A REVIEW OF HEAT TRANSFER ENHANCEMENT USING PERFORATED TWISTED TAPE

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ABSTRACT

Heat transfer enhancement techniques refer to different methods 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 plants, air-conditioning equipments, refrigerators, radiators for space vehicles, automobiles etc. These techniques broadly are of three types viz. passive, active and compound techniques. The present paper is a review of the passive enhancement techniques used in the recent past.

KEY WORDS : Heat transfer enhancement, twisted tape, twist ratio, passive methods.

INTRODUCTION

Nowadays, twisted-tape inserts have widely been applied for enhancing the convective heat transfer in various industries, due to their effectiveness, low cost and easy setting up. Energy and material saving consideration, as well as economical, have led to the efforts to produce more efficient heat-exchanger equipment. Therefore, if the thermal energy is conserved, the economical handling of thermal energy through heat-exchanger will be possible.

The development of high performance thermal systems has stimulated interest in methods to improve heat transfer. The goal of enhanced heat transfer is to encourage or accommodate high heat fluxes. The heat transfer techniques enables heat exchanger to operate at smaller velocity, but still achieve the same or even higher heat transfer coefficient. This means that a reduction of pressure drop, corresponding to less operating cost.

Heat transfer augmentation techniques refer to different methods 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 plants, air-conditioning equipments, refrigerators, radiators for space vehicles, automobiles etc. These techniques broadly are of three types viz. passive, active and compound techniques.

2. DIFFERENT TECHNIQUES FOR HEAT TRANSFER ENHANCEMENT

2.1 Active method

This method involves some external power input for the enhancement of heat transfer. Some examples of active methods include induced pulsation by cams and reciprocating plungers, the use of a magnetic field to disturb the seeded light particles in a flowing stream, mechanical aids, surface vibration, fluid vibration, electro-static fields, suction or injection and jet impingement requires an external activator/power supply to bring about the enhancement.

2.2 Passive method

This method generally uses a surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. For example, inserting an extra component, swirl flow devices, treated surface, rough surfaces, extended Surfaces, displaced enhancement devices, coiled tubes, surface tension devices and additives for fluids.

2.3Compound method

When any two or more techniques, i.e. passive and active may be employed simultaneously to enhance the heat transfer of any device, which is greater than that of produced by any of those techniques separately, the term known as Compound enhancement technique.

The passive heat transfer augmentation methods as stated earlier do not need any external power input. For the convective heat transfer, one of the ways to enhance the heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. 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 the effective surface area, residence time and consequently heat transfer coefficient in the existing system.

Although there are hundreds of passive methods to enhance the heat transfer performance, the following nine are most popular used in different aspects:

***Treated Surfaces*:**

This technique involves using pits, cavities or scratches like alteration in the surfaces of the heat transfer area which may be continuous or discontinuous. They are primarily used for boiling and condensing duties.

***Rough surfaces*:**

These surface modifications particularly create the disturbance in the viscous sub-layer region. These techniques are applicable primarily in single phase turbulent flows.

***Extended surfaces*:**

Plain fins are one of the earliest types of extended surfaces used extensively in many heat exchangers. Finned surfaces have become very popular now days owing to their ability to disturb the flow field apart from increasing heat transfer area.

***Displaced enhancement devices*:**

These inserts are used primarily in confined forced convection. They improve heat transfer indirectly at the heat exchange surface by displacing the fluid from the heated or cooled surface of the duct with bulk fluid from the core flow.

***Swirl flow devices*:**

They produce swirl flow or secondary circulation on the axial flow in a channel. Helical twisted tape, twisted ducts & various forms of altered (tangential to axial direction) are common examples of swirl flow devices. They can be used for both single phase and two-phase flows.

***Coiled tubes*:**

In these devices, secondary flows or vortices are generated due to the curvature of the coils which promotes higher heat transfer coefficient in single phase flows and in most regions of boiling. This leads to relatively more compact heat exchangers.

***Surface tension devices*:**

These devices direct and improve the flow of liquid to boiling surfaces and from condensing surfaces. Examples include wicking or grooved surfaces.

***Additives for liquids*:**

This technique involves the addition of solid particles, soluble trace additives and gas bubbles added to the liquids to reduce the drag resistance in case of single phase flows. In case of billing systems, trace additives are added to reduce the surface tension of the liquids.

***Additives for gases*:**

These include liquid droplets or solid particles, which are introduced in a single-phase gas flows either as dilute phase (gas–solid suspensions) or as dense phase (fluidized beds).

REVIEW OF WORK CARRIED OUT

P. Eiamsa- et al [1] reports on heat transfer enhancement and friction factor characteristics in the tubes inserted with rectangular-winged twisted tapes(TT-RWs). The wing-depth ratio (d/W) was varied from 0.1 to 0.3 while the tape twist ratio was kept constant at y/W = 4.0. According to the results, the TT-RW with d/W = 0.3 yields the highest Nusselt number which is around 100% higher than that of the plain tube.

Smith Eiamsa-et al [2] Influence of helical tapes inserted in a tube on heat transfer enhancement is studied experimentally. The maximum Nusselt number may be increased by 160% for the full-length helical tape with centered-rod, 150% for the full length helical tape without rod and 145% for the regularly-spaced helical tape, s = 0.5, in comparison with the plain tube.

B. Silapakijwongkul[3] In this work, effect of the tapes twisted in clockwise and counterclockwise arrangement (C-CC arrangement) on heat transfer and friction factor characteristics in a double pipe heat exchanger was investigated experimentally. The mean heat transfer rates obtained from using C-CC twisted-tape arrangement and original twisted-tape arrangement are found to be 219% and 204%,respectively over the plain tube.

C. Thianpong[4] This paper describes heat transfer enhancement attributed to helically twisted tapes(HTTs). Each helically twisted tape was fabricated by twisting a straight tape to form a typical twisted tape then bending the twisted tape into a helical shape. The experiments were performed using HTTs with three twist ratios (y/W) of 2, 2.5 and 3, three helical pitch ratios (p/D) of 1, 1.5 and 2 for Reynolds number between 6000 and

20,000. The conventional helical tape (CHT) was also tested for comparison. The obtained results reveal that at similar conditions(y/W and p/D), HTTs give lower Nusselt number and friction but higher thermal performance factor than CHTs. Heat transfer rate and friction factor increase as the tape twist ratio and helical pitch ratio decrease, while the thermal performance shows opposite trend.

Halit Bas[5] Flow friction and heat transfer behavior in a twisted tape swirl generator inserted tube are investigated experimentally. The twisted tapes are inserted separately from the tube wall. The effects of twist ratios (y/D = 2, 2.5, 3, 3.5 and 4) and clearance ratios (c/D = 0.0178 and 0.0357) are discussed in the range of Reynolds number from 5132 to 24,989, and the typical one (c/D = 0) is also tested for comparison. Uniform heat flux is applied to the external surface of the tube wall. The air is selected as a working fluid. The obtained experimental results from the plain tube are validated by using well known equations given in literature. The using of twisted tapes supplies considerable increase on heat transfer and pressure drop when compared with those from the plain tube. The Nusselt number increases with the decrease of clearance ratio (c/D) and twist ratio (y/D), also increase of Reynolds number.

V. M. Kriplani[6] Heat transfer augmentation techniques refer to different methods 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 plants, air-conditioning equipments, refrigerators, radiators for space vehicles, automobiles etc. These techniques broadly are of three types viz. passive, active and compound techniques. The present paper is a review of the passive augmentation techniques used in the recent past.

C. Thianpong[7] This article reports an experimental investigation on heat transfer and pressure drop characteristics of turbulent flow in a heating tube equipped with perforated twisted tapes with parallel wings (PTT) for Reynolds number between 5500 and20500. The design of PTT involves the following concepts: (1) wings induce an extra turbulence near tube wall and thus efficiently disrupt a thermal boundary layer (2) holes existing along a core tube, diminish pressure loss within the tube. The parameters investigated were the hole diameter ratio(d/W= 0.11, 0.33 and 0.55) and wing depth ratio(w/W = 0.11, 0.22 and 0.33). A typical twisted tape was also tested for an assessment. Compared to the plain tube, the tubes with PTT and TT yielded heat transfer enhancement up to 208% and 190%, respectively. The evaluation of overall performance under the same pumping power reveal that the PTT with d/W= 0.11 and w/W = 0.33, gave the maximum thermal performance factor of 1.32, at Reynolds number of 5500. Empirical correlations of the heat transfer, friction factor and thermal performance for tubes with PTTs were also developed.

Panida Seemawute[8] Visualization of flow characteristics induced by twisted tape consisting of alternate-axis (TA) has been comparatively investigated to that induced by typical twisted tape(TT). The visualization was carried out via a dye injection technique. The effects of twist ratios (y/W)on heat transfer and fluid friction were also extensively examined. The visualization results show that TA give better fluid mixing and thus higher heat transfer rate than TT, at similar conditions. Inaddition, swirl number and thus residence time of a fluid flow is promoted as tape twist ratio decreases, this visualization results is consistent with the superior heat transfer at smaller twist ratio.

S.S.Joshi[9] In this Study the overall performance of suitably designed concentric tube heat exchanger is analyzed with passive heat transfer augmentation technique. In the double pipe heat exchanger, different types of twisted tapes with different twist ratios are used. In addition to this, annular protrusions are used to augment the heat transfer by creating turbulence in the fluid flow. Effect of inserts on effectiveness of heat exchanger is analyzed for different Reynolds Numbers. Simultaneously the friction factors for both inner and annular flow are analyzed.

S.S.Giri, V.M.Kriplani, [10]They did the review of heat Transfer Characteristics using inserts in Tubes. The overall conclusions which they found during the study the twisted type insets heat transfer rate increase in turbulence of the flow and also the pressure drop increases. For conical ring inserts, the heat transfer rate more than that of the plain surface tube simultaneously increases the friction factor. In a wire inserts, the friction factor increases in the fully laminar region and increased the heat transfer coefficient with respect to the smooth tube. In mesh insert, pressure drop increases by increasing the ratio of porous material and enhancement of heat transfer rate when compared to the plain tube. Similarly In a baffle insert, the rate of pressure drop increases with varying the Reynolds number of transient flow conditions.

Prabhakar Ray, et al [11] they did the review on the heat transfer rate enhancement using wire coil inserts in a tube. They concluded that by using a Wire coiled tube it increases the pressure drop compare with an empty tube. If wire coil insert in transition and turbulent region flows it gives better results. In the transition flow region if wire coils are fitted in the smooth tube heat exchanger, than heat transfer rate can increase up to 200% if pumping power is constant. Similarly, in the turbulent flow region, wire coils causing a high pressure drop increase, which are mainly depends on the pitch to wire diameter ratio. Vice versa if pressure drop is not taken under consideration; wire coil inserts are suitable for both laminar and turbulent regions. The wire coil inserts depends on the shapes of the inserts, the Wire coil inserts gives better overall performance when it is compared to a smooth tube maintained constant pumping power, especially at low Reynolds number range.

The impact of multitwisted tapes on the enhancement, efficiency:-

From the previous research it is obvious that the twisted tape can improve the heat transfer efficiency, following this finds, **Eiamsa-ard etal**. [12] Investigated the effect of dual and multiple twisted tape impacts on the heat transfer enhancement. The heat transfer rate for the dual twisted tapes is increased by12%to29% in comparison with the single tape at the twist ratios from 3.0to5.0 by generating strongly dual swirling flows inside the test tube. Depending on the flow conditions and twist ratio y, the increases in heat transfer rate over the plain tube are about 146%,135%and 128% for y¼3.0, 4.0and5.0,respectively.The smaller space ratio of the dual twisted tapes in tandem is more attractive in heat transfer application due to the higher enhancement, efficiency than the single one. The multiple twisted tape vortex generators (MT-VG) were researched by **Eiamsa-ard et al.** [13]. The Nusselt numbers increase by 10% to170 % compared with the values of the smooth channel, while the friction factors are 1.45 to 5.7 times of those of the smooth channel.

Vermahmoudi[14] studied the overall heat transfer coefficient of water based iron oxidenanofluid in a compact air cooled heat exchanger. Their results say that the overall heat transfer Coefficient and the heat transfer rate of nanofluid have been improved with the enhancement in the nanofluid and air flow Reynolds numbers. The effect of using louvered strip inserts placed in a circular double pipe heat exchanger on the thermal and flow fields utilizing various types of nanofluid was studied by **Mohammed et al.** [15]. They found that the Nusselt number is augmented by around 4 times for the louvered strip insert than that of the smooth tube. The forward louvered strip arrangement can promote the heat transfer by approximately 350-400% at the highest angle of (α=300) and a pitch of 30 mm while the backward arrangement could improve the heat transfer by almost 367-411%.

Salimpour [16] conducted an experimental investigation in order to study the heat transfer characteristics of the temperature dependent property engine-oil inside shell and coiled tube heat exchangers. They found that the coil-side heat transfer coefficients of the coiled tubes with larger pitches are less than those of the ones with smaller pitches; and the effect of pitch on a Nusselt number is more discernible in high temperatures. The forced convection from the outside surfaces of helical coiled tubes was studied by **Moawed** [17]. He found that the average Nusselt number increases with the increase of D/do. Also, Nusselt number increases with the increase of P/do.

Aly [18] has been conducted a numerical study to investigate the heat transfer and pressure drop characteristics of water based Al2O3 nanofluid flowing inside the coiled tube-in tube heat exchangers. His results say that the friction factor increases with increase of curvature ratio and there is no pressure drop with increasingthe nanoparticles volume concentration up to 2%.

Swirl flow devices: These devices produce secondary recirculation on the axial flow for single phase or two-phase flow heat exchanger. Twisted tapes are the metallic strips twisted with some appropriate techniques at preferred shape and dimension, inserted in the flow. The twisted tape inserts are widely used in heat exchangers for heat transfer augmentation because twisted tape inserts increase heat transfer rates with less friction factor penalty of pumping power.

Typical twisted tape is tape having a length equal to the length of exchanger tube. An experimental investigation for a solar water heater with twisted tape inserts having twist pitch to the tube was studied by **Kumar and Prasad** [19]. They found that twisted tapes generate turbulence superimposed with swirls inside the flow tube and consequently result in enhanced heat transfer. Decreasing the values of the twist ratio leads to increasing values of heat transfer rate and the pressure drop.

Esmaeilzadeh et al. [20] investigated the heat transfer and friction factor characteristics of γ-Al2O3 water nanofluid through a circular tube with twisted tape inserts with various thicknesses at constant heat flux. They showed that the use of twisted tapes increase friction factor due to larger contact surface and reduction of fluid free flow is a cause's high speed swirl flow. Finally, the convective heat transfer enhancement outweighs the effect of the friction factor increase, leading enhanced thermal performance.

Eiamsa-ard et al. [21] studied the heat transfer enhancement attributed to helically twisted tapes (HTTs). They observed that the heat transfer rate and friction factor increase as the tape, twist ratio and helical pitch ratio decrease, while the thermal performance shows opposite trend. Experimental investigation of heat transfer, friction factor and thermal performance of solar water heater system fitted with helical and Left–Right twist has been performed by **Jai Sankar et al.** [22]. They showed that the helical twisted tape induces swirl flow inside the riser tubes unidirectional over the length. But, in Left–Right system the swirl flow is bidirectional which increases the heat transfer and pressure drop when compared to the helical system. The effects of the twisted tapes consisting off-center wings and alternate-axes (WT-A) on thermo-hydraulic properties in a round tube, were investigated by **Eiamsa-art et al.** [23]. They showed that the combined actions of the wing and alternate axis in the WTA resulted in a better fluid mixing and thus heat transfer enhancement compared to those induced by wing alone (WT) or alternate axis alone(T-A). Their results also revealed that Nusselt number increased with the increasing angle of attack. **Ghadirija- farbeigloo et al.** [24] studied the effect of a perforated louvered twisted tape on the heat transfer coefficient and the friction factor for an absorber tube of a solar parabolic trough collector. They observed that the high Nusselt number and friction factor for louvered twisted tape with respect to plain tube.

Murugesan et al. [25] studied the effect of V-cut twisted tape insert on heat transfer, friction factor and thermal performance factor characteristics in a circular tube. They found that the V-cut twisted tape Offered a higher heat transfer rate, friction factor and also thermal performance factor compared to the plain twisted tape. In addition, the influence of the depth ratio was more dominant than that of the width ratio for all the Reynolds number. The effects of twisted tapes with alternate-axes and wings on heat transfer, flow friction and thermal performance characteristics in a round tube were investigated by **Wongcharee and Eiamsa-ard** [26]. They concluded that the maximum thermal performance factor of 1.42 is found with the use of twisted tape with trapezoidal wings (T-Tra) at wing-chord ratio (dB/W) of 0.3 and a Reynolds number of 5500, where the heat transfer rate and friction factor, respectively increase to 2.84 and 8.02 times of those in the plain tube.

CONCLUSION

In this paper an effort has been made to present a critical review on passive methods which are used in order to enhance the heat transfer performance. Insertion of perforated twisted tapes inserts enhance the convective heat transfer by making swirl into the fluid motion and disturbing the boundary layer at the tube surface due to repeated changes in the surface geometry. The examination was done in perforated twisted tape insert either in thermal analyses, flow visualization, in heat exchangers, etc... The comprehensive study had been done on heat transfer in heat exchanger using various geometries of twisted tape inserts. That is to say such devices induce turbulence and vortex motion (swirl flow) which produces a thinner boundary layer and consequently results in a better heat transfer coefficient and higher Nusselt number due to the changes in the twisted tape geometry. However, the pressure drop inside the tube will be increased by introducing the twisted- tape insert.

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