

A REVIEW OF PASSIVE TECHNIQUE USED FOR HEAT TRANSFER ENHANCEMENT IN HEAT EXCHANGER

Ravindra M.Ghogare¹, Vijay G.Gore², A.S.Shaikh³

¹Technical Assistant, Dept. of Mechanical Engineering, NDMVPS's COE, Nashik-13, Maharashtra, India

^{2,3}Assistant Professor, Dept. of Mechanical Engineering, P.R.Pote(Patil)COE Amravati, Maharashtra, India

Abstract - Enhancement in heat transfer rate can be done by numerous method in various heat exchangers. Heat exchangers may be chemical reactor, refrigeration system or air conditioning systems. So many techniques have been already investigated to improve heat transfer rate with reduced cost and size. One of the most important technique is Passive heat transfer technique. These technique gives best result for thermal performance. This paper reviews experimental and numerical works taken by the researchers on this technique since 2004, such as twisted tape, wire coil, swirl flow generator, etc... to improve the thermal performance of heat exchanger. The author found that number of developed twisted tape inserts are popular researched and are used to strengthen the heat transfer of specific heat exchanger equipment. Twisted tape inserts are more useful laminar flow than turbulent flow. Also the other technique involving ribs, conical nozzle and conical ring are more efficient for turbulent flow than laminar flow.

Key Words: Heat transfer enhancement, Passive method, Inserts, Laminar & Turbulent flow

1. INTRODUCTION

Heat exchangers are mostly used devices in many areas of the industries, such as process industries, heating and cooling in evaporators, thermal power plants, refrigeration and air-conditioning equipment's, radiators for space vehicles, automobiles, etc. Increase in Heat Exchangers performance can lead to more economical design of the heat exchanger which can help to make energy, material & cost savings related to a heat exchange process. The need to increase the thermal performance of heat exchangers, there by effecting energy, material & cost savings have led to development & use of many techniques termed as Heat transfer augmentation. These techniques are also referred to call as Heat transfer Enhancement or Intensification. Augmentation techniques increase convective heat transfer by reducing the thermal resistance in a heat exchanger.

In many literature gap shows the experimentation on perforated twisted insert like in experimental analysis of heat transfer characteristics using inserts in tubes. Heat transfer enhancement techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. Heat transfer augmentation techniques refer to different methods used to increase these techniques and broadly divided in two

groups, passive and active. Active techniques involve some external power input for the enhancement of heat transfer. Passive heat transfer augmentation method does not use any external power input. One of the ways to enhance heat transfer performance in passive method is to increase the effective surface area and residence time of the heat transfer fluid.

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[1].

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]

2.3 Compound 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.

2.4 NANOMATERIAL

The nanotechnology is new, but it is an existence of the functional devices and structure of nanosized devices are not new in this world. In 1905, experimental data on the diffusion theory showed that the molecule has nanometer diameter, which is considered as the notable landmark in the scientific history of nanotechnology. In 29 December 1959: Visionary statement by Prof. R.P. Feynman, "There is enough space at the bottom". A carbon nanotube is a tube shaped material, made of carbon, having a diameter measuring on the nanometer scale. Carbon nanotubes are Allotropes of carbon with a cylindrical nanostructure. The cylindrical carbon molecules have unusual properties which are valuable for nanotechnology. In particular owing to their extraordinary thermal conductivity and mechanical and electrical properties carbon nanotubes find application as additives to various structural materials. [3]

2.4.1 Need of Nanofluids

a) High specific surface area, therefore more heat transfer surface between particles and fluids.

b) High dispersion stability with motion of particles.

c) Reduces pumping power as compare to the pure liquid to achieve the better heat transfer enhancement.

d) Reduces particle clogging as compare to

Conventional slurries and hence promoting the system miniaturization.

e) Nanofluids are most reliable for continuous heating and cooling systems.

f) With nano size particles, fluid is considered as integral fluid.

As per the heat transfer point of view, the most important challenge faced by the researcher is to increase the heat flux and simultaneously reduce the size of the heat exchanger for the efficient applications in various fields.

Although there are hundreds of passive methods to enhance the heat transfer performance, the following nine are most popular used in different aspects: [4]

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:








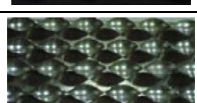


These devices direct and improve the flow of liquid to boiling surfaces and from condensing surfaces. Examples include wicking or grooved surfaces.



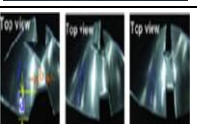
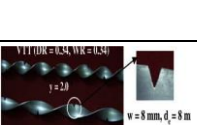
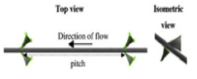
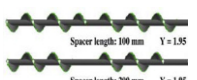
Additives for liquids:

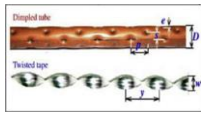
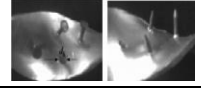


This technique involves the addition of solid particles, soluble trace additives and gas bubbles added to the liquids to reduce the drag resistance in case of single phase flows. In case of billing systems, trace additives are added to reduce the surface tension of the liquids.

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).

Various Geometric views of Twisted Tape		
Geometric views	Name	Reference
	Twisted tape with various widths	[22]
	Typical twisted tape	[23]
	Left and right twist tape with rod and space	[24,25]
	Jagged twisted tape	[26]
	Short-length twisted tape	[27]
	Peripherally-cut twisted tape with an alternate axis.	[22]
	Twisted tape with alternate axis	[28]
	Multiple twisted tape	[29]
	Twisted tape with center wing	[30]
	Twisted tape with trapezoid-cut	[31]

Various Geometric views of Twisted Tape		
Geometric views	Name	Reference
	Left-right twisted tapes	[32]
	Twisted tape with various twist ratios	[33]
	Twisted tapes with alternate-axes and triangular, rectangular and trapezoidal wings	[34]
	V-cut twisted tape insert	[20]
	Butter fly inserts	[26]
	Helical screw tape with various spacer length	[35]

	Dimpled tube fitted with twisted tape	[36]
	Twisted tape consisting wire nails	[37]
	Wire coil in pipe	[38]
	Twisted-tape with oblique teeth	[26]

WORK CARRIED OUT

S.S.Giri, V.M.Kriplani, [5] They did the review of heat Transfer Characteristics using inserts in Tubes. The overall conclusions which they found during the study the twisted type inserts 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, Dr. Pradeep Kumar Jhinge [6] 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 et al. [7] 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 by 12% to 29% in comparison with the single tape at the twist ratios from 3.0 to 5.0 by generating strongly dual swirling flows inside the test tube. Depending on the flow conditions and twist ratio γ , the increases in heat transfer rate over the plain tube are about 146%, 135% and 128% for γ 3.0, 4.0 and 5.0, 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. [8]. The Nusselt numbers increase by 10% to 170% 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 [9] studied the overall heat transfer coefficient of water based iron oxide nanofluid 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. [10]. 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 ($\alpha=300$) and a pitch of 30 mm while the backward arrangement could improve the heat transfer by almost 367-411%.

Coiled tubes: Coiled tubes are well suitable for more compact heat exchangers. These methods produce secondary flows which support higher rates of heat transfer. Salimpour [11] 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 Moawad [12]. He found that the average Nusselt number increases with the increase of D/d_o . Also, Nusselt number increases with the increase of P/d_o . Aly [13] 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 increasing the 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 [14]. 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. Esmailzadeh et al. [15] 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 freeflow 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. [16] 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. [17]. 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 thermohydraulic properties in a round tube, were investigated by Eiamsa-ard et al. [18]. 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-farbigloo et al. [19] 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. [34] studied the effect of Vcut 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 [21]. 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 swirl flow devices or metallic 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. In most of the review, nanofluid are not used for examining the heat transfer rate in the heat exchanging device. 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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