
**PASSIVE HEAT TRANSFER AUGMENTATION METHODS IN A CIRCULAR
TUBE: A REVIEW**

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ABSTRACT

The present paper is a review of the passive heat transfer augmentation in circular tubes used in the recent past and these techniques will be useful to designers while implementing in heat exchangers. Passive techniques, generally uses surface or geometrical modification to the flow channel by incorporating inserts or additional devices to increase the heat transfer rate. As the manufacturing process of inserts are simple and cheap, so these techniques can be easily employed in an existing heat exchanger. Inserts in a heat exchanger tube generates the swirls, which directs fluid in the Centre towards the heated wall and fluid near the heated wall towards Centre. This phenomenon results fluid flowing in a curvilinear path, which promotes mixing and increase in heat transfer rate.

Keyword: - Augmentation, Heat exchanger tube, Inserts, Passive heat transfer

1. INTRODUCTION

There are numerous techniques to embellish the heat transfer, such as fins, dimples, additives, etc. A great deal of research effort has been devoted to developing apparatus and performing experiments to define the conditions under which an enhancement technique will improve heat transfer. Heat transfer enhancement technology has been widely applied to heat exchanger applications in refrigeration, automobile, process industries etc. The aim of enhanced heat transfer is to encourage or accommodate high heat fluxes. This result in reduction of heat exchanger size, which generally leads to lower capital cost. So there is need to increase the thermal performance of heat exchangers, thereby effecting energy, material and cost savings have led to development & use of many techniques termed as Heat transfer Augmentation. These techniques are also called as Intensification or Heat Transfer Enhancement. Augmentation techniques increase convective heat transfer by reducing the thermal resistance in a heat exchanger. Use of Heat transfer augmentation techniques lead to increase in heat transfer coefficient but at the penalty of increase in pressure drop. So, while designing a heat exchanger using any of these methods, analysis of heat transfer rate and pressure drop has to be done. Apart from this, issues like long-term performance and detailed economic scrutiny of heat exchanger has to be studied. To achieve maximum high heat transfer rate in an existing or new heat exchanger while taking care of the increased pumping power, several methods have been proposed in recent years.

Generally, heat transfer augmentation techniques are classified in three broad categories. Active method, Passive method, Compound method; In active method some external power input are required for the enhancement of heat transfer for example surface vibration, fluid vibration, suction or injection etc. whereas passive method generally uses surface or geometrical modifications to the flow channel by incorporating inserts or additional devices for example inserts extra components, rough surfaces, additives for fluids etc. The passive methods are based on this principle, by employing several techniques to generate the swirl in the bulk of the fluids and disturb the actual boundary layer so as to increase effective surface area, residence time and heat transfer coefficient in existing system. Lastly compound method is a combination of both the active and passive methods; the compound method involves complex design and has limited applications.

2. LITERATURE REVIEW

Number of investigations has been carried out by using various inserts and tube geometries for heat transfer augmentation. Investigations of various researchers and their findings are as follows.

Naphon [1] experimentally investigated the effect of coil-wire insert shown in Fig. 1(a) on heat transfer enhancement and pressure drop of the horizontal concentric tube has been studied. It was observed that as the Reynolds number increases heat transfer rate decreases. Further Naphon et al. [2] in 2011 changes changes the geometry of insert, it was found that the swirl flow is generated as fluid flowing through the plain tube with twisted wire brush insert as shown in Fig.1(d) the presence of swirl flow the convective heat transfer obtained is higher.

Eiamsa-ard et al. [3] experimentally investigated the heat transfer characteristics in a tube fitted with helical screw-tape with/without core-rod inserts. It was observed that the heat transfer rate obtained by using the tape without core-rod shown in Fig. 1(h) is found to be better than that by one with core-rod around 25–60% while the friction is around 50% lower. Eiamsa-ard et al. [4] in 2008 used double pipe heat exchanger with different arrangement of louvered strip inserts, experimental results showed that the forward louvered strip arrangements as shown in Fig. 1(f) can promote the heat transfer rate by approximately 150% to 284%, while the backward arrangements could improve the heat transfer by approximately 133% to 264%. It was observed that Louvered strip insertions can be used efficiently to augment heat transfer rate because the turbulence intensity induced could enhance the heat transfer.

Further Eiamsa-ard et al. [5] in 2010 changed the geometry of insert in a heat exchanger tube and observed that the presence of novel alternate C–CC twisted-tapes shown below in Fig. 1(c), the periodic change of swirl direction and also the strong collision of the recombined streams behind the changing location, lead to superior chaotic mixing and to better heat transfer, compared with the typical twisted-tape. Murugesan et al. [6] experimentally investigated the heat transfer and pressure drop characteristics in a circular tube fitted with and without V-cut twisted tape insert. It was observed that the V-cut twisted tape shown in Fig. 1(e) offered a higher heat transfer rate, friction factor and also thermal performance factor compared to the plain twisted tape. The results obtained were same as that of [5].

Thianponga et al. [7] experimentally investigated the effect of perforated twisted-tapes with parallel wings on heat transfer enhancement in a heat exchanger tube. The result showed that as compared to plain twisted tube, PTT shown below in Fig. 1(g) increases heat transfer rate up to 208%, and compared with [5,6] showed good result. Fan et al. [8] numerically and computationally studied the heat transfer and flow characteristics in a circular tube fitted with louvered strip inserts shown in Fig. 1(f). It was observed that the nusselt number is augmented by around 4 times that of the smooth tube, also compared with [5] it showed better result, hence it confirms that the louvered strip has a good effect of heat transfer enhancement.

Promvongse et al. [9] experimentally investigated the heat transfer augmentation in a helical-ribbed tube with double twisted tape inserts. It was found that the compound enhancement devices of helical-ribbed tube and the twin twisted tapes shown in Fig. 1(i) show a considerable improvement of heat transfer rate and thermal performance relative to the smooth tube and the helical-ribbed tube acting alone. Mohammed et al. [10] numerically and computationally studied the heat transfer enhancement of Nano fluids in a double pipe heat exchanger with louvered strip insert as shown above in Fig. 1(j). The result obtained by [8] was same that is the nusselt number is augmented by around 4 times for the louvered strip insert than that of the smooth tube.

Bhuiya et al. [11] experimentally investigated the thermal characteristics in a heat exchanger tube fitted with triple twisted tape inserts. It was found that the nusselt number was obtained 1.73 to 3.85 times higher than those of the plain tube values for the tube with triple twisted tape inserts as shown in Fig. 2(b). The friction factor for the tube with triple twisted tape inserts was achieved 1.91 to 4.2 times higher than those of the plain tube values at the comparable Reynolds number.

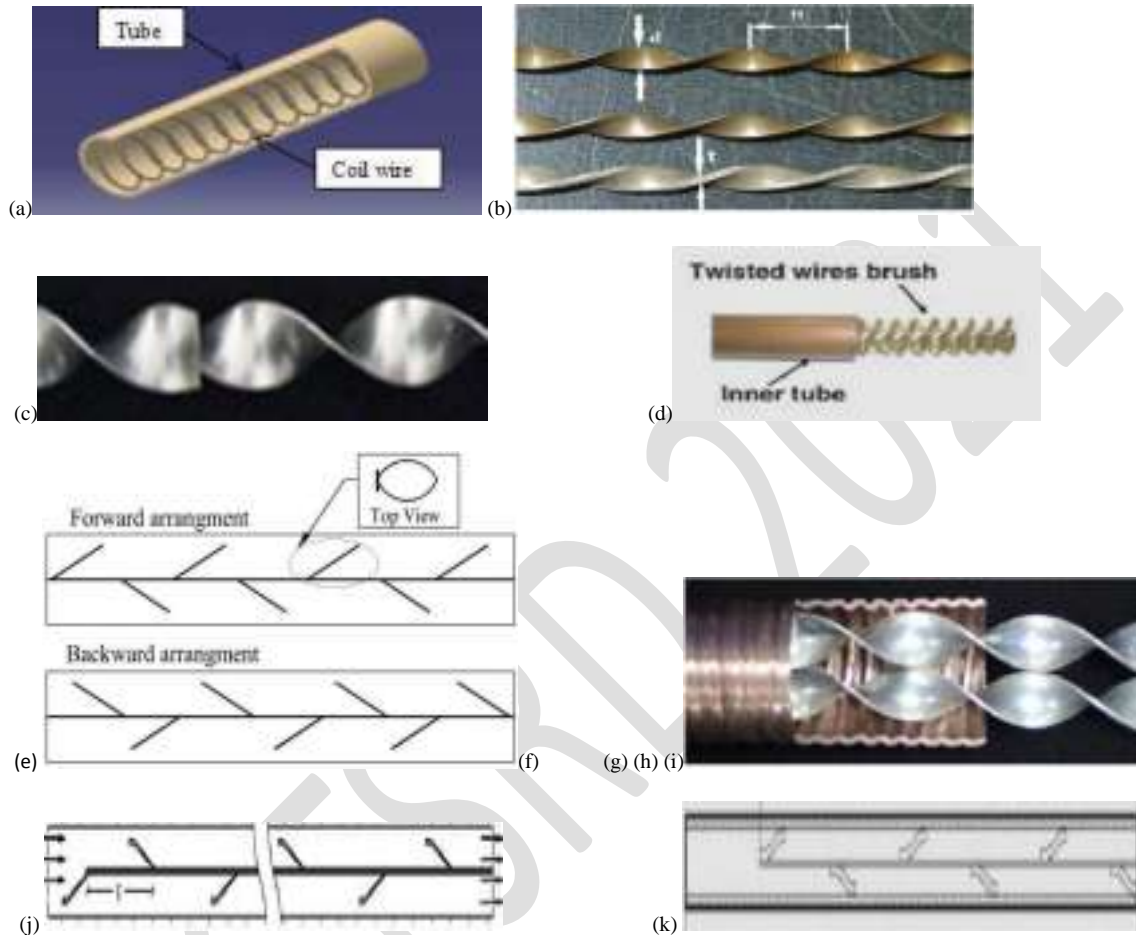


Figure-1: Various types of inserts used by researchers: (a) Tube with coil wire insert. (b) TT inserts with different thicknesses. (c) Alternate clockwise and CC twisted tape insert. (d) Tube with twisted wires brush insert. (e) V-cut twisted tape insert. (f) Tube with different arrangements of louvered strip insert. (g) PTT with parallel wings insert. (h) Tube fitted with helical screw-tape With/without core-rod inserts. (i) Helical-ribbed tube with double TT inserts.

(j) Tube with louvered strip insert. (k) Tube with small pipe inserts.

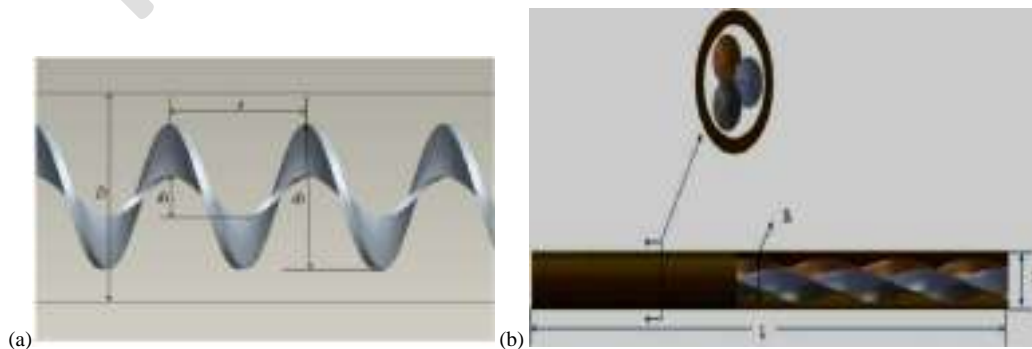


Figure-2: Various types of inserts used by researchers: (a) Helical screw-tape without core-rod Insert. (b) Tube fitted with triple twisted tape inserts.

Zhang et al. [12] numerically and computationally studied on heat transfer and friction factor characteristics of a tube fitted with helical screw-tape without core-rod insert shown above in Fig. 2(a). The results obtained were same as that obtained by [3] that is heat transfer rate increase around 25-60% while friction is around 50% lower. TuWenbin et al. [13] experimental studied on heat transfer and friction factor characteristics of turbulent flow through a circular tube with small pipe inserts. It was observed that the tube fitted with small pipe inserts shown above in Fig. 1(k) can achieve a high heat transfer with a lower increase in friction factor. The friction factor is less than most of those recorded in other literature and is only 1.24–1.87 times that of the smooth tube. Esmailzadeh et al. [14] experimental studied on heat transfer and friction factor characteristics of g-Al₂O₃/water through circular tube with twisted tape inserts with different thicknesses. It was observed that the highest enhancement is achieved at maximum thickness and volume concentration. Nano fluids have better heat transfer performance when utilized with thicker twisted tapes as shown above in Fig. 1(b). More the thickness of twisted tape is more the increase of friction factor is. Ultimately, the convective heat transfer enhancement outweighs the effect of friction factor increase, leading enhanced thermal performance.

Shirao et al. [15] experimentally carried out heat transfer analysis in a circular tube with different types of internal threads of constant pitch; experimental results showed that heat transfer along with the friction factor increases more in case of tube having buttress threads compared to knuckle and acme threads in a tube.

3. SUMMERY

From the above discussion we come to know that insert in a heat exchanger tube generates the swirls, which directs fluid in the Centre towards the heated wall and fluid near the heated wall towards Centre. This phenomenon results fluid flowing in a curvilinear path, which promotes mixing and increase in heat transfer coefficient. While going through literature review we studied the various geometries of twisted tape and circular tube used by the researchers to investigate various factors such as heat transfer rate, pressure drop etc. More importantly the use of louvered strip insert using various arrangements and the small pipe insert in a circular heat exchanger tube shows great improvement in heat transfer rate when compared with other geometries used by various researchers. It also seen that as per the available literature, the enhancement of heat transfer simply using different surface texture is limited. So the work will be carryout to study and analyze the various factors, such that this technique can be easily employed in an existing heat exchanger.

CONCLUSIONS

From the above literature review we come to know that the passive techniques are commonly used for augmentation of heat transfer rate because they do not require external power source. This paper reviews the investigation carried out by various researches in order to augment the heat transfer, nusselt number and various other factors by using circular tube with inserts of different shapes, sizes and orientation. Heat transfer rate is increase by using inserts in circular tube as compare to circular plain tube, as these passive techniques increase the turbulence of the fluid flow in the circular tube. Active techniques require external power source therefore a power cost that need to be considered, hence whole cost of system increases. This work is expected to serve as a road map for use of techniques in industrial applications.

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