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Research Article

Performance of Corrugated Copper Inserts in Heat Exchanger

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Abstract

The current experimental work is conducted with copper corrugated tape inserts 1mm thick and 8.33, 9.79 twist ratios, but having same wave-widths. The inserts when placed in the way of the flow of the fluid, generate a high degree of disorder resulting in a boost in the heat flow pace as well as the pressure drop. The work includes the determination of friction factor and Nusselt number for various wavy twisted tape inserts with varying twist ratios, different wave-widths & different materials. The Reynolds number is varied from 4000 to 10000. Correlations for Nusselt number and friction factor are developed for the corrugated tape inserts from the obtained results. The results of varying twists in copper tapes have been compared with the values for the smooth tube. The copper insert with twist ratio 9.79 & wave-width 16mm shows increase in Nusselt number values by 135% & in friction factor by 100% as compared to the smooth tube values. When the copper material is compared with aluminium inserts are compared then the copper is having 41% higher enhancement efficiency as compared to the aluminium, hence comparing all the inserts the copper is having high heat transfer enhancement for same Reynolds number. The experimental results of heat transfer in round pipe outfitted with the different inserts is studied using a MATLAB program and used to predict the output functions by designing a program. The inputs to the program are Reynolds No, Temperatures and the output of the system is Nusselt number & friction factor.

Keywords: *Corrugated, enhancement, heat transfer, turbulance, twist ratio*

1. Introduction

Heat exchangers are extensively used in a variety of manufacturing processes for heating and cooling applications like air habituation and refrigeration structures, heat revival processes cooking and dairy processes, element procedure plants etc. The main confront in designing a heat exchanger is to build the tools compact and attain a high heat transfer pace using lowest amount pumping power. Methods for heat transmission increase are related to several engineering applications. In current years, the high rate of energy and matter has resulted in an amplified effort meant at producing extra efficient heat exchange utensils. Also, occasionally there is a need for trimness of a heat exchanger in particular applications, such as space appliance, during an expansion of heat transfer. For instance, a heat exchanger for an ocean thermal energy conversion (OTEC) place necessitates a heat transfer shell region of the sort of 10000m2/MW. Consequently, a raise in the competence of the heat exchanger in the course of an augmentation practice may result in a significant economy in the material price. Furthermore, as a heat exchanger turn out to be older, the opposition to heat transfer augmentation owing to fouling or scaling. These harms are more ordinary for heat exchangers used in marine applications as well as in chemical industries. In number of specific applications, such as heat exchangers selling with fluids of little thermal conductivity (gases and oils) as well as desalination plants, there is a call for to boost the heat transfer pace. The heat transfer rate can be enhanced by introducing a disorder in the fluid stream thus breaking the viscous and thermal boundary film. Still, in the course pumping power may augment significantly and eventually the pumping price becomes elevated. Therefore, to reach a desired heat transfer rate in a present heat exchanger at a profitable pumping power, a number of techniques have been projected in current years and are discussed in the classification part.

For over a century, efforts have been made to create more competent heat exchangers by employing a variety of techniques of heat transfer improvement. The learning of enhanced heat transfer has added severe momentum through current years, however, due to increased burden by industry for heat exchange equipment that is less costly to manufacture and run than typical heat exchange devices. Savings in materials and power use also supply strong motivation for the progress of better methods of improvement. When designing cooling structure for vehicles and

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spacecraft, it is very important that the heat exchangers are particularly dense and trivial. Also, improvement devices are essential for the elevated heat duty exchangers created in power generating utilities (i.e. air-cooled condensers, nuclear fuel rods). These functions, as well as frequent others, have led to the progress of a range of improved heat transfer shells.

To compare the results of twisted tape having hole and v cut insert with plane twisted tape insert to observe increment or decrement in parameters like Nusselt number, friction factor, enhancement ratio.

Many methods are used to augment thermal recital of heat transport strategies such as treated planes, rough surfaces, eddy flow devices, coiled pipes and surface tension procedures [1]. Twisted tape eddy turbulator is one of the frequently used reactive types for heat flow increase due to their reward of stable act, simple configurations and easiness of fitting. These type inserts generate swirling flow and cause improved fluid mixing between central region and the nearly wall region so, the heat transfer in tubes can be enhanced by fluid mixing. Sarma *et al*. gave generalized correlations to predict friction factor and convective heat transfer coefficient in a tube fitted with twisted tapes for a wide range of Reynolds number and Prandtl number. The contribution to thermal performance of the conventional, short-width and center-cleared twisted tapes was studied numerically. Configuration optimization of regularly spaced short-length twisted tapes in a circular tube for turbulent heat transfer was carried out by Wang *et al*. by using computational fluid dynamics (CFDs) modeling. Eiamsa-ard *et al*. offered investigational study on convective heat flow in a round pipe among short-length warped tapes inserted under unvarying heat flux. Akhavan-Behabadi *et al*. performed a number of experiments to scrutinize effects of warped tapes on heat transfer development as well as pressure drop in horizontal evaporators.

2. Experimental analysis

The schematic diagram of experimental set-up is given in Fig.1. The experimental facility includes a blower, an orificemeter to measure the volumetric flow rate, the heat transfer test tube (700 mm). The MS test tube 26 mm inner diameter (D1), 26.4 mm outer diameter (D2), and 2 mm thickness (t). The wavy twisted tapes are tested in this experiment, with three different wave-widths as 13,16 and 24 mm but have same twist ratio (y/D =9.375). They are fabricated from aluminium. Also one plane twisted tape made up of aluminium is tested. A 0.24 hp blower is used to force air through the test tube. Uniform heat flux is applied to external surface of the test tube by means of heating with electrical winding, whose output power is controlled by a variac transformer to supply constant heat flux along the entire section of the test tube.

Fig.1 Experimental setup

The outer surface of the test tube is well insulated with glass wool to reduce the convective heat loss to the surroundings. The external surface temperatures of the test tube wall are measured by 6 K-type thermocouples, which are placed on the outer wall of the test tube. Also the inlet and outlet temperatures of the bulk air are measured by two K-type thermocouples at given points. An inclined manometer is used to measure pressure drop across the test tube. After air passes the test tube, it enters to the orificemeter for determining volumetric flow rate readings. For this purpose a separate U-tube manometer is placed across orificemeter.

The volumetric flow rate of air supplied from the blower is controlled by varying control valve position. The experiments are conducted by varying the flow rate in terms of Reynolds numbers from 4181 to 9466 of the bulk air. The test tube is heated from the external surface during the experiments, and the data of temperatures, volumetric flow rate, pressure drop of the bulk air and electrical output are recorded after the system is approached to the steady state condition. The Nusselt number, Reynolds number, friction factor, heat transfer enhancement are calculated based on the average outer wall temperatures and the inlet and outlet air temperatures. The data reduction of the obtained results is summarized in the following procedures:

$$T_s = (T_2+T_3+T_4+T_5+T_6+T_7)/6 \quad (1)$$

$$T_b = (T_1+T_8)/2 \quad (2)$$

Equivalent height of air column, $h_{air} = (\rho_w * h_w)/\rho_a$ (3)

Discharge of air, $Q_a = C_d * A_o \sqrt{2 * g * h_{air}}$ (4)

Velocity of air flow, $V = Q_a / A$ (5)

Reynolds number, $Re = V D/\nu$ (6)

$$Q = \dot{m} * C_p * (T_8 - T_1) \quad (7)$$

$$h = \frac{Q}{A\,(T_s - T_b)} \quad (8)$$

$$Nu = \frac{h\,D}{k} \quad (9)$$

$$f = \frac{\Delta P}{\frac{L}{D} * \frac{\rho_a V^2}{2}} \quad (10)$$

$$\eta = \frac{(Nu_i/Nu)}{(f_i/f)^{0.333}} \quad (11)$$

In this study, experimental results of Nusselt number and friction factor for the plain tube are obtained and validated with equations of Dittus Boelter and Petukhov as given below;

$$Nu_{th} = 0.023\, Re^{0.8}\, Pr^{0.4} \quad (12)$$

$$f_{th} = (1.82 * \log 10\, Re - 1.64)^{-2} \quad (13)$$

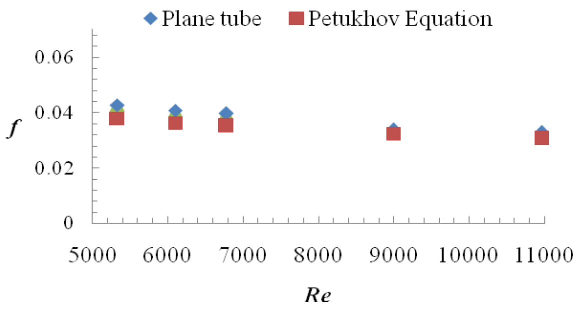

Fig.2 Validation results for friction factor

The comparisons of Nusselt number and friction factor for the present plain tube with existing correlations are shown in Figs. 2 and 3, respectively.

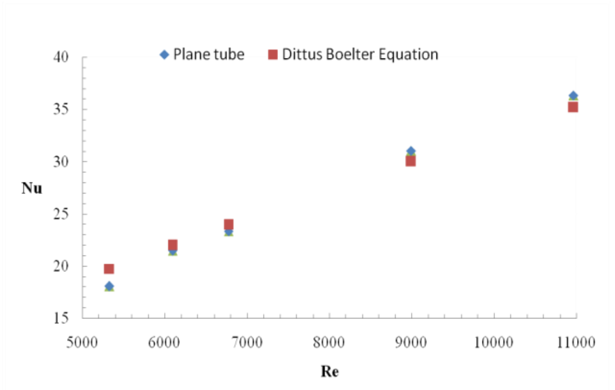

Fig.3 Validation results for Nusselt number

These figures shows that validation experiments of heat transfer in terms of Nusselt number and friction factor for the plain tube are in good agreement with the results obtained from Dittus-Boelter and Petukhov equations. The results of present plain tube and previous equations are nearly the same. Thus, this accuracy provides reliable results for heat transfer and friction factor in a tube with twisted tape inserts in this present study. The Reynolds number for validation test were ranged from 4500 to 11000 i.e. the range of Reynolds number used is for turbulent flow. Turbulent flow means Reynolds number greater than 4000. The results of the tests carried for performance checking of present wavy twisted tape are discussed further in results & discussion.

3. Results and Discussion

3.1 Heat Transfer and Overall Enhancement Characteristics

The variation of Nusselt number with Reynolds number for copper corrugated inserts is shown in Figure 4. Highest Nusselt number was obtained for tape with twist ratio 9.79. The Nusselt number for copper inserts varied from 31% to 86% compared to plain tube. This is due to strong turbulence intensity generated by corrugations on inserts leading to rapid mixing of the flow causing heat transfer enhancement.

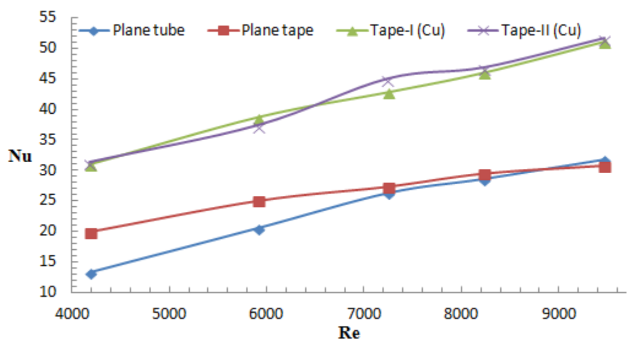

Fig.4 Variation of Nusselt number with Reynolds number

The variations of friction factor with Reynolds number for copper inserts are presented in Figure 5. It is observed that the friction factor gradually reduced with rise in Reynolds number. It is observed to be maximum for insert having twist ratio 8.83.

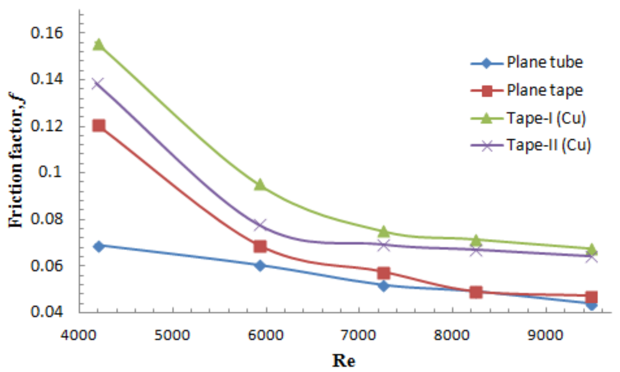

Fig.5 Variation of Friction number with Reynolds number

It is evident from above figures that when a copper corrugated twisted tape is inserted into a plain tube there is a significant improvement in Nusselt number because of secondary flow, with greater enhancement being realized at lower Reynolds numbers and higher twist ratio.

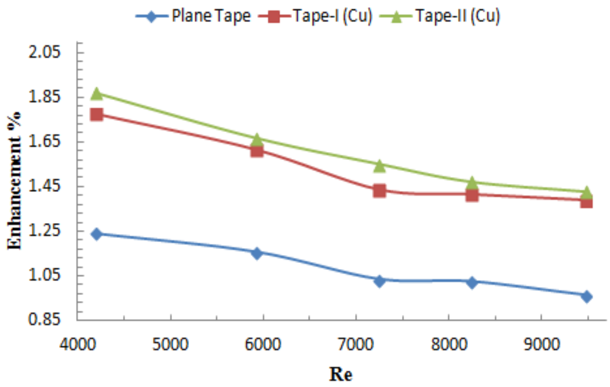

Fig.6 Variation of enhancement with Reynolds number

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. The percentage rise in Nusselt numbers for wavy twisted tapes compared to plain tube are about 32- 98%, 31-89% and 26-87% respectively. The overall enhancement ratio is useful to evaluate the quality of heat transfer enhancement obtained over plain tube.

Conclusion

The study presents an experimental investigation of the potential of wavy twisted tape inserts to enhance the rate of heat transfer in a horizontal circular tube with inside diameter 26 mm with air as working fluid. The Reynolds number varied from 4100 to 9400. The effects of parameter twist ratio, Reynolds number on the heat transfer and overall enhancement ratio are studied. The following conclusions can be drawn:

1) The enhancement of heat transfer with copper twisted tape inserts as compared to plain tube varied from 11 to 42% for twist ratio of 9.79 and 10 to 37% for wave-width 8.87. This enhancement is mainly due to the centrifugal forces resulting from the spiral motion of the fluid.
2) The Nusselt number along with the friction factor raises with increment in twist-ratio. The maximum friction factor rise was about 174% for 8.87and 148% for 9.79 twist ratio tape inserts compared to plain tube.
3) The overall enhancement for the tubes with wavy twisted tape inserts is 1.85 for twist ratio 9.79 and 1.70 for twist ratio 8.87 copper twisted tape insert.

Thus the enhanced performance can be achieved using copper twisted tapes as compared to plane twisted tape. Thus, from the considerations of enhanced heat transfer and savings in pumping power wavy-width tape inserts are seen to be attractive for enhancing turbulent flow heat transfer in a horizontal circular tube.

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