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SHORT COMMUNICATION

Comparative study for thermal-hydraulic performance of circular tube with inserts

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Abstract Several researchers have worked on the passive approach of heat transfer enhancement in tube heat exchangers. Some of them tried to modify the surface by creating dimple or using wire coil of different cross-section, while some worked on core fluid disturbance by using some insert geometries such as twisted tapes. But the ultimate aim of all was to create some disturbance in the flow in order to obtain enhanced heat transfer. This paper focuses on comparison of some of the most commonly used insert geometries. Insert geometry selected for this comparison is collection of core fluid disturbance, surface modification and combination of both. Different geometries taken in this study include twisted tape, twisted tape with ring, circular band, multiple twisted tape, twisted tape with conical rings, and so on and used air under turbulent flow regime as working fluid. On the basis of comparison made, it is observed that, in case of "single twisted tape insert" the thermal performance factor was maximum and in the event of "twisted tape with circular ring" the overall heat transfer rate is maximum. Future aspect is also proposed, which includes perforation in circular ring, and causes decrease in friction factor value because of less flow blockage.

1. Introduction

Heat transfer enhancement using turbulent promoters as inserts in heat exchangers has become a prime area of research for the researchers. Use of the different passive approach of heat transfer enhancement for improving thermo-hydraulic performance of heat exchanger, in order to cut down its size and price is the main motive for such kind of work. In the past two decades, several works have been carried out in this field in order to produce more efficient heat exchange devices for our thermal and mechanical systems. Different insert geometries with different parameter ranges have been used by researchers as turbulence promoters for the heat exchanger device. Some of the major recent studies include, Bas and Ozceyhan [1], who used single twisted tape as insert geometry separated from tube wall, and found very significant effect on the heat transfer. Similarly, Bhuiya et al. [2,3] used double counter twisted tape and triple twisted tape respectively in their study and found that, by decreasing the twist ratio of the twisted tapes, heat transfer rate increases to a great extent. Eiamsa-ard et al. [4], used circular ring with twisted tape as insert geometry

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Nomenclature

Abbreviations		η	thermal performance factor
TT	twisted tape	PR	pitch ratio
CRT	circular ring tuberator	DR	diameter ratio
Re	Reynolds number	CR	clearance ratio
Nu	Nusselt number	f_s	friction factor of plane tube
f	friction factor of tube with insert	Pr	Prandtl number
Nu_s	Nusselt number of plane tube		

for experimentation, and they found that by decreasing the spacing between circular ring, heat transfer increases. Promvonge [5] used twisted tape with uniform wire coil, Promvonge and Eiamsa-ard [6] used conical ring with twisted tape as their insert geometry, and they also found significant effect of ring spacing on the heat transfer in tube heat exchangers. Similarly, Gunes et al. [7] used triangular cross section wire coil as their insert geometry. Kongkaitpaiboon et al. [8] used circular ring tuberator in experimentation; significant effect of diameter ratio and pitch ratio was observed, which shows that as the value of diameter ratio increases heat transfer rate decreases, and as the value of pitch ratio decreases heat transfer increases. Promvonge et al. [9] used inclined vortex ring, and Eiamsa-ard and Promvonge [10,11] used double sided delta wing and serrated twisted tape respectively. Similarly some other important geometries used for such research are perforated twisted tape [12], conical nozzle [13], perforated conical ring [14], twisted ring [15], short length twisted tape [16], non uniform wire coil with twisted tape [17] and Protruded surface [18] with several geometrical and flow parameters respectively using air as working fluid. Chamoli et al. [19] shows several other geometries of turbulence promoters used in passive heat transfer enhancement technique in several solar thermal systems. In all of the above study, one thing is very common that all the researchers tried to bring turbulence in the fluid flow by creating surface modification or core fluid disturbance or both at the same time.

This comparative study focused on some of the most effective work in the recent year which includes, surface modification, core fluid disturbance and both of it, [1–9]. Comparison of heat transfer, friction factor and thermal performance factor is made on the basis of correlation developed by these researchers in their studies. This comparison also aims at developing some future aspect for the passive method of heat transfer enhancement.

2. Methodology

The study is borne out by comparing results and correlations of very similar variety of experimental study. Nine different insert geometries have been used up, which are single twisted tape, double twisted tape and triple twisted tape, TT with ring, CRT, etc. Each of the experiments has been performed on similar kind of experimental setup and because of their different geometries, different results and correlation have been obtained by different researchers. In this paper all the nine works had been compared in order to get optimal effect and future prospect. The different insert geometries and parameters used with their results are presented in Table 1. All the correlations for heat transfer, friction factor and thermal performance factor are presented in Table 2. Table 3 shows the values of parameters on which the correlation in each case shows the maximum result for heat transfer, friction factor, and thermal performance factor, respectively.

3. Results and discussion

3.1. Effect of twist ratio

3.1.1. Heat transfer

In each experimental run, it is observed that the heat transfer rate increases with decrease in twist ratio values. The results of heat transfer rate in terms of the Nusselt number for roughned tube and their enhancement over smooth tube are presented in Figs. 1(a) and (b) and it is observed from the graph that the heat transfer is maximum in case of twisted tape with circular ring insert [4], and minimum in case of single twisted tape insert [1]. In case of twisted tape with circular ring, the ring which is placed over the twisted tape plays an important role in the heat transfer. The insertion of ring modified the fluid flow, which accommodates to high heat transfer rate. It is also observed that for the higher Reynolds number, the heat transfer has higher values and as the value of the Reynolds number decreases the heat transfer rate also decreases.

3.1.2. Friction factor

In each experiment, it was found that the friction factor increases with a decrease in the twist ratio. Here along the basis of observation and the graph obtained by comparing each experiment which is presented in Figs. 2(a) and (b), it is found that in case of twisted tape with wire coiled insert [5] there is significant impact along the friction factor, only the maximum frictional factor can be understood in the case of the circular ring insert [7] and the minimum in case of single twisted tape [1], double twisted tape [2] and triple twisted tape insert [3]. It is also determined that as the value of the Reynolds number increases the frictional factor decreases and as it decreases the frictional factor increases. Hence, for the low Reynolds number the value of the frictional factor is more gamey.

And it can also articulate that in the case of core fluid disturbance which is induced by the twisted tape the value of frictional factor is more down as compared to the surface disturbance in the fluid which is done in the sheath of the circular ring insert [7], or combines both core and surface disturbance which is insured in case of twisted tape with circular ring [4].