EFFECT OF EXTERNAL THREADED INSIDE TUBE ON HEAT TRANSFER RATE IN A CONCENTRIC TUBE HEAT EXCHANGER: A CRITICAL REVIEW

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Abstract - *Engineers are continually being asked to improve processes and increase efficiency. These requests may arise as a result of the need to increase process throughout, increase profitability, or accommodate capital limitations. The present paper is a review of one of the passive augmentation techniques used in a concentric tube heat exchanger using inner threaded tube. The performance of counter flow heat exchanger will be studied with inner plain tube and inner threaded tube. Then this enhanced performance due to inner threaded tube will be compared with performance of heat exchanger with inner plain tube and percentage of enhancement will be calculated in different hot fluid temperature input and different mass flow rates of hot as well as cold water. Experimentally, Overall heat transfer enhancement will be studied and also, the experimental results will be validated with CFD simulation (FLUENT SOFTWARE).*

Key Words: **Heat transfer enhancement, passive techniques, threaded tube, Reynolds number, Pressure drop, CFD simulation.**

1. INTRODUCTION :

The economy of any thermal system mainly depends on efficiency of the Heat Exchangers used in it. The efficiency of Heat Exchanger can be raised by using appropriate method of heat transfer enhancement. 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. In heat exchangers the primary focus is to maximize heat transfer rate, reduce exchanger size by increasing Reynolds Number.

How can we improve heat transfer efficiency?

Basically there are different augmentation techniques to increases heat transfer efficiency in heat exchanger. Active, Passive and Compound techniques.

1. Active techniques
2. Passive techniques
3. Compound techniques

1) Active techniques- In this technique applicable some external power to increases the heat transfer rate in heat exchanger. Complexity in this technique is less as passive and compound technique e.g. Mechanical aids, Surface vibration, Fluid vibration, etc.

2) Passive techniques- In this technique change the flow pattern without any external power only by available power in system. This change of flow pattern leads to disturbing thermal boundary layer and pressure drop to enhance the heat transfer rate in heat exchanger e.g. rough surface, Swirl flow, etc.

3) Compound techniques- In This technique application of both active and passive techniques. Compound technique is more complexity which increases the pressure drop e.g. Rough tube with twisted tape, finned tubes in Fluidized bed, etc.

Benefit by augmentation techniques:

i. increase the heat transfer rate.

ii. Increase the Reynolds number,

iii. Reduce the fouling factor by generate threaded profile on inner tube .

iv. Permit closer approach temperature

What to Look for?

The heat exchanger is an important device in almost all of the mechanical industries as in case of process industries it is key element. Thus from long time many researchers in this area are working to improve the performance of these heat exchangers in terms of heat transfer rate, keeping pressure drop in limit. In view of this various active and passive techniques have been used over plain tubes. Threaded tube is a passive technique. The main aim of this study is to compare the performance of plain tube heat exchanger with threaded tube heat exchanger on various aspects to determine its feasibility for use in applications like automobile radiators, air conditioners or similar type of multi pass applications.

What do we need – A threaded profile on inner tube?

Heat Transfer Enhancement Techniques are commonly used nowadays in all Thermal industries, where there is heat transfer in the thermal system. Basically there are different augmentation techniques to increases the heat transfer rate in heat exchanger. Threaded profile on inner tube is a passive techniques which enhance the Reynolds number and produce swirl flow in pipe. The purpose of inserting these swirl flow devices is to improve heat transfer rate by decreasing the thickness of thermal boundary layer, disturbing velocity boundary layer and allowing core fluid to mix with peripheral fluid. This will reduce the size of heat exchanger and improve the effectiveness.

2. LITERATURE REVIEW

1) Ms.Vandita Thantharate, Dr.D.B.Zodpe :

They studied comparison of heat transfer performance of twisted tube and plain tube heat exchangers. They stated the effects of geometrical parameters on the performance of the twisted oval tube. The result reveals that the heat transfer coefficient and friction factor both increase with the increase of axis ratio a/b, while both decrease with the increase of twist pitch length P. In the present work, an experimental study of the heat transfer performance of plain tube and twisted tube for multipass heat exchanger has been carried out and compared with each other.

Analytical study has also been done to get the experimental and Numerical values verified. For determination of pressure drop analytical calculations are done. Tube and Duct type of cross flow heat exchanger was employed. Reynolds number range is from 600 to 7000 covering laminar and turbulent range.

2) Parag S. Desale Nilesh C. Ghuege:

Experimentally studied to investigate the wire coil geometry. The coiled wire used in many of the experiments is fabricated from aluminum by extrusion method in different cross sections like circular, square and equilateral triangular with side length of (a). Few researchers have worked on this dimension of cross section and have defined a ratio a/D, where D is the diameter of coil. The heat transfer augmentation, Pressure drop variation, friction factor and overall thermal performance of a tube inserted with wire coil inserts alone, twisted tape inserts alone and the combined devices between the twisted tape and constant or periodically varying wire coil pitch ratio are studied. They found that the coiled wire insert had a significant effect on the enhancement of heat transfer. However, the friction factor of the tube with the coiled wire insert also increases.

3) A M Mulla, Umesh Jangamashetti, Kiran K:

They studied thermal characteristics for the tube in the shell and tube heat exchanger working with water as working fluid for two different configurations of twisted tape.1)Typical twisted tapes and 2)twisted tape with baffles (TTWB).This process deals with only laminar flow in the tube side; Re varies from 200 to 600. Experiment carried out by maintaining the constant tube wall temperature with tube flow rate and shell flow constant. Twisted tapes used in this experiment have 2.2 twist ratio, and for baffled twisted tape, baffles are positioned at equal intervals, at an angle 450 with normal axis of twisted tape.

The heat transfer and pressure drop in case of twisted tape and twisted tape with baffles are found to increase by 110 to 120% and 130 to 140% respectively than that of plain tube. Nusselt number for same flow rate in tubes with TTWB is increased compared to that of plain tubes as well as tubes with typical twisted tapes. Heat transfer coefficient for tubes fitted with TTWB is highest compared to that of plain tubes as well as tubes with typical twisted tapes for same Re and flow rate. Pressure drop value is found higher in TTWB compared to that of in plain tubes and tubes with typical twisted tapes for same flow rate and Re .

4) Kevin M. Lunsford :

They studied on various heat transfer equipment which increase heat transfer performance. Since there are so many different types of heat exchanger enhancements, Finning Tube Inserts Tube Deformation Baffles Increasing heat exchanger performance usually means transferring more duty or operating the exchanger at a closer temperature approach. This can be accomplished without a dramatic increase in surface area. This constraint directly translates to increasing the overall heat transfer coefficient, U. The overall heat transfer coefficient is related to the surface area, A, duty, Q, and driving force, ΔT.

5) Nitesh B. Dahare, Dr. M. Basavaraj :

Numerical experimentation analysis of heat transfer in shell and twisted tube heat exchanger .It consist of series of finned tubes in which one of the fluid runs in the tube and the other fluid run over the tube to be heated or cooled during the heat exchanger operation high Pressure high temperature water or steam are flowing at high velocity inside the tube or plate system. A heat exchanger utilizes the fact that, where ever there is a temperature difference, flow of energy occurs. Analytical study has been done to get the experimental and Numerical values verified. By using twisted tube we get highly turbulent flow compare to plain tube. Tube and shell type of cross flow heat exchanger was employed. Reynolds number range for fully develop flow is from Re 2500 to 1.26 ×106 covering turbulent range. overall heat transfer coefficient of twisted tube heat exchanger increases compare to plain tube.

6) C. K. Pardhi , Dr. Prasant Baredar :

They studied experiment analysis of double pipe heat exchanger by using turbulator. present work describes the principal techniques of industrial importance for the augmentation of single phase heat transfer on the inside of tubes namely twisted tapes. so twisted tape should be used in heat exchanger when high heat transfer rate is required and pressure drop is of no significance.

They investigating different heat transfer augmentation techniques it has found that:. As compared to conventional heat exchanger the augmented has shown a significant improvement in heat transfer coefficient by 61 % for twisted tape. When only heat transfer capacity of heat exchanger is criteria regardless of pressure drop or pumping power the twisted tape is more superior as compared with smooth tube (1.6 to 1.8 times). On equal pressure drop and equal pumping power basis the smooth tube is better to twisted tape (1.3 to 1.7 times). With increase in floe rate of oil keeping flow rate of water constant the thermal performance decreases slightly for each other. Twisted tape of lower twist ratio (p/d =3.5) gives higher heat transfer coefficient (by 1.39 times) than higher twist ratio of p/d = 7.

7) Smith Eiamsa-ard, Pongjet Promvonge :

Effect of helical tape in flow through a double pipe heat exchanger has been investigated. The experimentation worked on cold water and hot air system having Reynolds number range 2300 – 8800 of flow. Heat transfer coefficient have increased using full length helical tape with/without centered rod and regularly spaced helical tape in heat exchanger. 10 % enhancement in heat transfer coefficient has occurred with helical tape with centered rod than helical tape without centered rod but increased in pressure drop. Different space free ratio (0.5, 1.0, 1.5, and 2.0) has studied to overcome pressure drop difficulties. S=0.5,The mean Nusselt number has increased by 145% for insert of regularly spaced helical tape, 150% for insert of full length helical tape without centered rod and 160% for inset of full length helical tape with centered rod as compared with pain tube.

8) Paisarn Naphon:

In that paper the investigated application of V corrugated plate on both sides surface of the tube and tested effect of heat transfer characteristics and pressure drop. The tested section has V corrugated plate with tile angles of 20o, 40o and 60o under experimentation condition as Reynold number and heat flux has 2000-9000 at and 0.5-1.2 kW/m2 respectively. Pressure drop and Heat transfer has been enhanced due to formation of recirculation zone in the tube. Formation of recirculation zone disturbing or breaking of thermal boundary layer of flow stream on the corrugated surface. As compared with the plain surface tube the enhancement in heat transfer has occurred 3.35 and pressure drop has occurred 1.96 times more in V corrugated surface tube

9) Manglik and Bergles :

Developed correlations for both turbulent flow and laminar flow. For an isothermal friction factor, the correlation describes most available data for laminar, transitional and turbulent flows within 10 per cent. However, a family of curves is needed to develop correlation for the Nusselt number on account of the non-unique nature of laminar–turbulent transition.

10) S. Suwannapan, S. Skullong, P. Promvonge:

The paper presents an experimental investigation on enhanced heat transfer, and pressure loss characteristics using zigzag-winglet perforated-tape inserts (ZW-PT) in a round tube having a uniform heat-fluxed wall for the turbulent air flow, Reynolds number (Re) from 4200 to 26,000. In the present work, the ZWPT having the winglet attack angle of 45° were inserted into the test tube at two different winglet pitch ratios (P/D = PR=1 and 1.5) and four winglet-width or blockage ratios (b/D = BR=0.1, 0.15, 0.2 and 0.25). The experimental results of the heat transfer and pressure drop in terms of the respective Nusselt number (Nu) and friction factor (f), respectively, reveal that the Nu and f increase with the increment of BR and Re but with the decreasing PR. The Nu for the inserted tube is in a range of 3.1-5.1 times above that for the plain tube while the f is around 12.5-53.6 times. In addition, the use of the ZW-PT with PR=1.0 leads to better thermal enhancement factor (TEF) than that with PR=1.5 around 3-5%.

11) Sanjay P. Govindani and Dr.M.Basavaraj :

Experimentally investigated on heat transfer augmentation in the double pipe heat exchanger using a new kind of insert called Rotor-assembled strand. The work includes the determination of friction factor and heat transfer coefficient for rotor assembled strand insert. The experiment will be first conducted on a plain tube and then tube with the insert. The results of both the experiment will be tallied and the changes in friction factor, Nusselt number, pressure drop and heat transfer coefficient will be calculated. The results of rotor assembled strand having different rotors will be compared with the values for the smooth tube. The correlations of Nusselt number and friction factor as function of Reynolds number and Prandtl number will be determined through multi variant linear normal regression.

12) Guo-Yan Zhou, Jingmei Xiao, Juntao Wang And Shan-Tung Tu:

Numerically investigated on Shell-and-tube heat exchangers with trefoil-hole baffles are new type heat transfer devices and widely used in nuclear power system due to their special advantages, with the fluid flowing longitudinally on the shell side. However, very few related academic literature are available. In order to obtain an understanding of the underlying mechanism of shell-side thermal augmentation, a CFD model including inlet and outlet nozzles is proposed in the present study. Based on the RNG k- model, numerical investigations on shell-side fluid flow and heat transfer are conducted by using commercial CFD software FLUENT14.0. The results show that the fluid is fully developed after the first trefoil-hole baffle.

13) Deepali Gaikwad and Kundlik Mali:

Both experimentally investigated on the thermal performance of heat transfer from hot water to cold water by double pipe heat exchanger for plain tube and plain tube with twisted wire brush inserts. The Nusselt number obtained for the tube with twisted wire brush inserts varied from 1.55 to 2.35 times in comparison to those of the plain tube. The inner convective heat transfer coefficient for twisted wire brush inserts is approximately 9-11 % higher than that for plain tube. The pressure drop for twisted wire brush inserts is 4- 5 % higher than that obtained for plain tube. The variation between theoretical Nusselt number and experimental Nusselt number is approximately 10-15 %.

14)S. Eiamsa-ard , K. Wongcharee , P. Eiamsa-ard , C. Thianpong :

Experimentally investigated on Heat transfer, flow friction and thermal performance factor characteristics in a tube fitted with delta winglet twisted tape, using water as working fluid. Influences of the oblique delta-winglet twisted tape (O-DWT) and straight delta-winglet twisted tape (S-DWT) arrangements are also described. The experiments are conducted using the tapes with three twist ratios (y/w = 3, 4 and 5) and three depth of wing cut ratios (DR = d/w = 0.11, 0.21 and 0.32) over a Reynolds number range of 3000–27,000 in a uniform wall heat flux tube. The obtained results show that mean Nusselt number and mean friction factor in the tube with the delta-winglet twisted tape increase with decreasing twisted ratio (y/w) and increasing depth of wing cut ratio (DR). It is also observed that the O-DWT is more effective turbulator giving higher heat transfer coefficient than the S-DWT. Over the range considered, Nusselt number, friction factor and thermal performance factor in a tube with the O-DWT are, respectively, 1.04– 1.64, 1.09–1.95, and 1.05–1.13 times of those in the tube with typical twisted tape (TT).

3. PROPOSED WORK:

The aim of the present work is to investigate experimentally, the effect of external threaded inner tube on heat transfer rate in a concentric tube heat exchanger. The details of the experimental set- up are as follows:

The parameters will be varied during the experimentation are mass flow rates and hot water inlet temperatures.

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4. CONCLUSIONS:

This review has considered heat transfer and comparison of heat exchanger under influence of inner plain tube and inner external threaded tube. For this study counter flow heat exchanger will be used. By generating the threaded profile on inner tube and introduce a disturbance in fluid flow (swirl flow), this may enhance a heat transfer rate. The aim of the study is to determine a Reynolds number, friction factor, Nusselt number and heat transfer rate. Hence, it is concluded that from this exhaustive literature review, it has been observed that the work undertaken is not done so far.

Table1. Details of experimental set-up

S.N.	Description	Material	Dimensions
1	Outer Tube	Copper	(51 mmOD,48 mm ID)*1000 mm
2	Inner Plain Tube	Copper	(26 mm OD,23 mm ID)*1500 mm
3	Inner threaded Tube	Copper	(26 mm OD,18 mm ID)*1500 mm
4	Hot Water Inlet Temp.	-	60 to 80 C

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