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HEAT TRANSFER ENHANCEMENT USING PASSIVE ENHANCEMENT TECHNIQUE

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ABSTRACT

Among many techniques (both passive and active) investigated for augmentation of heat transfer rates inside circular tubes, a 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 twisted tape inserts in tubes is a well-acclaimed technique employed in industrial practices. CFD investigations on enhancement of turbulent flow heat transfer with twisted tape inserts in a horizontal tube under forced convection with air flowing inside is carried out using ANSYS FLUNT. The variations of heat transfer coefficients; Nusselt number in the horizontal tube fitted with twisted tape is studied. A CFD investigation is conducted to study forced convection of fully developed turbulent flow through circular tube with twisted tape inserts. CFD solutions are obtained using commercial software ANSYS FLUENT v12.1. The working fluid in all cases is air.

KEYWORDS: Twisted tape, CFD, Heat transfer, Flow friction.

INTRODUCTION

Heat transfer augmentation techniques refer to different method used to increase rate of heat transfer without affecting much the overall performance of the system. Nowadays, the high cost of energy and material has resulted in an increased effort aimed at producing efficient heat transfer equipment's. The heat transfer rate can be enhanced by introducing the disturbance in the fluid flow (making and breaking thermal boundary layers) but in process industries pumping power may increase significantly and ultimately the pumping cost becomes high .Therefore to achieve the desired heat transfer rate in an existing heat exchange equipment's at an economic pumping power, several techniques have been proposed in recent years and are discussed in further sections. Heat transfer augmentation techniques refer to different method used to increase rate of heat transfer without affecting much the overall performance of the system. These techniques are used in heat exchangers. Some of the applications of heat exchangers are in process industries, thermal power plant, air conditioning equipment, refrigerators, radars for space vehicles, automobiles etc. The Heat transfer enhancement in duct flow by inserts such as twisted tape, coil inserts/spirals, ribs and dimples is mainly due to flow blockages, partitioning of the flow and secondary flow. The flow blockages increase the pressure drop and leads to increased viscous effect because of reduced fluid flow area. The blockages also increase flow velocity and in some situations it leads to a significant secondary flow. The secondary flow further provides a better thermal contact between surface and fluid as secondary flow creates swirl and this results in mixing of fluid that enhances the thermal gradient which ultimately enhances the heat transfer coefficient. In the past decade, several studies on the passive techniques of heat transfer augmentation have reported. The present paper review mainly focus on the rib turbulators heat transfer enhancement and its design modification towards the enhancement of heat transfer and saving pumping power. Enhancing heat transfer surface are used in many engineering applications such as gas turbine blade cooling passages (i.e. channel/duct), air heater, heat exchanger surfaces, gas-cooled reactor fuel elements, ventilation equipment of micro-electronic systems and air conditioning/ refrigeration systems, hence many techniques have been investigated on enhancement of heat transfer rate and decrease the size and cost of the involving equipment especially in heat exchangers. One of the most important techniques used are passive heat transfer technique. These techniques when adopted in heat transfer surfaces proved that the overall thermal performance improved significantly. A twisted tape insert is the chief method of inducing swirl or vortex flow to a fluid flowing inside a tube. Insertion of twisted tape results in an increase in pressure drop along with the increase in heat transfer. A twisted tape inserts mixes the bulk flow well and therefore performs better in laminar flow, because in laminar flow the thermal resistant is not limited to a thin region. The previous result also shows twisted tape insert is more effective in laminar flow, and pressure drop penalty is created during turbulent flow. This review article presents the effect of twisted tape on the heat transfer enhancement, pressure drop, flow friction and thermal performance factor characteristics in a heat exchanger tube. Guo et al. [1] studied the heat transfer and thermal performance factor in tube with a center-cleared twisted tape. They found that the thermal performance of the tube with center-cleared twisted tape was enhanced up to 20% as compared with that of tube with the typical twisted tape (TT). Wang et al. [2] conducted the computational fluid dynamics (CFD) modeling to predict the configuration optimization of regularly spaced sort-length twisted tape in a round tube. It was observed that the tape with larger rotated angle yielded a higher heat transfer value and a greater flow resistance, whereas the one with smaller twist ratio resulted in better heat transfer performance. Cui et al. [3] carried out numerical simulation of the heat transfer characteristics and the pressure drop of air flow n a circular tube with an edge fold-twisted tape insert. It was reported that the Nusselt number and friction factor in the tube with edge fold-twisted tape were higher than those in the tube with TT up to 9.2 % and 74%, respectively. Eiamsa-ard et al. [4] numerically analyzed the swirling flow in the tube induced by loose-fit twisted tape insertion with different clearance ratios. The mean flow patterns in a tube with loose-fit twisted tapes in terms of contour plots of velocity, path line, pressure, temperature and turbulent kinetics energy were also described and compared with those in the tube fitted with tight-fit twisted tapes. Rahimi et al. [5] predicted the friction factor, Nusselt number and thermal-hydraulic performance of a tube equipped with the classic and three modified twisted tape inserts with CFD. Among the tapes of interest, the jagged insert yielded the highest Nusselt number and thermal perform factor which were higher than those given TT by around 31% and 22%, respectively. Changhong Chen et al. [6] analyzed the computational fluid dynamics (CFD) modeling for the optimization of regularly spaced short-length TT in a circular tube. The configuration parameters are given by the ‘S’, ’y’ and ‘α’. The result is made such that the mean heat transfer and flow resistance increase with an increase in α. Yadav [7] experimentally investigated on the half length TT insertion on heat transfer & pressure drop characteristics in a U-bend double pipe heat exchanger. The experimental results revealed that the increase in heat transfer rate of the TT inserts is found to be strongly influenced by tape-induced swirl. Eiamsa-ard et al. [8] made a comparative investigation of enhanced heat transfer and pressure loss by insertion of single TT, full-length dual TT and regularly-spaced dual TT as swirl generators. The result shows that all dual TT with free spacing yield lower heat transfer enhancement in comparison with the full-length dual TT. Hata and masuzakib [9] investigated the TT- induced swirl flow heat transfer due to exponentially increasing heat inputs with various exponential periods and the TT-induced pressure drop were systematically measured. The influence of ‘y’ and ‘Re’ based on swirl velocity, ‘Resw’ on the TT-induced swirl flow heat transfer was investigated and predictable correlation was derived. Eiamsa-ard et al. [10] studied the influences of multiple twisted tape vortex generators (MT-VG) on the heat transfer and fluid friction characteristics in a rectangular channel From the experiment it is revealed that, the channel with the ‘y’ and ‘S’ provides higher heat transfer rate and pressure loss than those with the larger ‘y’ and free-spacing ratio under similar operation condition. C.B. Sobhan et al. [11] experimentally investigated on a 1-2 shell and tube heat exchanger, to study the spiral turbulators on its performance. Date [12], Date and Saha [13] numerically predicted the friction and heat transfer characteristics for laminar flow in a circular tube fitted with regularly spaced twisted-tape elements that were connected by thin circular rods. Choudhari and Taji [14] have been studied the experimental investigation of the heat transfer and friction factor characteristics of a double pipe heat exchanger fitted with coil wire insert made up of three different material as copper, aluminum and stainless steel and different pitches for Reynolds number in range of 4000-13000. Ray and Date [15] investigated experimentally correlations of heat transfer and flow frictions in a square duct with twisted-tape insert. Seemawute and Eiamsa-Ard [16] have been conducted the experiments for heat transfer in heat exchanger tubes by means of TRs compared to that of CRs at different width and pitch ratio has been investigated for Reynolds number between 6000 and 20,000. At the same width ratio (W/D=0.15) and a given pitch ratio, only TRs with the smallest pitch ratio (p/D) of 1.0 give higher Nusselt numbers than the CRs by around 3 to 4%. Kumar and Prasad [17] reported the improved solar collectors of water heating types by means of twisted tapes inserted in the water flow tubes.

COMPUTATIONAL MODEL

The heat exchanger with twisted tape inserts used in this study is shown in Fig. 1. The effects of five various-lengths of twisted tapes on Heat Transfer and Flow Friction Characteristics are studied. The solution domain is a circular

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tube with twisted tape inserts. After defining the computational domain, uniform and non-uniform mesh is generated. In creating this mesh, it is desirable to have more cells near the plate because we want to resolve the turbulent boundary layer, which is very thin compared to the height of the flow field. After generating mesh, boundary conditions have been specified. We will first specify the left face is the tube inlet and right face is the tube outlet. Meshing of the domain is done using ANSYS ICEM CFD V12.1 software. Since low-Reynolds-number turbulence models are employed, the grids are generated so as to be very fine. To select the turbulence model, the previous experimental study is simulated using different low Reynolds number models such as Standard k-ω model, Renormalization-group k-ε model, Realizable k-ε model and Shear stress transport k-ω model. The results of different models are compared with experimental results. The RNG k-ε model is selected on the basis of its closer results to the experimental results. The working fluid, air is assumed to be incompressible for the operating range of duct since variation is very less. The mean inlet velocity of the flow was calculated using Reynolds number. Velocity boundary condition has been considered as inlet boundary condition and outflow at outlet. Second order upwind and SIMPLE algorithm were used to discretize the governing equations. The FLUENT software solves the following mathematical equations which governs fluid flow, heat transfer and related phenomena for a given physical problem.

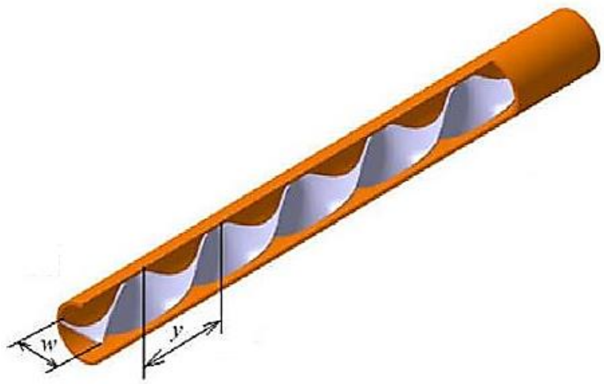

Figure 1. Heat exchanger with twisted tape inserts

RESULTS AND DISCUSSION

Fig. 2 shows the effect of Reynolds number on average Nusselt number for different lengths of twisted tape (T1>T2>T3>T4>LR). The average Nusselt number is observed to increase with increase of Reynolds number due to the increase in turbulence intensity caused by increase in turbulence kinetic energy and turbulence dissipation rate.

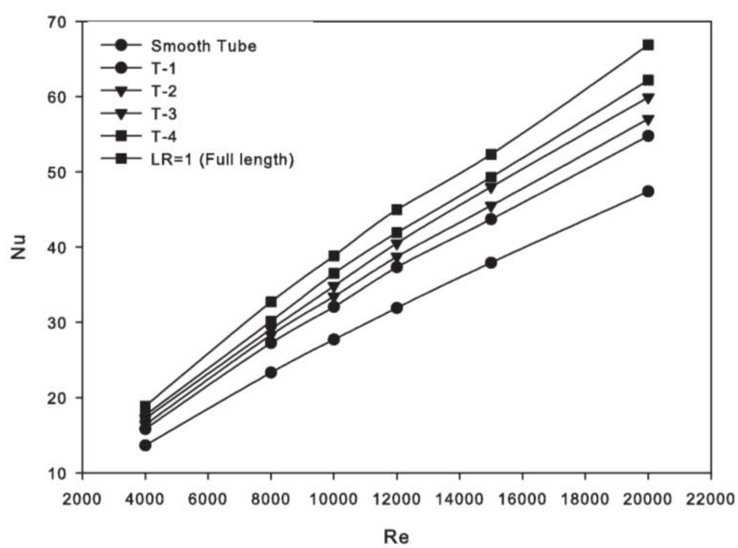

Figure 2. Nusselt number vs Reynolds number

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It can be seen that the enhancement in heat transfer of the heat exchanger with twisted tape inserts with respect to the smooth heat exchanger also increases with an increase in Reynolds number. It can also be seen that Nusselt number values increases with the increase in length of twisted tape inserts. This is due to the fact that heat transfer coefficient is low at the leading edge of the twisted tape and high at the trailing edge. Higher value of length of twisted tape produced more reattachment of free shear layer which creates the strong secondary flow. The heat exchanger with full length twisted tape inserts provides the highest Nusselt number at a higher value of Reynolds number. The heat transfer phenomenon can be observed and described by the Vector plots of velocity for different lengths of twisted tape (Fig. 3).

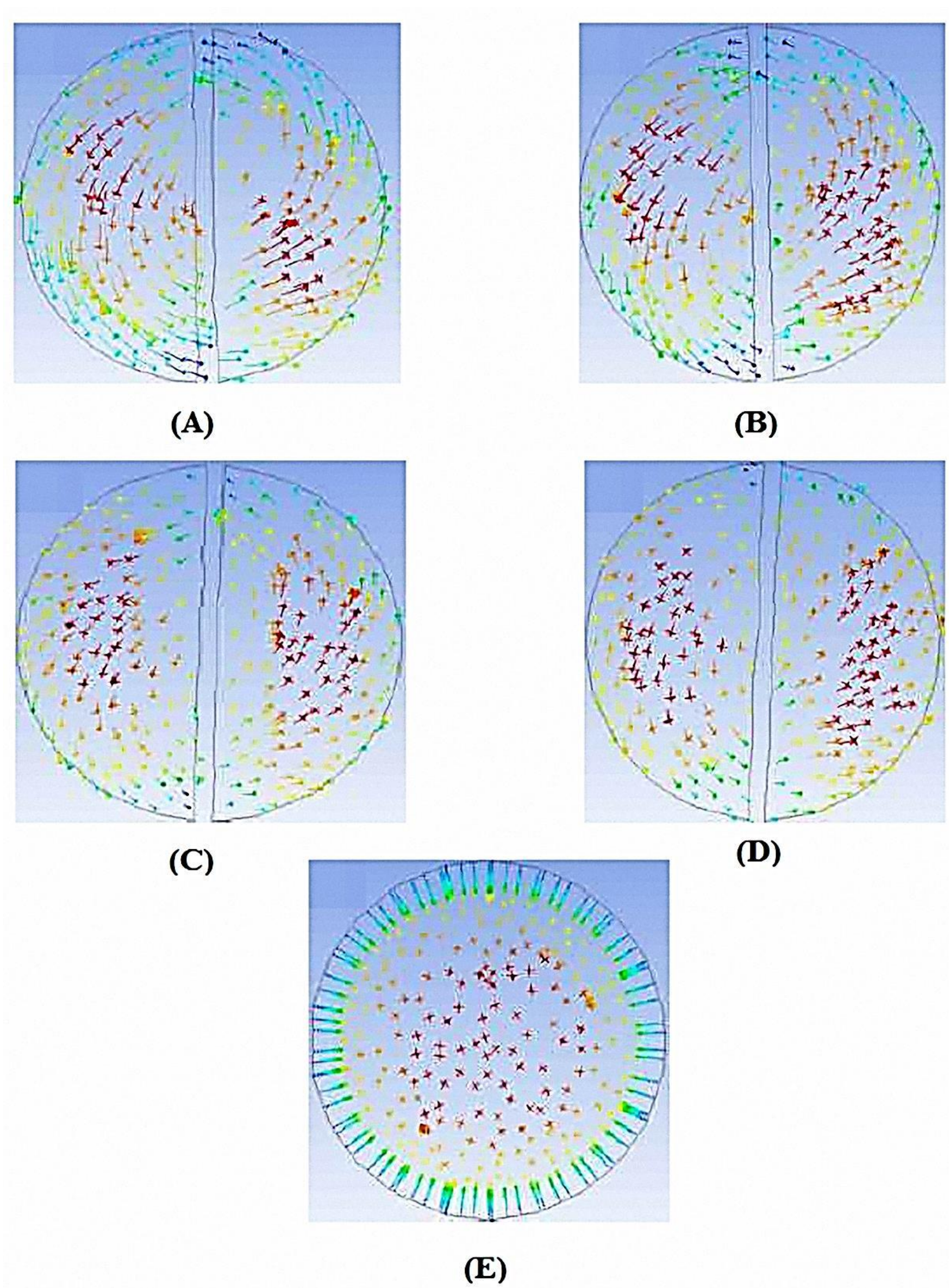

Figure 3. Contour plot of turbulence intensity

CONCLUSION

The air flow through heat exchanger with twisted tape inserts is studied to examine the heat transfer characteristics as well as the friction characteristics. CFD analysis has been carried out to study heat transfer and fluid flow behavior in a heat exchanger with twisted tape inserts. The effect of Reynolds number and length of twisted tape on the heat transfer coefficient and friction factor have been studied. In order to validate the present numerical model, results have been compared with available experimental results under similar flow conditions. CFD Investigation has been carried out in medium Reynolds number flow. The following conclusions are drawn from present analysis:

1. Insertion of twisted tape in a tube provides a simple passive technique for enhancing the convective heat transfer by producing swirl into the bulk flow and by disrupting the boundary layer at the tube surface. However, the increase in friction is seemed to be the penalty of the technique. Thus, tube with twisted tape insert is frequently used in heat exchanger systems because of it low cost, less maintenance and compact.
2. There is a definite increase in heat transfer through heat exchanger with twisted tape inserts with increase in friction to the flow.
3. The heat exchanger with full length twisted tape inserts provides the highest Nusselt number at a higher value of Reynolds number.
4. The short-length twisted tape insert still provides higher heat transfer rate (Nu) than the plain tube.

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