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Experimental Investigation of Convective Heat Transfer From Rectangular baffle With Different Vortex Generators In Circular Channel

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Abstract

Among frequent techniques (both active and passive)are widely used to investigated for heat transfer rates augmentation inside circular tubes. Wide range of inserts has been utilized, particularly when turbulent flow is considered. The inserts studied included coil wire inserts, brush inserts, mesh inserts, strip inserts, twisted tape inserts etc. Augmentation of convective heat transfer in internal flows with tape inserts in tubes is a recent technique employed in industrial practices. A Experiment is carried on plain Tube, Twisted tape of different twist ratio without baffle and same Twisted tape with Baffled. The result of this experiment is that there is a increasing the rate of heat transfer with Twist Ratio of twisted tape and it is maximum for Baffled twisted tape with 4.5 Twist ratio.

Keywords: *Baffled twisted tape, Nusselt number, Reynold number, Heat transfer coefficient, Twist ratio.*

1. Introduction

The heat exchangers with convective heat transfer of fluid inside the tube surfaces are widely used in various industrial processes for heating and cooling applications such as chemical process plants, air conditioning and refrigeration systems, etc. In the designing of heat exchanger is to obtained a high heat transfer rate using minimum pumping power and in less space. When the fluid having low thermal conductivity passing through heat exchanger, there is necessity to increase a heat transfer rate but in some of applications like in marine application and chemical industries the resistance to heat transfer increases cause to fouling or scaling. Fouling is the main problem having a dirt layer that build in inner side of the heat transfer surface which, increases thermal resistance to avoid the fouling in laminar flow heat exchanger is cleaned periodically but flow is turbulent it well resist the fouling also due to higher shear stress. For high heat transfer rate achieving introducing disturbance in the fluid flow which break the viscous and boundary layer. The fluid is enters axially and remaining is enter tangentially at various places along the tube axis. Twisted-tape is one of the most important members of heat intensification techniques, which mostly used in heat exchanger. The efficiency of heat exchanger is depends upon the type of flow, if the flow is laminar the heat transfer at the boundary of fluid is maximum and at the Centre it is not efficient but in turbulent flow the heat is concentrated at the Centre of fluid flow then the heat is spread equally and temperature of a fluid is same through flow of fluid. If the surface factor of tube is considered to transfer the heat it is a transitional flow. Heat transfer augmentation techniques related to the improvement of thermo hydraulic performance of heat exchangers. There are three method to increase the heat transfer rate and thermo hydraulic performance are as follows:-
1.1 Active Method: This method are more complicated because it require an external power input to improve the thermal performance and intensification of heat transfer rate. It used in limited applications, some examples are fluid vibration, mechanical aids and surface vibration.
1.2 Passive Method: In the flow of fluid inserting a tube or geometrical modifications flow get disturbing the behavior of existing fluid flow. These method is very efficient and widely used in a various engineering applications because no need of any external power source to intensification heat transfer rate.
1.3 Compound Method: When two or more method used simultaneously to obtain improvement in thermal performance and intensification in heat transfer rate is greater than that produced by any one of the method used individually.

In this paper, the study of various categories research papers on the Hear enhancement are studied. Research work includes its different swirl generator with different dimensions

Experimental Investigation for heat transfer and pressure drop of laminar flow in horizontal tubes with/without longitudinal inserts. They reported that enhancement of heat transfer as compared to a conventional bare tube at the same Reynolds number to be a factor of 16 at Re ≤ 4000, while a friction factor rise of only 4.5.(Shou-Shing Hsieh, I. W. Huang., 2000) A comparative Research of the thermal Characteristics of ordinary full-width full-length twisted tapes with tapes having modified surface configurations. (Monheit. M., 1987). Experimentally Investigation of heat transfer rate and thermo hydraulic efficiency of the combined devices of twisted tape and wire coil by arranging in the form D-coil and DI-coil while the twisted tape was made with two different twist ratios.

(S. Eiamsa-ard, P, 2010). Experimental investigation of heat transfer augmentation to viscous non-Newtonian fluids in laminar flow using full width interrupted twisted tapes under the uniform wall temperature condition.(Dasmahapatra and Rao, 1991). The effect of tube-tape clearance on heat transfer under fully developed turbulent flow conditions in a horizontal isothermal tube is investigated through Experiment.(Al-Fahed. 1996). Experimental Studies on the heat transfer enhancement and pressure drop characteristics with twisted tape inserts, during flow boiling of R-134a inside a horizontal evaporator for plain flow and four tubes with twisted tapes having 6, 9, 12 and 15 twist ratios and 54, 85, 114 and 136 kg/s-m2 are the four refrigerant mass velocities of for each tape. It has been found that the twisted tape inserts enhance the heat transfer coefficient on relatively higher pressure drop penalty in comparison to that for the plain tube flow. (Akhavan-Behabadi M. ,2009). thermal performance, Heat transfer and flow friction factor characteristics are experimentally investigated for oblique delta-winglet twisted tape (O-DWT) and straight delta-winglet twisted tape (S-DWT). arrangements over a Reynolds number range of 3000–27,000 by considering three twist ratios (y/w = 3, 4 and 5) and three depth of wing cut ratios (DR = d/w = 0.11, 0.21 and 0.32).(Wongchareeb, P. Eiamsa-ardc and C. Thianpongc. 2010)

2. Experimental Setup

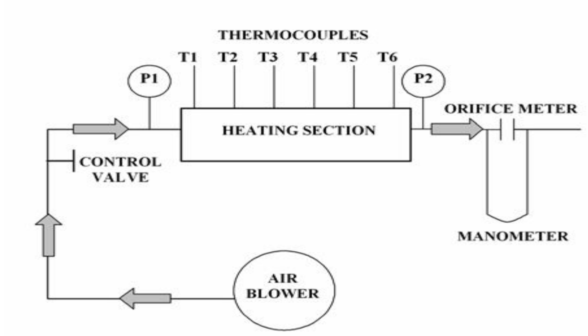

Fig. 2 Schematic Diagram of Experimental Setup

An electric supply is given to the blower motor and the valve is opened slightly. A heat input of 40 Watt is given to the nichrome heating wire wound on the test section by adjusting the dimmer stat. Thermocouples 2 to 5 are fixed on the test surface and while 1 to 6 are fixed inside the pipe. The readings of the thermocouples are observed every 5 minutes until they show constant values. Under steady state condition, the readings of all the six thermocouples are recorded. The experiment is repeated for different openings of the valve, thus varying the airflow rate. The fluid properties are calculated from average between the inlet and the outlet bulk temperature. It took 110 minutes to reach steady state conditions. Experiment was carried out at constant heat flux conditions and heat input of 40 W at different mass flow rates.

Initially the experiment is carried out on plain tube (without any insert experiment). The working fluid air flows through the pipe section with least resistance. The experiment is carried out in similar fashion with twisted tape inserts with twist ratios 3.2, 3.9 and 4.5 with and without baffle. the inserts are made of aluminium. Each insert is inserted into the test section axially. The precaution must be taken that the strip does not scratch the inner wall of the pipe and get deformed. The insert in the pipe lead to develope resistance to flow and increases turbulence.

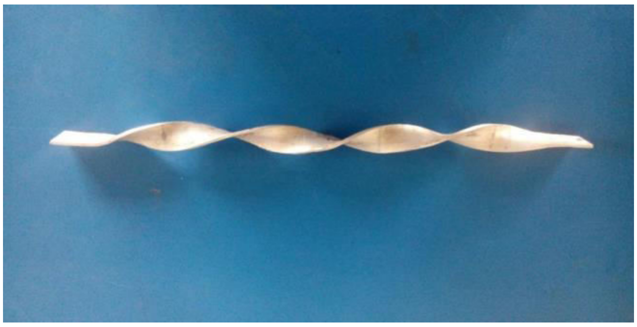

Fig. 2 Twisted Tape Without Baffle

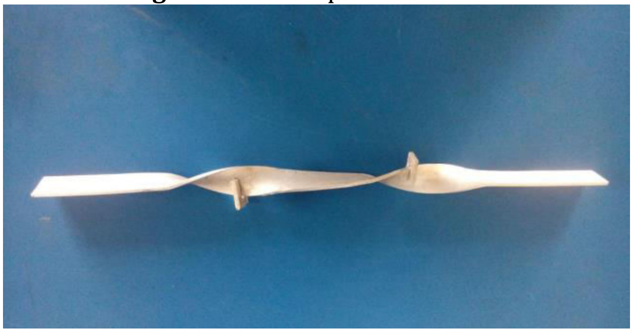

Fig. 3 Twisted Tape With Baffle

3. Experimental Analysis

3.1 Reynold Number Evaluation

Average Surface temperature of the working fluid, (°C)

$$Ts = \frac{T_2+T_3+T_4+T_5}{4}$$

Bulk temperature, (°C)

$$Tb = \frac{T_1+T_6}{2}$$

Equivalent height of air column, (m)

$$ha = \frac{\rho_w \times h_w}{\rho_a}$$

Air discharge through test section, (m3/sec)

$$Qa = Cd \times Ao \times \sqrt{2gh_a}$$

Where

A_0 — Cross sectional area of orifice.

Air velocity through test section, (m/sec)

$$V = \frac{Q_a}{A}$$

Reynolds number (experimental) for plain tube,

$$Re = \frac{V \times D}{\nu}$$

Where

V= Velocity of the fluid.
ν = Kinematic viscosity of the fluid.

Reynolds number (experimental) with tape inserts

$$Re = \frac{V \times D_h}{\nu}$$

Where

Dh - hydraulic diameter (m) = $\frac{4A}{P}$

3.2 Nusselt Number Evaluation

For internal flow conditions, if Reynolds number (Re) is greater than 4000 then the flow is said to be turbulent. After the flow is decided i.e. laminar or turbulent then the Nusselt number can be calculated. Nusselt number for plain tube (theoretical) calculated below without considering friction which is theoretical Nusselt number and then calculated by considering friction which will be experimental Nusselt number.

$$Nu_{the} = 0.023\ Re^{0.8} Pr^{0.4}$$

This equation is called Dittus-Boelter equation.

Total heat transferred to air (Q), (W)

$$Q = m \times Cp \times (T_1 - T_6)$$

Experimental convective heat transfer coefficient, (W/m2K)

$$h = \frac{Q}{A\,(T_s - T_b)}$$

Nusselt number (experimental) for plain tube

$$Nu = \frac{h \times D}{K}$$

Nusselt number (experimental) with tape inserts

$$Nui = \frac{h \times D_h}{K}$$

4. Result and Discussion

The variation of Heat Transfer Coefficient with Reynolds number for Swirl Generator having T.R. – 3.2, T.R.-3.9, T.R.-4.5 is shown in Figure Highest Heat Transfer was obtained for Baffled Twisted tape . The mean heat transfer gain for Baffled Twisted tape for T. R. 3.2 is increased by 25% compared to plain tape. For T.R. 3.9 is 32% and for T.R.-4.5 is 37 %. This is due to strong turbulence intensity generated by tape inserts leading to rapid mixing of the flow causing heat transfer enhancement

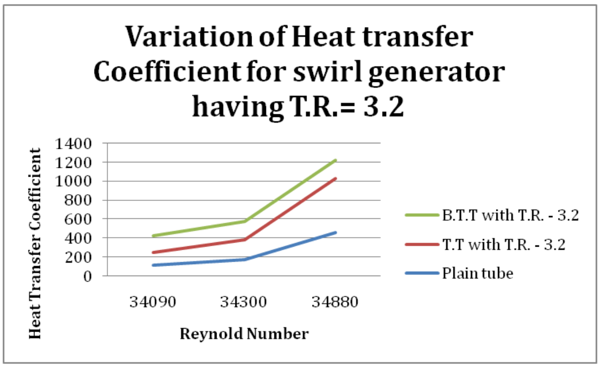

Fig. 4 Variation of Heat Transfer Coefficient with Reynolds number for T.R – 3.2

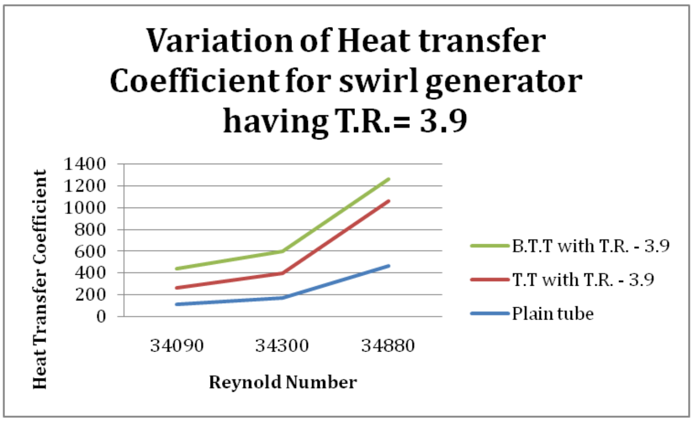

Fig. 5. Variation of Heat Transfer Coefficient with Reynolds number for T.R – 3.9

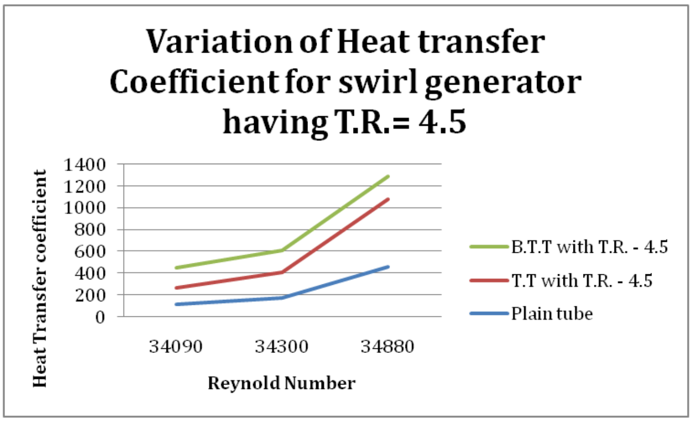

Fig. 6. Variation of Heat Transfer Coefficient with Reynolds number for T.R – 4.5

It is evident from Fig. 7, Fig. 8, Fig. 9 that when a twisted tape with different twist ratio with and without baffle are inserted into a plain tube there is a significant growth in Nusselt number, this enhancement is mainly due to the centrifugal forces resulting from the spiral motion of the fluid and partly due to the tape acting as fin. It is observed that the reduction in Twist Ratio causes reduction in Nusselt numbers. The Nusselt number for Baffled Twisted tape for T. R. 3.2 is increased 18% compared to plain tape. For T.R. 3.9 is 29% and for T.R.-4.5 is 41 %.

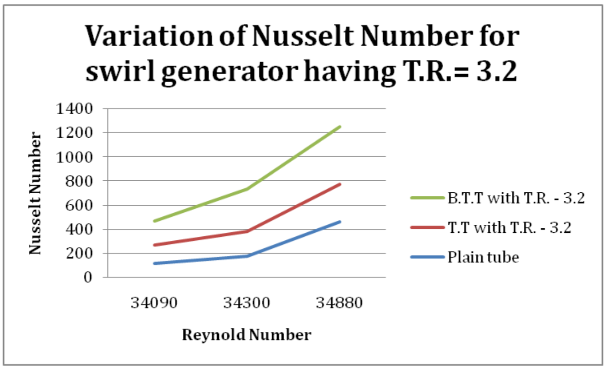

Fig. 7. Variation of Nusselt Number with Reynolds number for T.R – 3.2

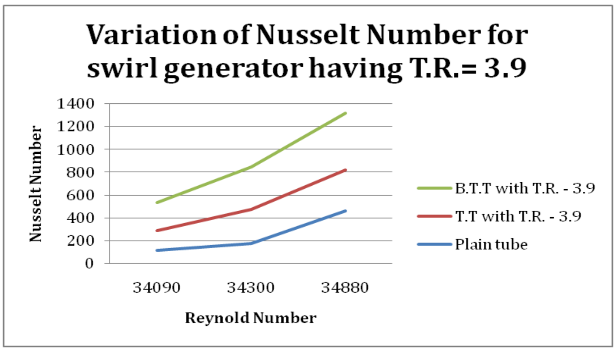

Fig. 8. Variation of Nusselt Number with Reynolds number for T.R – 3.9

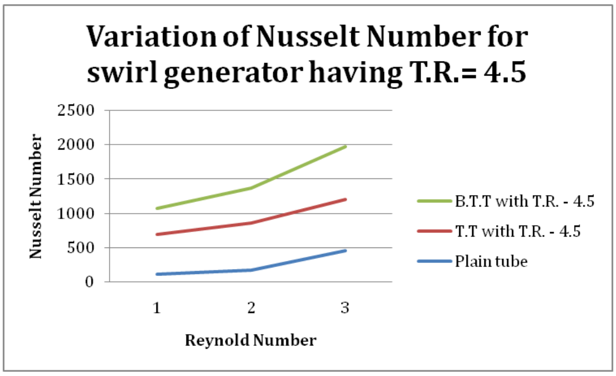

Fig. 9. Variation of Nusselt Number with Reynolds number for T.R – 4.5

5. Conclusions

This report present experimental investigation of baffled twisted tape inserts to enhance the rate of heat transfer in a horizontal circular tube with inside diameter 28 mm with air as working fluid. The effects of parameters such as twist ratio, Reynolds number on the heat transfer are studied. The following conclusions can be drawn.

- Heat transfer Co-efficient of Tube with Twisted Tape of 3.2 T. R. is increases by 23% than that of with Plain twisted tape.
- Heat transfer Co-efficient of Tube with Twisted Tape of 3.9 T. R. is increases by 29% than that of with Plain twisted tape.
- Heat transfer Co-efficient of Tube with Twisted Tape of 4.5 T. R. is increases by 33% than that of with Plain twisted tape.
- Heat transfer Co-efficient of Tube with Baffled Twisted Tape of 3.2 T. R. is increases by 25% than that of with Plain baffled twisted tape.
- Heat transfer Co-efficient of Tube with Baffled Twisted Tape of 3.9 T. R. is increases by 32% than that of with Plain baffled twisted tape.
- Heat transfer Co-efficient of Tube with Baffled Twisted Tape of 3.2 T. R. is increases by 37% than that of with Plain baffled twisted tape.

6. Refernce

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