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Design And Other Factor Involved In The Fabrication Of Heat Exchanger Experimentation Setup.

Dharmesh A. Agrawal[1], Aswin M. Saigopal[2], Mannan P. Tewar[3], Ankit C. Shukla[4]

[1]*Asst. Professor, Department of Mechanical Engineering,*
JD College Of Engineering & Management, Nagpur-441501, Maharashtra.

[2, 3,4] *UG Scholars, Department of Mechanical Engineering,*
JD College Of Engineering & Management, Nagpur-441501, Maharashtra.

ABSTRACT:- *This review paper deals with the use of modified twisted tape inserts as Passive Heat transfer Augmentation device. Effect of Reduced width twisted tape (RWTT), Baffled Reduced width twisted tape (BRWTT1) & Baffled Reduced width twisted tape with holes (BRWTT2) on heat transfer and friction factor for heating of water for Reynolds number range 2500-30000, was studied experimentally in a double pipe heat exchanger. Based on constant flow rate, the heat transfer coefficient were found to be 1.18-3.66, 2.61-7.07 & 3.58-8.08 times the smooth tube values for RWTT, BRWTT1 & BRWTT2 respectively. The friction factor values were found to be 3.23-5.96, 7.79-11.23 & 8.86-14.44 times the smooth tube values for RWTT BRWTT1 & BRWTT2 respectively. Based on constant pumping power, the heat transfer coefficient values were found to be 0.88-1.62, 1.59-3.70 & 2.12-4.49 times the smooth tube values for RWTT, BRWTT1 & BRWTT2 respectively. Based on the increase in Heat transfer coefficient, Performance evaluation criteria R1 & R3, it was concluded that Baffled Reduced width twisted tape & Baffled Reduced width twisted tape with holes performs much better than the Reduced width twisted tapes(RWTT) of the same twist ratio. Whenever inserts are used for the heat transfer enhancement, along with the increase in the heat transfer rate, the pressure drop also increases. This increase in pressure drop increases the pumping cost. Thus it's highly essential not to allow the pressure drop to go beyond a specified value while going for heat transfer enhancement techniques using inserts.*

1. INTRODUCTION

Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment. Heat exchangers are used in different processes ranging from conversion, utilization & recovery of thermal energy in various industrial, commercial & domestic applications. Some common examples include steam generation & condensation in power & cogeneration plants; sensible heating & cooling in thermal processing of chemical, pharmaceutical & agricultural products; fluid heating in manufacturing & waste heat recovery etc. Increase in Heat exchanger's performance can lead to more economical design of heat exchanger which can help to make energy, material & cost savings related to a heat exchange process. Furthermore, as a heat exchanger becomes older, the resistance to heat transfer increases owing to fouling or scaling. These problems are more common for heat exchangers used in marine applications and in chemical industries. In some specific applications, such as heat exchangers dealing with fluids of low thermal conductivity (gases and oils) anddesalination plants, there is a need to increase the heat transfer rate. The heat transfer rate can be improved by introducing a disturbance in the fluid flow (breaking the viscous and thermal boundary layers), but in the process pumping power may increase significantly and ultimately the pumping cost becomes high. Therefore, to achieve a desired heat transfer rate in an existing heat exchanger at an economic pumping power, several techniques have been proposed in recent years and are discussed in the following sections.

2. IMPORTANT DEFINITIONS

In this section a few important terms commonly used in heat transfer augmentation work are defined.

- Thermohydraulic performance For a particular Reynolds number, the thermohydraulic performance of an insert is said to be good if the heat transfer coefficient increases significantly with a minimum increase in friction factor. Thermohydraulic performance estimation is generally used to compare the performance of different inserts such as twisted tape, wire coil, etc., under a particular fluid flow condition.

- Overall enhancement ratio The overall enhancement ratio is defined as the ratio of the heat transfer enhancement ratio to the friction factor ratio. This parameter is also used to compare different passive techniques and enables a comparison of two different methods for the same pressure drop.

- Nusselt number The Nusselt number is a measure of the convective heat transfer occurring at the surface and is defined as hd/k, where h is the convective heat transfer coefficient, d is the diameter of the tube and k is the thermal conductivity.

- Prandtl number The Prandtl number is defined as the ratio of the molecular diffusivity of momentum to the molecular diffusivity of heat, n=a.

- Pitch Pitch is defined as the distance between two points that are on the same plane, measured parallel to the axis of a twisted tape.

- Twist ratio, y The twist ratio is defined as the ratio of pitch to inside diameter of the tube y ¼ H/di, where H is the twist pitch length and d is the inside diameter of the tube.

3. HEAT TRANSFER AUGMENTATION

In general, some kind of inserts 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, wire coils, ribs and dimples is mainly due to flowblockage, 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.

Heat transfer enhancement or augmentation techniques refer to the improvement of thermohydraulic performance of heat exchangers. Existing enhancement techniques can be broadly classified into three different categories:
1. Passive Techniques
2. Active Techniques
3. Compound Techniques.

1. **PASSIVE TECHNIQUES:** These techniques generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. They promote higher heat transfer coefficients by disturbing or altering the existing flow behavior (except for extended surfaces) which also leads to increase in the pressure drop. In case of extended surfaces, effective heat transfer area on the side of the extended surface is increased. Passive techniques hold the advantage over the active techniques as they do not require any direct input of external power. Heat transfer augmentation by these techniques can be achieved by using:

 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 a 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 5 (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 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.

2. ACTIVE TECHNIQUES: These techniques are more complex from the use and design point of view as the method requires some external power input to cause the desired flow modification and improvement in the rate of heat transfer. It finds limited application because of the need of external power in many practical applications. In comparison to the passive techniques, these techniques have not shown much potential as it is difficult to provide external power input in many cases. Various active techniques are as follows:

 Mechanical Aids: Examples of the mechanical aids include rotating tube exchangers and scrapped surface heat and mass exchangers. These devices stir the fluid by mechanical means or by rotating the surface.

 Surface vibration: They have been used primarily in single phase flows. A low or high frequency is applied to facilitate the surface vibrations which results in higher convective heat transfer coefficients.

 Fluid vibration: Instead of applying vibrations to the surface, pulsations are created in the fluid itself. This kind of vibration enhancement technique is employed for single phase flows.

 Electrostatic fields: Electrostatic field like electric or magnetic fields or a combination of the two from DC or AC sources is applied in heat exchanger systems which induces greater bulk mixing, force convection or electromagnetic pumping to enhance heat transfer. This technique is applicable in heat transfer process involving dielectric fluids. 6

 Injection: In this technique, same or other fluid is injected into the main bulk fluid through a porous heat transfer interface or upstream of the heat transfer section. This technique is used for single phase heat transfer process.

 Suction: This technique is used for both two phase heat transfer and single phase heat transfer process. Two phase nucleate boiling involves the vapour removal through a porous heated surface whereas in single phase flows fluid is withdrawn through the porous heated surface.

 Jet impingement: This technique is applicable for both two phase and single phase heat transfer processes. In this method, fluid is heated or cooled perpendicularly or obliquely to the heat transfer surface.

3. COMPOUND TECHNIQUES: A compound augmentation technique is the one where more than one of the above mentioned techniques is used in combination with the purpose of further improving the thermo-hydraulic performance of a heat exchanger.

About the inserts...

The insert used for the experiment are twisted aluminium tapered clips and stainless steel twisted tapes. While much literature can be found about passive heat transfer augmentation using twisted tapes as mentioned earlier, tapered aluminium clips are a new kind of insert where no such experiments have been done thus giving us ample room for experimental studies. The present work deals with finding the friction factor and the heat transfer coefficient for the TATC's with various twist ratios and comparing those results with that of twisted tapes of varying twists and finally finding the heat transfer enhancement as compared to a smooth tube. The tapered aluminium clip was chosen for its wide availability and low cost. These tapes are used for plywood partitioning and is available in any plywood shop. Each tapered aluminium clip originally measured 12ft long and 20mm wide. While the twisted tapes were 20mm wide.

4. FABRICATION

The aluminium tapered clips(length 12ft) were first cut into 3 equal sizes .Holes were drilled at both ends of each tape so that the two ends could be clamped. Lathe was used to give the tapes the desired twist. One end was kept fixed on the tool part of the athe while the other end was given a slow rotatory motion by holding it on the chuck side, while the tape was kept under tension by applying a mild pressure on the tool part side, to avoid its distortion, thus creating the required twist in the tapes. Three tapes with varying twist ratios were fabricated (Y=8.73,Y=5.23,Y=3.27) as shown in fig 3.1 to fig 3.4. The end portions of the fabricated tapes were cut and holes drilled for joining the two tapes. Each twisted tapered clip measured 1.15m.Three tapes with the same twist ratio and twist in the same direction were joined, thus giving a total length of 3.45m, sufficient for the double pipe heat exchanger used for the experimental study.

5. PERFORMANCE EVALUATION CRITERIA

In most practical applications of enhancement techniques, the following performance objectives, along with a set of operating constraints and conditions, are usually considered for optimizing the use of a heat exchanger:

1. Increase the heat duty of an existing heat exchanger without altering the pumping power (or pressure drop) or flow rate requirements.
2. Reduce the approach temperature difference between the two heat-exchanging fluid streams for a specified heat load and size of exchanger.
3. Reduce the size or heat transfer surface area requirements for a specified heat duty and pressure drop or pumping power.
4. Reduce the process stream's pumping power requirements for a given heat load and exchanger surface area.

It may be noted that objective 1 accounts for increase in heat transfer rate, objective 2 and 4 yield savings in operating (or energy) costs, and objective 3 leads to material savings and reduced capital costs.

6. ROUGH SURFACES:

Small scale roughness or surface modification promotes turbulence in the flow field near the wall region by disturbing the viscous laminar sub layer. This disturbance causes higher momentum and heart transfer. This small scale roughness has little effect in laminar flows, but is very effective in turbulent single phase flows. Nowadays instead of natural roughness, artificial and structured roughness is used in most applications. Structured roughness can be integral to the surface. Wire coil type inserts can be inserted inside the tube to provide protuberances in the surface. In case of structured roughness almost an infinite number of geometric variations can be produced by machining, casting, or welding. Corrugated tubes,a type of 2-D roughnes heat transfer in single phase flows both inside tubes and outside tubes.

7. SWIRL FLOW DEVICES:

Swirl flow devices causes swirl flow or secondary flow in the fluid .A variety of devices can be employed to cause this effect which includes tube inserts, altered tube flow arrangements, and duct geometry modifications. Dimples, ribs, helically twisted tubes are examples of duct geometry modifications. Tube inserts include twisted-tape inserts, helical strip or cored screw–type inserts and wire coils. Periodic tangential fluid injection is type of altered tube flow arrangement. Among the swirl flow devices, twisted- tape inserts had been very popular owing to their better thermal hydraulic performance in single phase, boiling and condensation forced convection, as well as design and application issues. Fig 2.5 shows a typical configuration of twisted tape which is used commonly.

Fig. 7.1

Twisted tape inserts increases the heat transfer coefficients with relatively small increase in the pressure drop. 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.

8. COILED TUBES:

A coiled or curved tube, causes secondary flows due to continuous change in the bulk velocity vector at the curve surface of the duct. Coiled tubes are used in domestic water heaters, chemical process reactors, solar heating system, industrial & marine boilers, kidney dialysis devices and blood oxygenators. Secondary flows are generated due the centrifugal force on the fluid motion, induced because of the curvature of the coils. This curvature induced flow characteristics of the coiled tubes depends on the geometrical attributes like radius of curvature, helical number etc.

Fig. 8.1

9. TWISTED TAPE IN LAMINAR FLOW:

Twisted tape increases the heat transfer coefficient with an increase in the pressure drop. Different configurations of twisted tapes, like full-length twisted tape, short length twisted tape, full length twisted tape with varying pitch, reduced width twisted tape and regularly spaced twisted tape have been studied widely by many researchers. Use of twisted tapes for augmentation can be dated back to as early as up to the end of nineteenth century. One of the early researches on heat transfer enhancement by means of twisted tapes was carried out by Whitman, [I]. Saha et al. [II] concluded that the short length twisted tapes perform better than the full length twisted tapes because the swirl generated by the short length twisted tape decays slowly downstream which increases the heat transfer coefficient with minimum pressure drop. Regularly spaced twisted tape decreases the friction factor and reduces the heat transfer coefficient but the reduction in heat transfer coefficient is not much because the spacing of twisted tape disturbs the swirl flow. Date and Singham [9] studied the heat transfer and friction factor characteristics of fully developed laminar flows in tube containing twisted tape inserts. Laminar viscous liquid flow with uniform heat flow boundary condition for high prandtl number (appro.730) was investigated by Hong and Bergles [III]. Tariq et al [IV] found that twisted tape in a laminar flow was more efficient than internally threaded tube. Manglik and Bergles [V] developed the correlation between friction factor and Nusselt number for laminar flows including the swirl parameter.

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