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Experimental Analysis of Heat Transfer Improvement of Water Utilizing Double Counter Twisted Tape Insert

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ABSTRACT

This investigation was done for improving tube side heat transfer execution by double counter twisted tape insert. The test segment comprises of a long copper tube of 26.6 mm inlet diameter and 30 mm external diameter and length was 900 mm. The inserts were 850 mm in long, 8.5 mm in width, 1.5 mm in thickness and twist ratio was 6.25. Two thermometers were utilized at the inlet and outlet segment of the circular tube for estimating the bulk temperature. Five K type thermocouples were utilized in the test area to estimate the outer surface temperature. From rotameter, a certain amount of mass flow rate was estimated for calculation of water flow velocity. Just as from manometer reading, pressure head was estimated for measuring the pressure difference of the flow segment. After measuring all the parameter values, Reynolds Number, heat transfer rate, convective heat transfer coefficient, Nusselt Number, Prandtl Number, experimental friction factor was calculated. At comparable Reynold number 2960 to 5382 Nusselt Number was increased by 60.5% to 70.8% for double counter twisted tape insert compared to plain tube. At comparable Reynold number 2960 to 5382 friction factor of the insert was also increased 1.05 to 1.37 times compared to plain tube. From previous data of segmented twisted tape there showed a comparison of Nusselt number of Double counter twisted tape (31.6 to 42.6) which is higher than the segmented twisted tape (20 to 37) at same Reynold number 2960 to 5382.

Keywords: Double counter twisted tape, Reynolds number, Plain tube, Heat transfer co-efficient

1. Introduction

Heat transfer improvement innovation is regular in many building applications including thermal recuperation methodology, cooling, and cooling frameworks, nuclear vitality, compound reactors, elite laser framework, normal procedure plants, and others [1]. The procedures of heat transfer upgrade to oblige high heat motion for example to diminish size and cost of heat exchangers have gotten genuine consideration spent years [2]. Heat transfer growth procedures are every now and again utilized in gadget frameworks to help heat move and increment heat execution [3]. Dynamic expansion requires the expansion of outside capacity to bring the necessary stream adjustment. The Passive expansion technique needn't bother with any outer force input. Inside the convective heat transfer, one in all the approaches to fortify the heat transfer rate is to expand the viable territory and length of the heat transfer liquid [4]. Inserts improve the heat transfer coefficient ability and limit the loss of friction factor. Tube inserts are using in heat transfer improvement and fouling alleviation in a few enterprises like oil treatment facilities and manufactory for quite a long while. During this writing inserts are grouped into the louvered insert, twisted tape, swirl flow devices insert, wire coil insert, conical ring insert, winglet type vortex generators, and brush and pin elements inserts [5]. Twisted tapes are generally introduced during a tube device to advertise the liquid blending between the focal area and about the divider locale. The fundamental target of this investigation is to estimate the heat transfer enhancement for double counter twisted tape insert. A double counter twisted tape actuates counter whirling stream which advances liquid blending among center and divider districts, upsets the thermal boundary layer, and in this way upgrades the heat transfer coefficient. In any case, the friction factor of a framework furnished with twisted tape is typically higher than the one without twisted tape. Along these lines, the friction loss compel is a significant factor for assessing the advantages of a twist application. The twist tape which is reasonable for useful use should give a decent tradeoff between the improved heat transfer and the expanded friction loss. In this way, planning an appropriate twist tape is a difficult assignment [6]. The primary targets of this examination were to decide about the heat transfer improvement for double counter twisted tape insert, to research the heat transfer coefficient, Nusselt number just as a frictional loss for plain tube just as double counter twisted tape, to discover the level of increment of heat transfer upgrade utilizing double counter twisted tape insert and contrasted it with the tube. Nusselt number and friction factor with double counter twisted tape versus segmented twisted tape were likewise analyzed. There were numerous impediments related with the innovation which incorporate wasteful utilization of shell side pressure drop. It was very hard to make double counter twisted tape insert in light of the fact that the internal diameter of the copper tube was little and there was adequate leeway for water to travel. In this work as the width of the insert is little, it was hard to twist and get an ideal double counter insert. To take the specific perusing of the pressure head from the manometer was

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troublesome on the grounds that the pressure head was little. It was hard to keep up to take the perusing without heat loss.

2. Methodology

In this investigation, double counter twisted tape insert was utilized to upgrade the heat transfer which is appeared in Fig. 1. The entire insert was 850 mm long and width 8.5 mm, gap between each insert and wall was approximately 3 mm, likewise hole between two inserts around 3 mm and twist ratio 6.25.

Fig. 1 Photographic view of double counter twisted tape

The test area was 914 mm long copper tube having 26.6 mm inside measurement and 30 mm external distance across of which 900 mm was utilized for this investigation. Two stainless steel double counter twisted tapes were embedded inside the copper tube. A consistent cold-water flexibly was kept up by a centrifugal pump (limit 0.5 hp) from a supply tank. A steady warmth flexibly to the test area was kept up from fundamental force source. A voltage controller was utilized to deal with the steady heat and 120 volts was utilized for heating the test segment. The heating wire was secured with fiber glass for protection. Five T-type thermocouples were set on five similarly dispersed purposes of the test segment to quantify the external surface temperature of the tube. Inlet and outlet pressure drop were estimated by a manometer and the flow rate of water through the tube was estimated by a rotameter whose limit was 27.5L/min. Inlet and outlet temperature of water was estimated by two thermometers. The inlet thermometer was set at inlet tank and outlet thermometer was set in a blending shower appended with the test segment to discover the blending high temp water temperature. At first the capacity tank was topped off with cold water and a pump made flow of water all through the experimental device. Various flow through the rotameter were constrained by the control valve. The test segment was heated at consistent voltage (120 volts) by the voltage controller and the tube outside temperature was estimated by the advanced temperature meter. At that point the inlet and outlet temperatures were estimated by the alcohol thermometer. All the information was taken at consistent state condition and it was taken around 8-15 minutes to get the consistent state condition. Similar strategies were applied for taking Fig. 2 shows the full test facility.

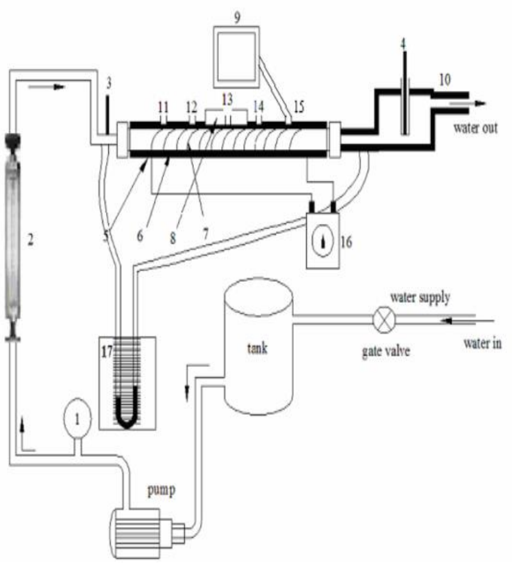

Fig. 2 Schematic diagram of experimental apparatus [7].

1. Pump
2. Rotameter
3. Inlet thermometer
4. Outlet thermometer
5. Insulation
6. Test section
7. Nichrome wire
8. AC source
9. Temparture reading device
10. Mixing Chamber
11-15. Thermocouples
16. Voltage regulator
17. U-tube manometer

3. Mathmatical Modeling

Outer surface area, $A_0 = \pi d_0 L$ (1)

Inner surface area, $A_i = \pi d_i L$ (2)

Heat transfer rate = $mc_p\ (T_o - T_i)$ (3)

Cross sectional area, $A_c = \pi d_i^2/4$ (4)

Velocity, $U_m = q/\ A_c$ (5)

Reynolds Number, $Re = \rho\ U_m\ d_i/\mu$ (6)

Nusselt number, $Nu = hd_i/k$ (7)

Prandtl number, $Pr = \mu C_p/k$, μ and k at bulk temperature (8)

Convective heat transfer coefficient, $h = Q/A_c\ (T_i - T_b)$ (9)

Nu_{th}= ((f/8) (Re-1000) pr)/(1+12.7(f/8) ^.5(pr^.66-1)) (10)

Pressure difference, $\Delta p = \Delta h \times \rho \times g \times 13.6$ (11)

$Q = 2\pi Lk\ (To - Ti)/\ln(d_0/di)$ (12)

Bulk temperature, $T_b = (T_o + T_i)/2$ (13)

Outer surface temp = (Thermocouple1 reading+………+Thermocouple5 reading)/5 (14)

Inner surface temp = (Outer surface temp – Wall temperature difference) (15)

Experimental friction co-efficient, $f_{exp} = (2\Delta p d_i/\rho L U_m^2)$ (16)

4. Results and Discussion

4.1 For plain Tube
Reynolds number, Re = 2960.2 to 5382.2
Heat transfer rate, Q = 751 to 786 W
Convective heat transfer coefficient, h= 449 to 589 $W/m^2.K$
Experimental Nusselt number, Nu_{exp} = 19.3 to 25.3
Experimental friction factor, f_{exp} = 0.04 to 0.0597

4.2 For plain tube with combination of two inserts
Reynolds number, Re = 2960.2 to 5382.2
Heat transfer rate, Q = 599 to 601 W
Convective heat transfer coefficient, h= 712 to 962 $W/m^2.K$
Experimental Nusselt number, Nu_{exp} = 31.6 to 42.7
Experimental friction factor, f_{exp} = 0.09 to 0.1416

4.3 Comparison for double counter twisted tape and segmented twisted tape insert
Reynolds number, Re = 2960.2 to 5382.2
Experimental Nusselt number for double counter twisted tape, Nu_{exp} = 31 to 42.7
Experimental friction factor for double counter twisted tape, f_{exp} = 0.09 to 0.14
Experimental Nusselt number for segmented twisted tape, Nu_{exp} =20 to 37
Experimental friction factor for segmented twisted tape, f_{exp} = 0.1 to 0.3

5. Discussion on result

Fig. 3 displays that the average heat transfer coefficient incriments with expanding Reynolds number for plain tube as well as the insert. At high Reynolds number mixing of fluid occurs and more heat is taken away from the tube. So, temperature difference decreases but the heat transfer coefficient increases.

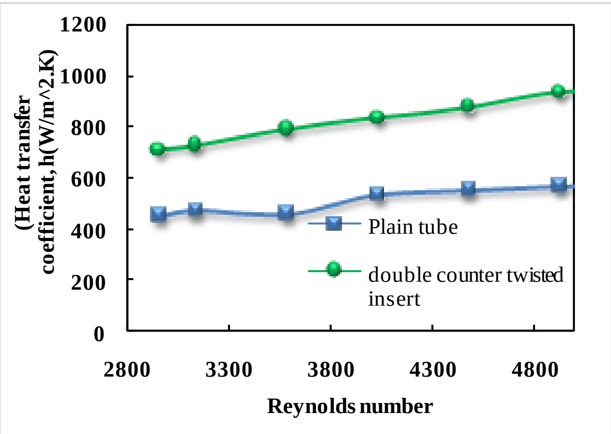

Fig. 3 Changes of heat transfer coefficient with Reynolds number

Fig. 4 displays that Nu_{exp} expands with expanding Reynolds number because more Reynolds Number reveals more mixing which expands heat transfer coefficient. Thus, greater value of h results in greater value of Nu_{exp}. Using double counter twisted tape inserts Nusselt Number expanded by separately contrasted with the 60-70% plain tube.

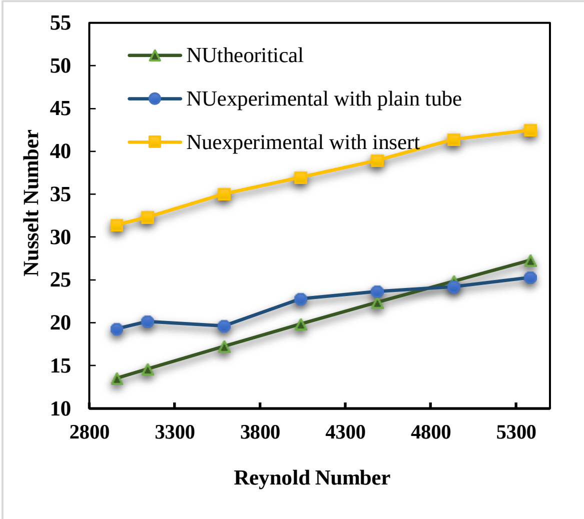

Fig. 4 Changes of Nusselt number with Reynolds number

Fig. 5 displays that exploratory friction factor diminishes with expanding Reynolds number. It was discovered that, where aggravation in water stream is more noteworthy, separating of the water film increment the pressure drop this way diminishing friction factor. Utilizing double counter twisted tape inserts friction factor expanded by 104-135% separately contrasted with the plain tube.

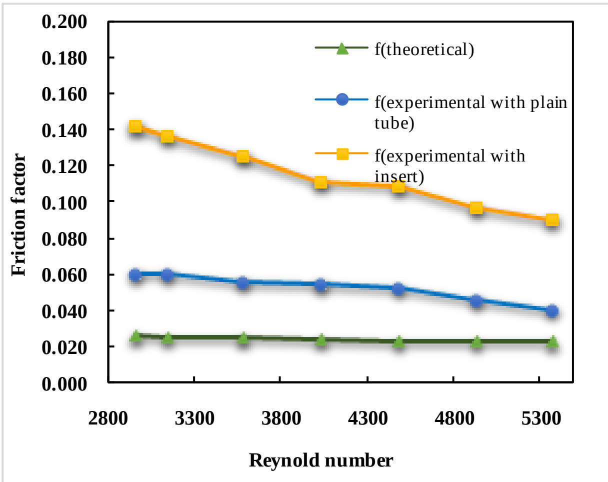

Fig.5 Changes of friction factor with Reynolds number

Fig. 6 represents that friction factor of double counter twisted tape insert for same Reynolds Number is much lower than segmented twisted tape insert.

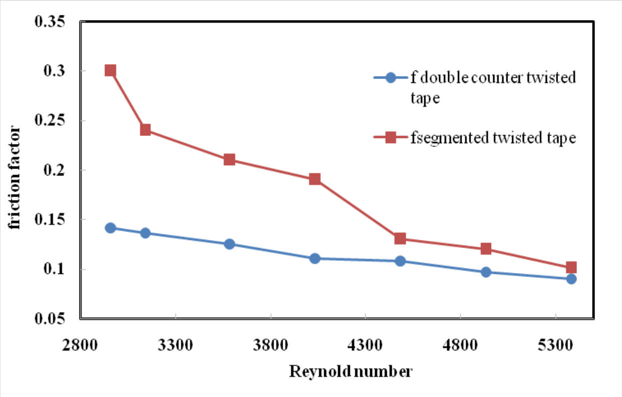

Fig. 6 Changes of friction factor with Reynolds number for two inserts

Fig. 7 displays that changes of Nusselt number with Reynolds number for two inserts. Nusselt number of double counter twisted tape is higher than segmented twisted tape as there is swirl and counter-swirl motion generate more rapid mixing of double counter insert than the segmented twisted tape.

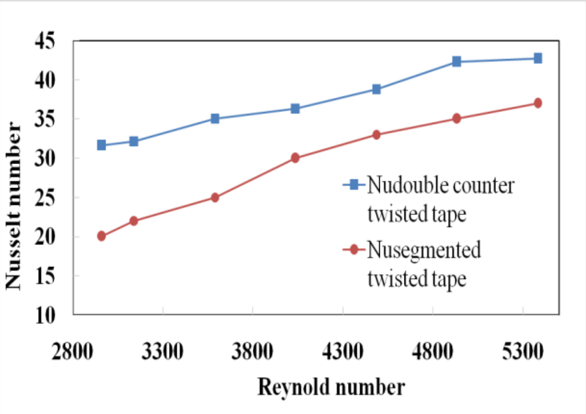

Fig. 7 Changes of Nusselt number with Reynolds number for two inserts

6. Conclusion

To expand heat transfer is the target of this research**.** The measurement of the tube side heat transfer coefficient is a crucial part of heat transfer related subjects. A number of the more successful enhancement techniques currently used for heat transfer augmentation are reviewed here. Several active techniques are identified as possibilities for heat transfer enhancement. These techniques do require external power. But there's an influence cost that must be considered. There also are passive techniques that are identified as possibilities for tube side heat transfer enhancement. Insertion of twisted tape into a tube provides an easy passive technique for enhancing the convective heat transfer by introducing swirl into the majority flow. It's going to be guessed that the swirl flow helped in decreasing the boundary layer thickness.

- Using insert Nusselt number expanded by 60.5%-70.8% individually contrasted with the plain tube.
- Using insert Friction factor expanded by 104-135% individually contrasted with the plain tube.
- Nusselt number of double counter twisted tape for same Reynold number is higher than segmented twisted tape.
- Friction factor of double counter twisted tape for same Reynold number is lot of lower than segmented twisted tape.

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NOMENCLATURE

d_i	: Tube inner diameter, m
d_o	: Tube outer diameter, m
L	: Tube length, m
A_0	: Tube outer surface area, m^2
Ai	: Tube inner surface area, m^2
Ac	: Tube cross sectional area, m^2
T_0	: Tube outer wall temparature, K
T_i	: Tube inner wall temparature, K
T_b	: Bulk temparature, K
C_P	: Specific heat, J/kgK
μ	: Dynamic viscosity, Kg/ms
ρ	: Density, kg/m^3
Δp	: Pressure difference, N/m^2
k	: Thermal Conductivity, W/mk
m	: Mass flow rate of water, Kg/s

Q : Heat transfer rate, W
q : Heat flux, W/m^2
U_m : Mean velocity, m/s
Nu : Nusselt number, dimensionless
Re : Reynonlds number, dimensionless
Pr : Prandtl number, dimensionless
f : Friction factor, dimensionless