Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 04, April -2018

EXPERIMENTAL ANALYSIS OF HEAT TRANSFER AUGMENTATION USING COMPOUND METHODOLOGY

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ASTRACT:-*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. Passive techniques, where inserts are used in the flow passage to augment 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. In design of compact heat exchangers, passive techniques of heat transfer augmentation can play an important role if a proper passive insert configuration can be selected,according to the heat exchanger working condition (both flow and heat transfer conditions). In the past decade, several studies on the passive techniques of heat transfer augmentation have been reported.The present paper is a review of the passive enhancement techniques used in the recent past.*

INTRODUCTION [1,1]

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. 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. 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) and desalination 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.

IMPORTANT DEFINITIONS [1,2]

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

1. 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.

2. **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.

3. **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.

4. **Prandtl number**

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

5. **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.

6. **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.

DIFFERENT METHODS OF HEAT TRANSFERENHANCEMENT

Generally, heat transfer enhancement methods areclassified in three broad categories:

Active method: This method involves some external power input for the enhancement of heat transfer. some examples of active methods includeinduced pulsation by cams and reciprocatingplungers, the use of a magnetic field to disturb theseeded light particles in a flowing stream, etc.

Passive method: These methods generally usesurface or geometrical modifications to the flow channel by incorporating inserts or additionaldevices. For example, use of inserts, use of roughsurfaces etc.

Compound method: Combination of above twoMethods

Twisted tapes are the metallic strips twisted withsome suitable techniques with desired shape and dimension, inserted in the flow. Following are the main categories of twisted tape which are analyzed.

Full length twisted tape: These tapes have length equal to length of test section.

Varying length twisted tape: These are distinguished from first category with regards that they are not having the length equal to length of test section, but half length, ¾ th length, ¼ th length of section etc.

Regularly spaced twisted tapes: These are shortlength tapes of different pitches spaced by connecting together.

Tape with attached baffles: Baffles are attached to the twisted tape at some intervals so as to achieve more augmentation.

Slotted tapes and tapes with holes: Slots and holes of suitable dimensions made in the twisted tape so as to create more turbulence.

Tapes with different surface modifications: Someinsulating material is provided to tapes so that fin effect can be avoided. In some cases dimpled surfaced material used for tape fabrication.

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 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. Twisted tape generates a spiral flow along the tube length. Performance and cost are the two major factors that play an important role in the selection of any passive technique for the augmentation of heat transfer. Generally, twisted tape and wire coil inserts are more widely applied and have been preferred in the recent past to other methods, probably because techniques such as the extended surface insert suffer from a relatively high cost and a mesh insert suffers from a high pressure drop and fouling problems.

PRESENT EXPERIMENTAL WORK

The experimental study on passive heat transfer augmentation using twisted aluminium tapered clips(TATC) and twisted tapes(TT) were carried on in a double pipe heat exchanger having the
specifications as listed below:- specifications--
inner pipe ID = 22mm
inner pipe OD=25mm
outer pipe ID =53mm
outer pipe OD =61mm
material of construction= Cu.
Water at room temperature was allowed to flow through the inner pipe while hot water (set point 65oC) flowed through the annulus side in the counter current direction.

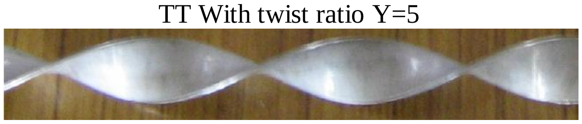
ABOUT THE INSERTS

The insert used for the experiment are twisted aluminium tapered clips and stainless steel twistedtapes. While much literature can be found about passive heat transfer augmentation using twistedtapes as mentioned earlier, tapered aluminium clips are a new kind of insert where no suchexperiments 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 theTATC's with various twist ratios and comparing those results with that of twisted tapes ofvarying 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 areused for plywood partitioning and is available in any plywood shop. Each tapered aluminiumclip originally measured 12ft long and 20mm wide. While the twisted tapes were 20mm wide.

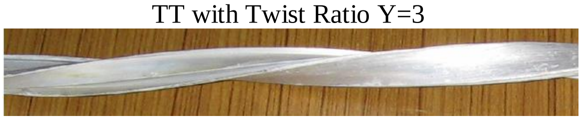
FABRICATION

The aluminium tapered clips(length 12ft) were first cut into 3 equal sizes .Holes were drilled atboth ends of each tape so that the two ends could be clamped. Lathe was used to give the tapesthe desired twist. One end was kept fixed on the tool part of the lathe while the other end wasgiven a slow rotatory motion by holding it on the chuck side, while the tape was kept undertension by applying a mild pressure on the tool part side, to avoid its distortion, thus creating therequired twist in the tapes. Three tapes with varying twist ratios were fabricated(Y=3,Y=5,Y=7) as shown in 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 1m, sufficient for the double pipe heat exchanger used for the experimental study. The cross sectional view of the Al Taper Clip is shown in fig.

TT With twist ratio Y=5



TT with Twist Ratio Y=3



TT with wist Ratio Y=7

PROCEDURE

1. All the rotameters used were calibrated first.
2. RTD used for measuring the temperatures was calibrated.
3. For friction factor determination
   - The manometer used contained ccl4 as the manometric liquid and a little of bromine crystals was added to it to impart a colour to it. The manometer was first adjusted so that the liquid level in both the limbs were equal.
   - After the manometer had been set, water(at room temperature) was allowed to flow through the inner pipe of the exchanger.
   - The manometer reading was noted for each of the flow rates.The above procedures were followed for each of the inserts used.
   - Standardization of smooth tube:- Before starting the experimental study on heat transfer augmentation using inserts, standardization of the smooth tube (without insert) has to be done so that the % difference between the theoretical frictional factor value and the actual value can be obtained.
4. For heat transfer coefficient determination

   a) Standardization of the smooth tube:-Before starting the experimental study on heat transfer augmentation using inserts,standardization of the smooth tube (without insert) has to be done so that the % differencebetween the theoretical heat transfer coefficient and the actual heat transfer coefficient can beobtained.

   b) Water to be flown throw the annulus side was first heated to a set temperature of 64oC in a constant temperature water bath of capacity 500 lts.

   c) When the set point was attained, the water at room temp was allowed to flow through the inner pipe of the exchanger.

   d) Hot water flowed through the annulus side at a constant flow rate of (1250kg/hr) thus exchanging heat with the cold water on the tube side.

   e) For each of the flow rates of the cold water, the temperatures T1, T2, T3, T4 were noted down only after the temperatures attained a constant value.

   f) The steps (4b-4e) were followed for each of the inserts used.

OBSERVATIONS

TWISTED TAPE IN LAMINAR FLOW

A twisted tape insert mixes the bulk flow well and therefore performs better in a laminar flow than any other insert, because in a laminar flow the thermal resistance is not limited to a thin region. However, twisted tape performancealso depends on the fluid properties such as the Prandtl number. If the Prandtl number is high, say Pr . 30, the twisted tape will not provide good thermohydraulic performance compared with other inserts such as wire coil.On the basis of a constant pumping power, short-lengthtwisted tape is better than full-length twisted tape. In thedesign of a compact heat exchanger for laminar flow,twisted tape can be used effectively to enhance the heattransfer.

TWISTED TAPE IN TURBULENT FLOW

Twisted tape in turbulent flow is effective up to a certain Reynolds number range but not over a wide Reynolds number range. Compared with wire coil, twisted tape is not effective in turbulent flow because it blocks the flow and therefore the pressure drop is large. Hence, the thermohydraulic performance of a twisted tape is not good compared with wire coil in turbulent flow. Therefore, it may be concluded that, for compact heat exchanger design, wire coil is a good choice in turbulent flow. However, a short-length twisted tape yields good thermohydraulic behavior compared with full-length twisted tape in turbulent flow.

WIRE COIL IN LAMINAR FLOW

Wire coil in laminar flow enhances the heat transfer rate significantly. However, the performance depends on the Prandtl number. If the Prandtl number is high, the performance of the wire coil is good because, for a high Prandtl number, the thickness of the thermal boundary layer is small compared with the hydrodynamic boundary layer and the wire coil breaks this boundary layer easily. Therefore, both heat transfer and pressure drop are large.

WIRE COIL IN TURBULENT FLOW

Wire coil enhances the heat transfer in turbulent flow efficiently It performs better in turbulent flow than in laminar flow. The thermohydraulic performance of wire coil is good compared with twisted tape in turbulent flow.

OTHER PASSIVE TECHNIQUES

There are several passive techniques other than twisted tape and wire coil to enhance the heat transfer in a flow, such as ribs, fins, dimples, etc. These techniques are generally more efficient in turbulent flow than in laminar flow.

SL.NO.	m	T1	T2	T3	T4	LMTD	Ui	Rec	hi(exp)	R1
1	0.0163	32.8	49.2	54.7	53.7	11.536	664	1110	994	5.65
2	0.0313	32.6	46.7	55.7	54.3	14.430	801	2132	1336	6.13
3	0.048	32.6	44.6	56 5	4.2	15.960	938	3270	1765	3.22
4	0.063	32.6	43	56.1	54.1	16.955	992	4292	1968	2.46
5	0.077	32.5	42	56.5	54.3	17.903	1041	5245	2171	2.13
6	0.0789	32.5	42.3	56.8	54.6	18.034	1062	5375	2265	2.16
7	0.0927	32.4	41.6	57	54.6	18.593	1130	6315	2598	2.08
8	0.1081	32.4	40.7	57.2	54.7	19.255	1142	7364	2665	1.82
9	0.1357	32.4	39.8	57.7	54.8	20.066	1249	9244	3326	1.82
10	0.1622	32.4	39	57.9	54.9	20.648	1275	11049	3516	1.78
11	0.1901	32.4	38.4	58	54.8	20.969	1338	12950	4044	1.80
12	0.2205	32.4	37.9	58.1	54.8	21.281	1381	15021	4463	1.76
13	0.2471	32.3	37.4	58.2	54.8	21.639	1406	16833	4730	1.70
14	0.2752	32.4	37.1	58.4	54.8	21.845	1451	18747	5285	1.74
15	0.302	32.4	36.8	58.4	54.7	21.948	1484	20573	5750	1.76
16	0.3319	32.5	36.6	58.6	54.7	22.100	1531	22610	6527	1.85
17	0.3431	32.5	36.6	58.6	54.8	22.150	1534	23373	6579	1.82

CONCLUSION

1. The difference in the heat transfer coefficient for the actual and the theoretical values for low Reynolds number (upto 6000) in the smooth tube can be attributed to the natural convection which occurs along with the forced convection. This phenomena is prominent in the case of low Re. In case of higher Re, natural convection is negligible as compared to forced convection.

2. The pressure drop and the heat transfer coefficient increase as the degree of twist in the tapes goes on increasing.

3. For almost the same twist ratio, twisted aluminium taper clips show greater friction factor and heat transfer coefficient than the twisted tapes, because of higher degree of turbulence generated.
4. In a heat exchanger, while the inserts can be used to enhance the heat transfer rate, they also bring in an increase in the pressure drop. When the pressure drop increases, the pumping power cost also increases, thereby increasing the operating cost. Since we have to keep the operating cost to a minimum, there has to be a proper balance between the heat transfer rate and the pressure drop. While there is a need for the heat transfer rate to be increased, the pressure drop can't be allowed to go beyond a certain specified limit. So depending on the requirement, one of the above mentioned inserts can be used for heat transfer augmentation. As per the performance evaluation criteria R1,the taper aluminium twisted tape gives better performance as compared to the twisted tape having the same twist ratio.

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