PAPER ID –MP07

HEAT TRANSFER ENHANCEMENT THROUGH SWIRL FLOW DEVICES

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***Abstract*— This survey suggests a broad review of the various heat transfer enhancement techniques caused due to swirl flow has various applications in the area related to engineering field such as chemical and mechanical mixing and separation devices, turbo machinery, chemical reactors, combustion chambers. To enhance the heat and mass transfer, there is a need of the better utilization of swirl flow. The swirl flow can be generated by various techniques either by active or passive. Passive techniques, where inserts are used in the flow passage to increase the heat transfer rate, are advantageous compared with active techniques, because the insert manufacturing process is simple and these techniques can be easily employed in an existing heat exchanger. Twisted-tape is one of the most important members of enhancement techniques, which employed extensively in heat exchangers. Twisted tapes are the metallic strips twisted with some suitable techniques with desired shape and dimension, inserted in the flow. This paper demonstrates the various studies heat transfer through swirl flow devices.**

***Keywords*— heat transfer, swirl flow, enhancement, active and passive devices**

I. INTRODUCTION

The process of improving the performance of a heat transfer system or increase in heat transfer coefficient is referred to as heat transfer augmentation or enhancement. This leads to reduce size and cost of heat exchanger. An increase in heat transfer coefficient generally leads to additional advantage of reducing temperature driving force, which increases second law efficiency and decreases entropy generation. As far as heat transfer enhancement in heat exchanger is concerned, the prime aim is to increase the heat transfer coefficient. For that purpose it is needed to increase the turbulence level. So more is the turbulence, more will be the heat diffusion causing augmentation in heat transfer rate. Heat transfer enhancement at heat exchangers maybe achieved by numerous techniques, and these techniques can be classified into three groups: passive, active and compound techniques.

In the active techniques, which requires extra external power, for example mechanical aids, surface fluid vibration, use of electrostatic fields i.e. heat transfer is improved by giving additional flow energy into the fluid. In the passive techniques, however, this improvement is acquired without giving any extra flow energy. Such as twisted tapes, helical screw tape inserts, rough surfaces, extended surfaces, additives for liquid and gases. Passive methods are found more inexpensive as compared to other group. In the compound techniques, two or more of the active or passive techniques may be utilized simultaneously to produce an enhancement that is much higher than the techniques operating separately.

Twisted tape is one of the most important members useful in laminar flow from this group. Twisted Tape Twisted tape inserts increases the heat transfer coefficients with relatively small increase in the pressure drop.

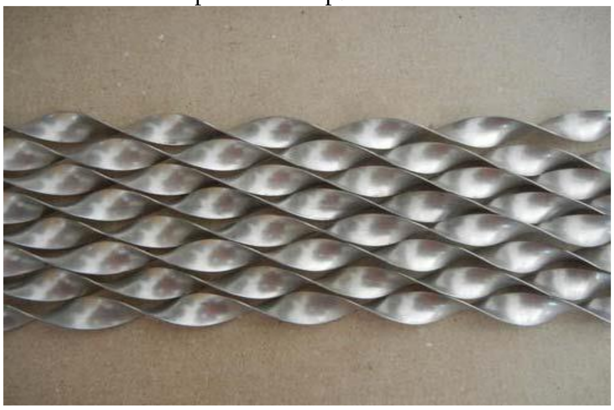

Fig.1: Twisted Tape

They are known to be one of the earliest swirl flow devices employed in the single phase heat transfer processes. Because of the design and application convenience they have been widely used over decades to generate the swirl flow in the fluid. Size of the new heat exchanger can be reduced significantly by using twisted tapes in the new heat exchanger for a specified heat load.

Thus it provides an economic advantage over the fixed cost of the equipment. Twisted tapes can be also used for retrofitting purpose. It can increase the heat duties of the existing shell and tube heat exchangers. Twisted tapes with multi-tube bundles are easy to fit and remove, thus enables tube side cleaning in fouling situations. Inserts such as twisted tape, wire coils, ribs and dimples mainly obstruct the flow and separate the primary flow from the secondary flows. This causes the enhancement of the heat transfer in the tube flow. Inserts reduce the effective flow area thereby increasing the flow velocity. This also leads to increase in the pressure drop and in some cases causes' significant secondary flow. Secondary flow creates swirl and the mixing of the fluid elements and hence enhances the temperature gradient, which ultimately leads to a high heat transfer coefficient.

Fig.2: Insert model

In general, swirl flow generators are placed in the flow passage to augment the heat transfer rate, and this reduces the hydraulic diameter of the flow passage. Heat transfer enhancement in a tube flow by inserts such as twisted tapes, screw tape is mainly due to flow blockage, partitioning of the flow and secondary flow. Flow blockage increases the pressure drop and leads to increased viscous effects because of a reduced free flow area. Blockage also increases the flow velocity and in some situations leads to a significant secondary flow. Secondary flow further provides a better thermal contact between the surface and the fluid because secondary flow creates swirl and the resulting mixing of fluid improves the temperature gradient, which ultimately leads to a high heat transfer coefficient. Fig. 2 shows a typical configuration of twisted tape which is used commonly.

II. Literature Review

Shaha and Dutta- reported experimental dataon twisted tape generated laminar swirl flow friction factor and Nussult number for a large Prandle number ($205<Pr< 518$) and observed that on the basis of constant pumping power short length twisted tape is good choice because in this case swirl generated by the twisted tape decays slowly down streams which increases the heat transfer coefficient with minimum pressure drop as compared to full length twisted tape.

Manglik and Bergles- considered twisted tape with twist ratio (3, 4.5 and 6.0) using water ($3.5<Pr<6.5$) and proposed correlation for Nussult number and friction factor and reported physical description and enhancement mechanism.

Loknath- reported experimental data on water ($240<Re<2300$, $2.6<Pr<5.6$) of laminar flow through horizontal tube under uniform heat flux condition and fitted with half-length twisted tape. He found that on the basis of unit pumping power and unit pressure drop half-length twisted tape is more efficient than full length tape.

Shaha and Chakraborty- found that laminar flow of water ($145<Re<1480$, $4.5<Pr<5.5$, tape ratio $1.92<y<5.0$) and pressure drop characteristics in a circular tube fitted with regularly spaced, there is drastic reduction in pressure drop corresponding reduction in heat transfer. Thus it appears that on basis of constant pumping power a large number of turn may yield improved thermo hydraulic performance compared with single turn on twisted tape.

Royds- reported that A tube inserted with twisted tape performs better than plain tube and twisted tape with tight twist ratio provides better heat transfer at a cost of increase in pressure drop for low Prandle number fluid. This is due to the small thickness of thermal boundary layer for low Pradle number fluid and tighter twist ratio disturb entire thermal boundary layer thereby increasing heat transfer with increase in pressure drop.

III. Heat transfer enhancement through swirl flow devices

The concept of Heat transfer techniques in heat exchange using the thermal energy has many applications in several engineering and industrial applications. Accurate analysis of heat transfer rate and pressure drop estimations makes the design procedure of heat exchanger complicated one. Making the equipment compact and achieving high heat transfer rate are main obstacles in designing heat exchanger. Techniques that are used to enhance convective heat transfer by reducing the thermal resistance in a heat exchanger are referred to as the Heat Transfer Augmentation which leads to reduce the cost and size of the heat exchanger. Heat transfer augmentation technology has been developed and widely employed to heat exchanger application such as automotive industries, chemical industries, refrigeration, thermal power plant, process industries, electronics devices, air conditioning equipments etc. These techniques are listed as:

A. Active techniques.
B. Passive techniques.
C. Compound techniques.

Heat transfer enhancement is the process of increasing the effectiveness of heat exchangers. This can be achieved when the heat transfer power of a given device is increased or when the pressure losses generated by the device are reduced. A variety of techniques can be applied to this effect, including generating strong secondary flows or increasing boundary layer turbulence. There are several available options for enhancing heat transfer. The enhancement can be achieved by increasing the surface area for convection or/and increasing the convection coefficient. For example, the surface roughness can be used to increase in order to enhance turbulence. This can be achieved through machining or other kinds of insertions like coil-spring wire. The insert provides a helical roughness in contact with the surface. The convection coefficient may also be increased by an insert of a twisted tape that consists in a periodical twist through 360 degrees. Tangential inserts optimize the velocity of the flow near the tube wall, while providing a bigger heat transfer area. While, increased area and convection coefficient can be achieved by applying spiral fin or ribs inserts. Other aspects such pressure drop must be taken into consideration in order to meet the fan or pump power constraints.

IV. Application of heat transfer through swirl flow devices

Heat exchanger as equipment to facilitate the convective heat transfer of fluid inside tubes is frequently utilized in many industrial applications, such as chemical engineering process, heat recovery, air conditioning and refrigeration systems, power plant and radiators for automobiles. Heat transfer related processes are present in the equipment used and produced by all the major industrial sectors. A few real life applications where heat transfer plays an important role are:

a) Automotive industry (radiator, cooling circuits, lamps)
b) Aerospace (de-icing system, cooling systems)
c) Chemical Process Industry (heat recovery systems, heat exchangers)
d) Energy (kilns, boiler, cross flow heat exchangers, solar panels)
e) Home appliance (ovens, household heaters)

V. CONCLUSION

From this review, various ways of enhancing the heat transfer rate by generating the swirl flow either by active or passive method can be observed. It is seen that in most of the cases, enhancement in active method is more pronounced than passive method but simultaneously friction factor is also increased. The combined use of full-length twisted-tape and transverse ribs enhances the thermo-hydraulic performance of the square and rectangular ducts compared to the use of only twisted-tape or only transverse ribs for laminar flow. The short-length twisted tape in square and rectangular ducts performs worse than the full-length twisted tape. However, regularly spaced twisted-tapes perform significantly better than the full-length twisted tapes.

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