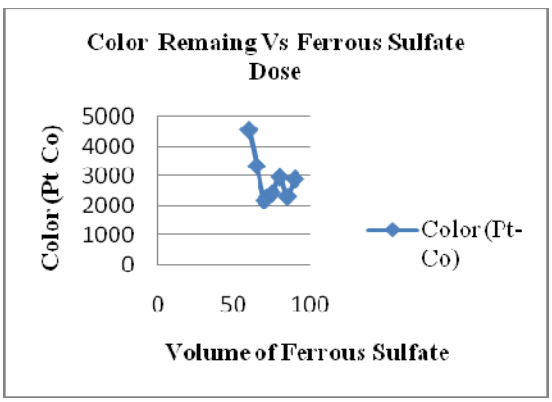

Fig. 11. Color Remaining Vs $FeS0_4$ dose

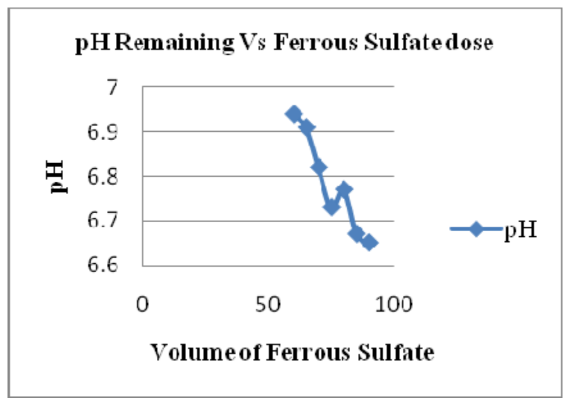

Fig. 12. pH Remaining Vs $FeS0_4$ dose

For this purpose, this research work may help to characterize all the textile effluent precisely as well as provide assumption how the characteristics of all textile industrial waste water situated in Kumarkhali Upazilla will be, because all the textile industries in this study area are denoted as same in their functions. Here the local sand of the River Gorai and brick aggregate have been used for making the sand bed filter.

4. Conclusion

Analysis of textile waste water has shown the environmental pollution near the bulbul textile industry. If there will not be setup any ETP further, there will be seen a very vulnerable environmental condition in this study area. For this work, the analysis and Treatment of the effluent may be acted as the forerunner in setting up Effluent Treatment Plant or Common Effluent Treatment Plant. This research work will help replicating through such research like treatment and management of textile waste water in Kumarkhali Upazilla that will provide the international provisions to export the textile product which improves economic development of the industry, the maintenance of sustainable water quality to enhance the quality of life of human and aquatic organism of the river and opportunity to involve more textile labors as well as insurance of their better livelihood pattern, all of which terms as Sustainability in Management.

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Investigation of powder and binder mixing mechanism in metal injection molding

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Abstract

In this study, fine aluminium powders were combined with two types of binder systems to produce different sets of feedstock for metal injection molding. Binder system A contained High Density Polyethylene (HDPE), Paraffin Wax (PW) and Stearic Acid (SA) while binder system B consisted of HDPE and SA, without PW. Investigations were performed on analysing the effects obtained among the feedstock on the availability of PW. The feedstock were prepared with different powder loading (58wt.%, 62wt.%, 70wt.%) and binder composition ratio but conducted under similar mixing temperature and mixing time. The mouldability of the feedstock and evolution on interface of the microstructure were investigated. Rheological analysis was carried out to determine the optimum range of binder composition for ideal molding. The morphological changes on the structure of the green (injected) parts and brown (debinded) parts were examined through FeSEM analysis. Result revealed that optimum powder loading of 62wt.%and binder composition ratio of 38wt.%with binder system consisting of HDPE, PW and SA at the ratio of 55:35:10 under the mixing speed of 350rpm and mixing time of 6 hours provided the good performance.

Keywords: *Color strength; dyeing process; dye concentration; FLES.*

1. Introduction

Metal Injection Molding (MIM) is a technique applied to manufacture small metal parts with complicated designs in a high density and high performance mode. As a subset of Powder Injection Molding (PIM), MIM combines the technologies of thermoplastic injection molding and powder metallurgy to produce complex-shapes cost effectively and improved mechanical properties. MIM has four main processing steps as mixing, injection molding, debinding and sintering (Fig. 1).

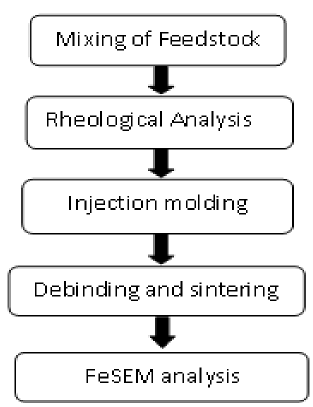

Fig.1 Design experimental setup with the four main processes in MIM.

In order to enable better rheological properties for molding and improved mechanical properties for handling, metal powders are hot mixed with thermoplastics polymers (binder) and some additives. Supati et al.,

[1] has stated that when powder is increased, the viscosity is also increased while with low mixing speed, high viscosity is resulted. Altering mixing temperature has insignificant effects on viscosity. The mixture of metal powder and binders (feedstock) is injection-molded into the required shape and the binder is removed and the powder is sintered to full density incorporating certain shrinkage. Fine (20 μm) powder exhibits higher packing density and produces improved mechanical properties [2]. It is also reported that finer starting powders give lower porosity after the sintering process of MIM [3]. The typical ratio of powder and binder mixing is about 60vol.% powder, 40vol.% binders whereas aluminium mixture constitutes about 86% powder by weight for typical mix ratio [4]. However, very few investigations have been carried out on the effects of composition ratio between aluminium powder and binder. Therefore, a desired aluminium powder mixing and binding strategy are to be developed for the better performance of MIM.

2. Materials and Methods

2.1 Material Properties

Aluminium powder of 99.9% purity, GF290-600-18 with particle size in the range of 0 to 60 micron meter and relative density of 2.7g/cm^3 by the supplier Good Fellow was used in the feedstock preparation. The microstructure of the aluminium powder particles was observed using the Scanning Electron Microscopy (SEM) analysis. Figure 2 shows the morphology of the raw material of powder and binder components used in the mixing.

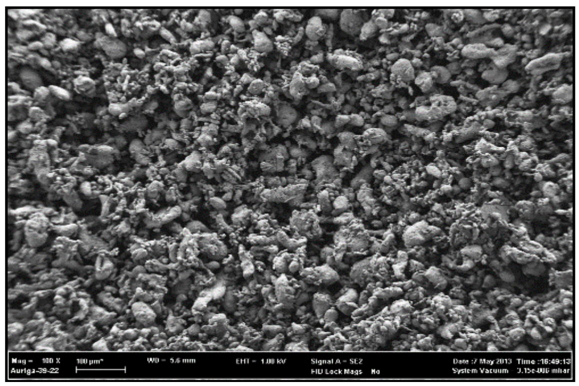

Fig.2 SEM micrographs on the morphology of the aluminium powder.

A binder system consisted of three different polymers was prepared. High Density Polyethylene (HDPE), Paraffin Wax (PW) and additives of Stearic Acid (SA) were mixed together at a constant composition ratio of 55%, 35% and 10% respectively. Few characteristics of the binder components used are shown in Table 1. Mixing experiments were conducted in a Retsch Planetary Ball Mill PM 100. 50ml grinding jar was clamped eccentrically on the sun wheel with the amount of feedstock restricted to less than two third of the jar volume. The extremely high centrifugal forces of Planetary Ball Mills create very high pulverization energy. The interplay between the frictional and impact forces produces an effective degree of mixing and homogenizing of the metal powder and binder system.Six feedstock formulations with the powder loading range between 58 wt. % and 70 wt. % were prepared. Identifications for each feedstock was labelled as listed in Table 2. Constant mixing speed of 350 rpm and mixing time of 6 hours were applied. Two types of binder systems were prepared for mixing. Binder System A consisted of all three binder components of PW, HDPE and SA while Binder System B consisted of only two components which are the HDPE and SA, without PW.

Table 1 Characteristics of binder components used.

Binder Component	Supplier	Melting Temperature (°C)
Paraffin Wax (PW)	Leica	57
High Density Polyethylene (HDPE)	Good Fellow	130
Stearic Acid (SA)	Aldrich	72

Table 2 Identification for various powder and binder composition

	Powder Loading (wt.%)	HDPE (wt.%)	PW (wt.%)	SA (wt.%)	Label
Binder System A	58.0	23.10	14.70	4.20	A58
	62.0	20.90	13.30	3.80	A62
	70.0	16.50	10.50	3.00	A70
Binder System B	58.0	35.00	-	7.00	B58
	62.0	32.00	-	6.00	B62
	70.0	25.00	-	5.00	B70

2.2. Rheological Analysis

After each mixing experiment, the feedstock viscosity was measured using a Physica MCR 301 Rheometer. A measuring plate with diameter of 15mm was used. Thermal equilibrium was achieved after charging the barrel for 10 minutes. Each feedstock was loaded onto the pre-heated barrel at 90°C. By increasing the speed of piston, shear rates were varied within the range of 100 to 10000 s^{-1}. Shear stress was obtained by measuring the pressure drop across the die length.The injection molding of feedstock was carried out using the in-house prototype injection molding machine. Five sets of molds were used to form different geometrical shapes, including the tensile mold and mold with various gear sizes. The injection pressure was set to be 7 bar and the injection temperature were varied within the range of 80 to 100°C. The specimen produced is shown in Fig. 3.Solvent debinding of the green part was done by immersing the specimen in hexane at 50°C for 5 hours. Subsequently, thermal debinding was carried out in a vacuum furnace at 250-500°C for 30 to 90 minutes. The parts were sintered under vacuum phase at 580-640°C for 30-120 minutes.

Fig.3 Tensile specimen produced with dimension 64mm x 10mm x 3mm.

3. Result and discussion

3.1 Rheological Properties

Flow and viscosity curves were dictated the flow ability of feedstock under various shear rates.The zero shear viscosity at low shear rates is a vital material property and is directly proportional to the average molar mass. Empirical studies have revealed that for the range of shear rates in the gates and the mold is within 100 to 1000s^{-1}, feedstock with flow viscosity less than 1000 Pa.s is mouldable [5]. Different flow curves of the various powder binder compositions were combined and compared for each binder system respectively (Fig. 4). From the flow curves it was observed that the viscosity is inversely proportional to the shear rate. It is reported that the range of parameters in which the feedstock exhibits pseudoplastic flow is desired [3]. Pseudoplastic flow where the viscosity decreases with increasing shear rate can help to reduce the required temperature and pressure for successful molding. Pseudoplastic flow or shear thinning behaviour is vital to ease mold filling, reduce jetting and assisting in shape retaining. It is best suited for injection molding process due to its viscosity of the mixture decreases when approaching the nozzle and when the mold is filled the viscosity increases [7-8].

As shown in Fig.4, the viscosity of feedstock obtained is relatively low and thus is expected to be injected. Sample A70 which contained 70% of aluminium powder loading has higher viscosity when compared to Sample A62 and A58. It is reported that torque of the mixture decreases when the composition of PW increases indicating viscosity reduces [12]. Behaving as Newtonian fluid, viscosity of paraffin wax remains constant as shear rate increases. Meanwhile, the viscosity of polyethylene which displays pseudoplastic behaviour decreases as the shear rate increases. For feedstock with Case B, higher range of viscosity was found with the similar range of shear rate. It can be observed that the maximum and minimum viscosities obtained are not varied too much from each other. The range of minimum viscosity falls in between 14 Pa.s and 30 Pa.s whereas the maximum viscosity range is 330 Pa.s to 360 Pa.s. Compared to the maximum allowable viscosity for molding of 1000 Pa.s, all the samples are suitable to be molded.

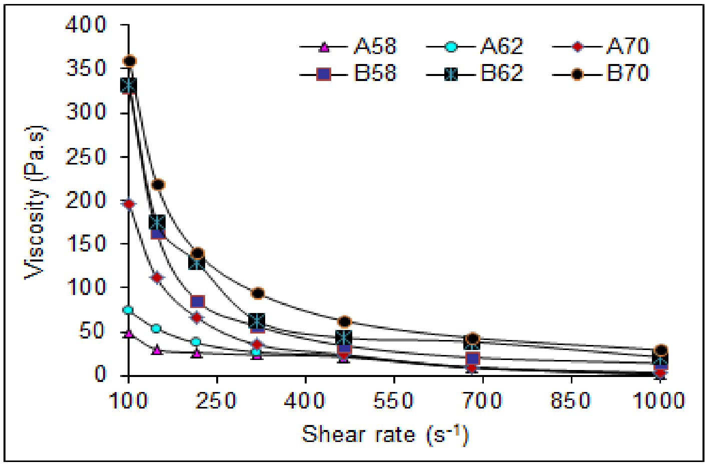

Fig. 4 Flow curve for feedstock with different mixing combinations.

3.2 Powder loading

Pseudoplastic fluid which exhibits shear-thinning properties is correlated by the Power Law as followed,

$$\tau = k\left(\dot{\gamma}\right)^{n} \quad (1)$$

where τ is the shear stress, $\dot{\gamma}$ is the shear rate, k the fluid consistency coefficient and n is the flow behaviour index or flow exponent (<1). It is noted that low value of flow behaviour index, n indicates rapid changes between feedstock viscosity and shear rate. However, a rapid decrease in feedstock viscosity with increasing shear rate during moulding is desirable.After completing the rheological testing, the data of the shear stress for each different feedstock formulation was collected and the log τ - log $\dot{\gamma}$ graphs for all six feedstocks have been plotted as shown in Fig. 5.

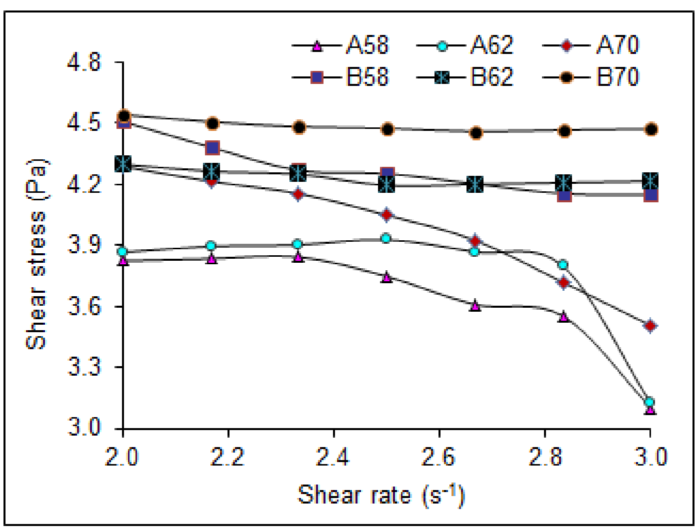

Fig. 5 Relations of shear stress and shear rate for feedstock.

Fig. 5 shows that all the six feedstocks are maintaining basically the pseudo-plastic flow characteristics. In general, it is observed that all the mixing formulations were pseudo-plastic but, the flow exponent values are different. Flow exponent values, *n* were obtained as 0.0796, 0.0801, 0.0899, 0.106, 0.108, and 0.115, respectively for different mixing conditions. It is also noticed that the flow exponent has started to increase with the increase of powder loading from 58 to 62% for both binder systems, achieving the lowest value of 0.0801 and 0.108, respectively. On the other hand, the flow exponent has started to decrease with the increase of shear rate for both of cases. Higher powder loading is preferred to ensure higher shear sensitivity of feedstock in order to produce complicated parts. Hence, the lower flow exponent for 62% powder loading has enabled it to be an optimum powder–binder composition for MIM feedstock. This is to achieve fast powder re-packing and binder molecule orientation during molding. Shear thinning of the samples feedstock with increasing shear rate was mainly due to the powder particle ordering and the binder molecule orientation with flow [5]. Furthermore, the SEM photograph of the feedstock for Case A with powder loading corresponding to 62% is shown in Fig. 6. It is observed that the particles are uniformly dispersed in the matrix and are enveloped by the binder. Thus, the resulting homogeneity is properly revealed for the selected feedstock formulation A62.

3.3 Injection Molding

Feedstock A58, A62, B58 and B62 were successfully molded. However, there were failures during injection molding for samples A70 and B70 with maximum flow viscosity of 196Pa.s and 361Pa.s respectively as shown in Fig. 8. These samples were tested to be with the viscosity flow of less than 1000 Pa.s, which were expected to be mouldable. Although the injection temperature has been set above 130°C which was over the melting point of the binder HDPE, the feedstock was still could not be injected due to the relatively high viscosity flow of the feedstock.

Fig.8 Incomplete molding of feedstock A70.

3.4 Debinding and Sintering

Significant sample size reduction and colour change on the debound brown parts were observed. The volume shrinkage and weight loss after the process of solvent debinding were mainly caused by the elimination of PW component. The microstructure of the brown parts was examined through SEM analysis as shown in Fig. 9. It was shown in the fractograph that, a layer of wax formed material was covering the surface of the part before debinding (Fig. 9a). After debinding (Fig. 9b), the layer of wax has been removed, hence the mixture of other remaining components were exposed.

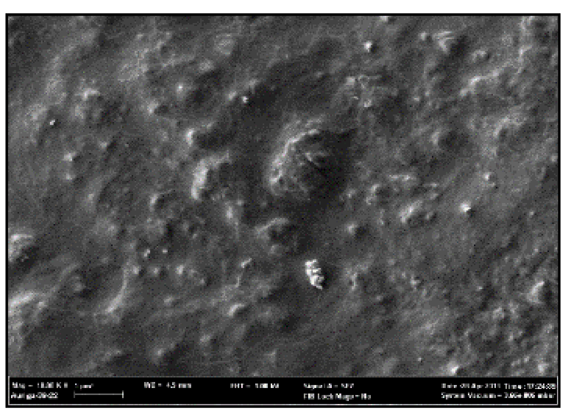

Fig.9a Comparison on the surface microstructure before debinding

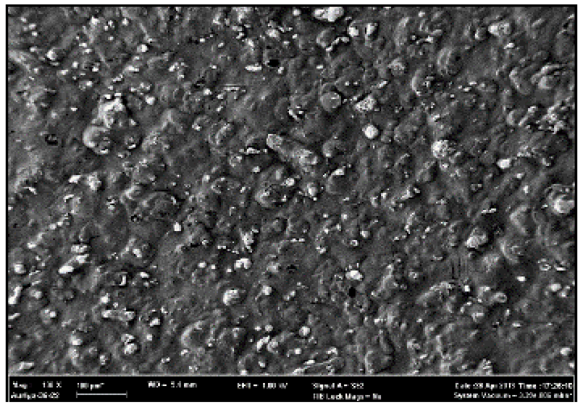

Fig.9b Comparison on the surface microstructure after debinding

4. Conclusions

The critical feedstock combination for better performance in MIM is found to be of 62wt% powder loading and binder composition of 38wt% with binder system A consisting of 20.9wt% HDPE, 13.3wt% PW and 3.8wt% SA at the ratio of 55:35:10 under the mixing speed of 350 rpm and mixing time of 6 hours. This is mainly due to its better rheological properties of maximum viscosity of 73.8Pa.s and relatively low flow behaviour index of 0.0801.

5. Acknowledgements

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Epistemic Uncertainty Study of the Conceptual Phase of Product Development by Multi-valued Logic and Information Content

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Abstract

Product Development studies the activities underlying a product life cycle in a concurrent manner. In the conceptual phase of product development, a set of key solutions are determined by using an appropriate Decisionmaking approach. However, decisionmaking in this phase is a difficult task to perform due to incomplete information, lack of knowledge, and abundance of choice. This study describes logical approaches for making decisions in conceptual phase of product development. In particular, the emphasis is given on such issues as customer needs and creativity. Multi-valued logic and information content from the context of epistemic uncertainty have been used for the sake of computation.

Keywords: Product Development, Customer Needs Assessment, Sustainability and Creativity.

1. Introduction

Product Development is a field of study wherein the activities underlying product lifecycle are studied in a concurrent manner (Ulrich and Eppinger 2004, Dieter and Schmidt 2009). The internal customers first try to make sure the liking-disliking of external customers (the potential real-customers who will use the product to get satisfied). The internal customers need to be creative to suggest many potential key solutions for satisfying the needs of external customers.

However, around 80% cost of a product is decided by the key solution determination process (in the conceptual phase) and it cannot be rectified by making adjustments in the downstream of product lifecycle (Wood and Agonigo 1996). This means that the decisionmaking in conceptual phase of product development is a critical task. In addition, in conceptual phase the knowledge is very limited and there is an abundance of choice (Dieter and Schmidt 2009). This means that the decisionmaking in conceptual phase is a very difficult task to perform on top of its criticalness. Thus, decisionmaking in conceptual phase of product development decides around 80% cost of the product and the decisionmaking process suffers lack of knowledge and abundance of choice (Dieter and Schmidt 2009, Ullman 2009, Ulrich and Eppinger 2004, Ullah 2005). However, decisionmaking in conceptual phase of product development requires an explicit measure that quantifies the lack/abundance of knowledge. For example, consider the measures called degree of certainty of knowledge in robust decisionmaking (Ullman 2006) and certainty compliance (entropy) in general-pinion-desire based decisionmaking (Ullah 2005). In addition, a measure is needed to quantify the degree of fulfillment of requirement, though the requirement might be vaguely defined or vary across the external customers. For example, consider the measure called criteria satisfaction in robust decisionmaking (Ullman 2006) and requirement compliance (entropy) in general-opinion-desire based decisionmaking (Ullah 2005).

2. Methodology

A methodology is presented in this section regarding quantify method of the different uncertainty issues in product development.

2.1 Information Content

In 1940s, Shannon introduced the concept of information content as a part of his information theory wherein an obvious event has low information content and less likely event has high information content. Thus, if the probability of an event is *Pr*, then the information content of the event is given by -log(1/*Pr*). In systems design, Suh have utilized this concept introducing an axiom called the Information Axiom: *minimize the information content of a design* (Suh 1990, 1998). According to the information axiom, the information content of a functional requirement (*FR*) of a system is defined as follows:

$$I(FR) = -log\left(\frac{1}{S}\right) \quad (2.1)$$

In equation (2.1), *S* is the area under the probability density function of system range (*sr*) (the performance of the system designed) for a given design range (*dr*) (the requirement defined the designer). A schematic illustration of *S*, *sr*, and *dr* is shown in Fig. 2.1.

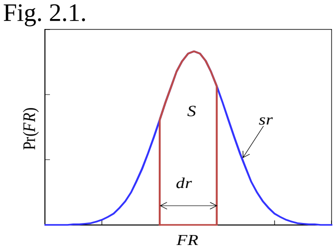

Figure 2.1. Definition of information content for systems design.

In particular, CE is defined as follows:

$$CE = \frac{\sum_{i}^{n} I_c(TV(Pi))}{n} \quad (2.2.1)$$

This means that *CE* is the average epistemic information content, $I_c(.)$, of *TV*(*P*1),...,*TV*(*Pn*). The epistemic information content $I_c(.)$ is determined as follows:

$$I_c(TV(Pi)) = max\left(0, min\left(\frac{TV-0}{0.5-0}, \frac{1-TV}{1-0.5}\right)\right) \quad (2.2.2)$$

Figure 2.2 illustrates $I_c(.)$. As seen from Fig. 2.2, epistemic information content of the truth value of a proposition is a tent function in the universe of discourse of [0,1].

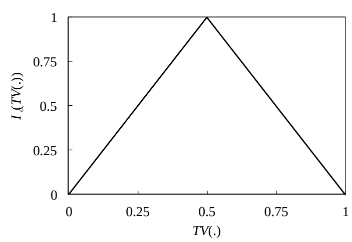

Figure 2.2. Epistemic information content.

The following function can be used to measure *RE* (Ullah 2005a):

$$RE = max\left(0, min\left(1, \frac{a - TV(P_R)}{a-b}\right)\right) \quad (2.2.3)$$

$$a = max(TV(Pi) \mid i = 1,\ldots,n) \quad b = min(TV(Pi) \mid i = 1,\ldots,n)$$

The procedure to determine the $TV(P_R)$ from *TV*(*P*1),...,*TV*(*Pn*) shown in Ullah 2005a is used in this paper. A typical nature of RE is illustrated in Fig. 2.3 corresponding to $a = 0.9$ and $b = 0.05$.

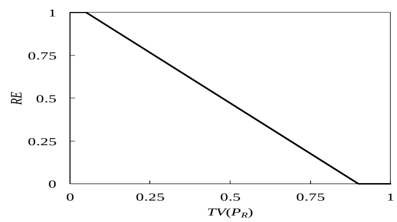

Figure 2.3. A function to determine requirement entropy.

The two-dimensional information content of key solutions can be plot on a *RE* versus *CE* plot and a measure called coherency measure (λ) can be determined. The coherency measure actually aggregates the variability in the information content of a key solution using the following expression:

$$\lambda = e + f + g + h + (f - e)(h - g) \tag{2.2.4}$$

In ideal case, λ = 0 that means the solution fully fulfills the requirement the knowledge of the solution is complete. In reality it does not happen. What is seen in reality is schematically illustrated in Fig. 2.4. This way decisionmaking can be carried out in conceptual phase of product development.

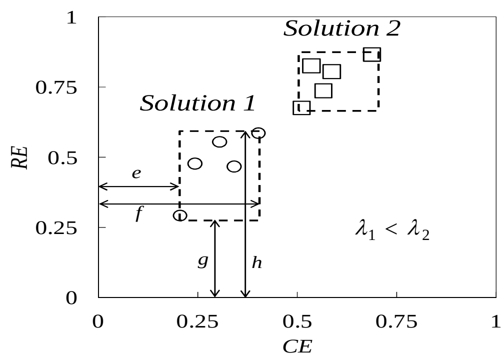

Fig. 2.4. Decisionmaking using two-dimensional information content.

3. Customer Needs Assessment

This section deals with the customer needs assessment based on the work of Rashid et al. 2010 and Rashid et al. 2012. The following issues are emphasized: How to deal with the unknown customer needs as described in Fig. 3.1-3.3 ?

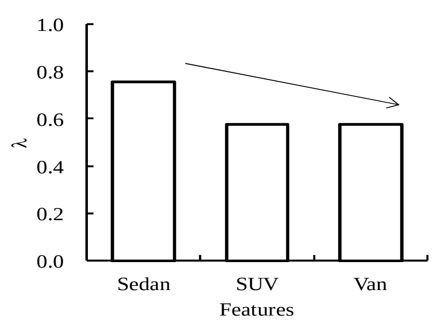

Figure 3.1. Reduction in overall information content for could be included.

Figure 3.2 shows the value of coherency measure when the requirement refers to "should be included" for Sedan, SUV, and Van. As seen from Fig. 3.2, if Van is introduced side by side Sedan in a large volume in Bangladesh, the level of satisfaction of vehicle users "should" increase. This time, SUV does not increase the level of satisfaction compared to that of Sedan. This decision however, underlies a great deal of uncertainty (a large value of coherency measure).

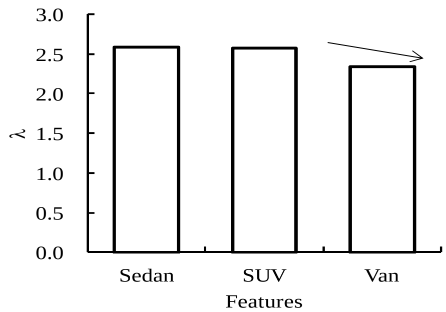

Figure 3.2. Reduction in overall information content for should be included.

Figure 3.3 shows the value of coherency measure when the requirement refers to "must be included" for Sedan, SUV, and Van. As seen from Fig. 3.3, if SUV and Van are introduced side by side Sedan in a large volume in Bangladesh, the level of satisfaction of vehicle users "must" increase. The trend seen here similar to that of could be included (Fig. 3.1). This time a great deal of uncertainty (a large value of coherency measure) is associated with the decision.

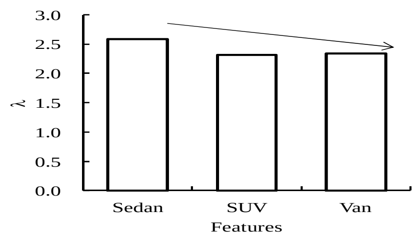

Figure 3.3. Reduction in overall information content for must be included.

In synopsis, the following statements can be made: Injecting more and more SUV and Van into the market could increase the level of satisfaction of car users in Bangladesh (Fig. 3.1). SUV and Van are not that much unexpected surprises to the car users in Bangladesh (Fig. 3.2).SUV and Van must increase the level of satisfaction of car users in Bangladesh but this conclusion possesses a great deal of uncertainty (Fig. 3.3).

4. Creativity Assessment

This section deals with the assessment of creativity in key solutions determination process in the conceptual phase of product development. This section is based on the work of Ullah et al. 2012. This section describes the results of how a creative concept (an engine for Mars exploration) has been differentiated from an ordinary engine (an existing fossil-fuel based engine) using the method described in the previous section. At the beginning the C-K mapping takes the form of the map shown in Fig. 5.1.

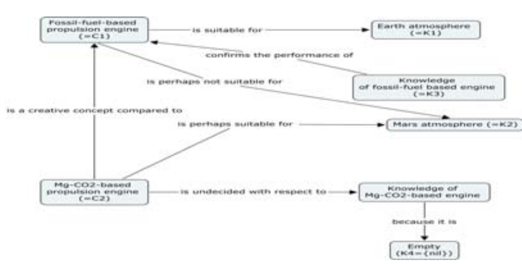

Figure 5.1. C-K mapping of a creative key solution for Mars exploration (Ullah et al.2012)

As seen from Fig. 5.1, two solutions C1 = Fossil-fuel based propulsion engine and C2 = Mg-CO_2 based propulsion engine have been considered. C1 is suitable for earth whereas C2 is suitable for Mars. The performance of C1 is known whereas the performance of C2 is quite unknown. This implies the propositions and their truth values as shown in Table 5.1.

Table 5.1. The states of ordinary and creative concepts.

C1 = Fossil-fuel based propulsion engine

Propositions		Linguistic *TV*	Numerical *TV*	Requirement (P_R)	*TV*
P11:	C1 is suitable for Mars exploration	mostly false (*mf*)	0.1	C1 should be suitable for Mars exploration	0.1
P12:	C1 is not suitable for Mars exploration	perhaps true (*pt*)	0.733		
P13:	C1 performs well	mostly true (*mt*)	0.9	C1 should perform well	0.9
P14:	C1 does not perform well	mostly false (*mf*)	0.1		

C2 = Mg-CO_2 based propulsion engine

Propositions		Linguistic *TV*	Numerical *TV*	Requirement (P_R)	*TV*
P11:	C2 is suitable for Mars exploration	perhaps true (*pt*)	0.733	C2 should be suitable for Mars exploration	0.733
P12:	C2 is not suitable for Mars exploration	perhaps false (*pf*)	0.267		
P13:	C2 performs well	not sure (*ns*)	0.5	C2 should perform well	0.5
P14:	C3 does not perform well	not sure (*ns*)	0.5		

Table 5.2. States of C2 and C2 based on C-K mapping

Propositions		Truth Values		Requirement (P_R)
P1	C2 is *acceptable* in terms of Specific Impulse	*pt*	0.733	An engine should be acceptable in terms of Specific Impulse
P2	C2 is *not acceptable* in terms of Specific Impulse	*mf*	0.1	
P3	C3 is *acceptable* in terms of Specific Impulse	*mt*	0.9	
P4	C3 is *not acceptable* in terms of Specific Impulse	*mf*	0.1	
P5	C2 is *acceptable* in terms of toxicity, ignitability, combustion rate, slag formation, etc.	*mt*	0.9	An engine should be acceptable in terms of toxicity, ignitability, combustion rate, slag formation, etc.
P6	C2 is *not acceptable* in terms of toxicity, ignitability, combustion rate, slag formation, etc.	*mf*	0.1	
P7	C3 is *acceptable* in terms of toxicity, ignitability, combustion rate, slag formation, etc.	*mf*	0.1	
P8	C3 is *not acceptable* in terms of toxicity, ignitability, combustion rate, slag formation, etc.	*pt*	0.733	

C2 = Mg-CO_2 Propulsion Engine, C3 = Y-CO_2 Propulsion Engine, Y $\in$ {Be, BeH_2, Al}

According to C-K mapping , is it possible to show that the information content of concept C2 (Mg-CO2-based propulsion engine) has come down significantly? An answer to this question is needed to make sure the effectiveness of the transformation of knowledge from K4 to K′4. Otherwise, new knowledge (K′4) does not add any value to key solution determination process.

To answer the question, as set of propositions P1,…,P8 and two alternatives C2 (same as before) and C3 (=Y-CO_2-based propulsion engine, Y is either Be or BeH_2 or Al) are considered. The propositions and their truth values are listed in Table 5.2.

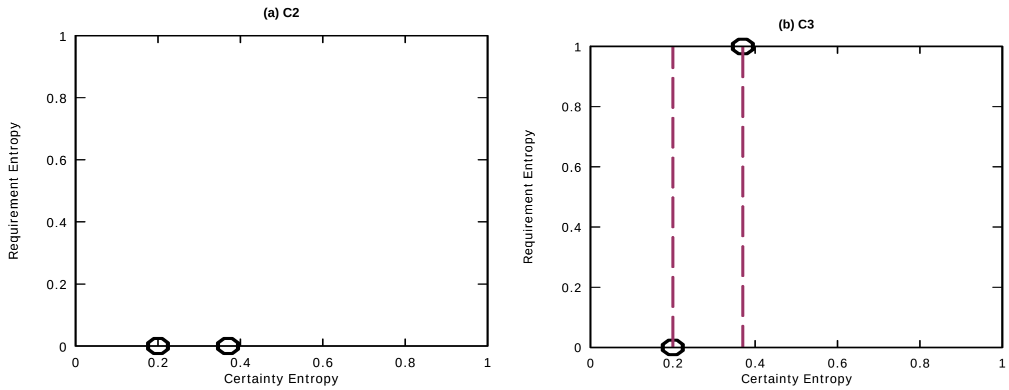

Figure 5.2. Information content of C2 and C3 based the settings in Table 5.2.

The information content in terms of Certainty and Requirement Entropies (*CE*,*RE*) are determined by using the same methods used in the previous section. The results are shown in Fig. 5.2. C2 has information contents (0.37,0) and (0.2,0) for {P1,P2} and {P5,P6}, respectively. The overall information content of C2 is now equal to 0.57. On the other hand, C3 has information content (0.2,0) and (0.37,1) for {P3,P4} and {P7,P8}, respectively. The overall information content of C3 is equal to 1.74. Thus, C2 is preferred over C3, as the key solution to develop a propulsion engine for Mars exploration, the decisionmaking now underlies “minimization of information content,” i.e., the process holds the Information Axiom (Suh 1998).

In synopsis, creativity is first controlled by the maximization of information content in presence of such motivating factors as compelling reason and epistemic challenge and then by the minimization of information content in presence of new knowledge.

5. Conclusion

Making decisions, i.e., identifying a key solution (or a set of key solution), in conceptual phase of product development is not only critical but also difficult. It is critical in a sense that around 80% cost of a product is decided by the key solution determination process in the conceptual phase of product development and it cannot be rectified by making adjustments in the downstream of a product lifecycle. It is difficult in a sense that in conceptual phase of product development, the knowledge is very limited and there is an abundance of choice. To shed some light on this issue (decisionmaking in conceptual phase of product development) this paper poses and answers the following questions: How to differentiate a creative key solution from a non-creative key solution? What is the appropriate customer need model? How to deal with the unknown customer needs? How to classify the key solutions based on customer responses? How to deal with the sustainability of materials (used in the product) in key solution determination process?

Nevertheless, the following remarks can be made on the findings:

On the customer needs assessment:

One of the ways to identify a key solution to develop a product is to take opinions of customers regarding a set of key solutions. To deal with the intrinsic complexity of customer responses, logical aggregation of customer opinions is a better choice compared to frequency based analysis. This faculty of thought is demonstrated to be true by logically aggregating the field data of customer needs collected from Bangladesh on small passenger vehicles using Kano model. It has been found that a product feature needs to be classified either into a must be included feature, or into a should be included feature, and or into a could be included feature. The link among these classifiers and Kano evaluations (Must-be, Attractive, One-Dimensional, Indifferent, Reverse, and Questionable) has been established. The multi-valued logic plays an important role in the customer needs assessment. In particular, a two-dimensional information content (in epistemic sense) scheme has been found effective in logically computing the degree of customer satisfaction of a given product feature in terms of must be included, should be included, and could be included. To increase the degree of satisfaction of vehicle users in Bangladesh, it is important to develop SUV- and Van-type passenger vehicles replacing some of the Sedan-type vehicles.

On the creativity assessment

To identify a useful key solution in conceptual phase of product development, the product development team members needs to be creative. To differentiate a creative concept from a non-creative concept, Concept-

Knowledge mapping as prescribed in C-K theory can be employed. Creative concept means a concept which is undecided when it is being conceived. Conceiving a creative concept is rather a motivation driven process. Information content of a creative concept is high compared to that of a non-creative concept. The information content means here the two-dimensional information content in epistemic sense. When a creative concept is pursued and new knowledge becomes available, the information content should go down significantly. Otherwise, the new knowledge does not add any value to product development process. A non-creative key solution does not exhibit the abovementioned behavior of information content.The effectiveness of the abovementioned approach has been demonstrated by calculating the information contents of two concepts Mg-CO_2 based propulsion engine (a creative concept) and fossil-fuel base propulsion engine (an non-creative concept). It has been found that the Mg-CO_2 based propulsion engine exhibits high information content compared to that of fossil-fuel base propulsion engine for Mars exploration. The information content of Mg-CO_2 based propulsion engine have gone down significantly under the presence of new knowledge.

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