Effect of Wavy Tube on Heat Transfer in a Concentric Tube Heat Exchanger: A Review

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ABSTRACT: *The heat exchanger is an important device in almost all of the mechanical industries as in case of process industries it is key element. Heat transfer augmentation techniques refer to different methods used to increase rate of heat transfer such as active, passive and compound technique. The present paper is a review of one of the passive augmentation techniques used in a concentric tube heat exchanger using inner wavy tube. The performance of counter flow heat exchanger will be studied with inner plain tube and inner wavy tube. Then this enhanced performance due to inner wavy 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).*

Keywords:-Heat Exchanger, Heat Transfer Augmentation Techniques, Passive Techniques, Inner Wavy Tube, CFD Simulation.

1. INTRODUCTION

Heat transfer is the exchange of thermal energy between physical systems. The rate of heat transfer is dependent on the temperatures of the systems and the properties of the intervening medium through which the heat is transferred. The three fundamental modes of heat transfer are conduction, convection and radiation. A heat exchanger is a device used to transfer heat between one or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. Different heat exchangers are named according to their application. For example, heat exchangers being used to condense is known as condensers, similarly heat exchanger for boiling purposes are called boilers. Performance and efficiency of heat exchangers are measured through the amount of heat transfer using least area of heat transfer and pressure drop. A much better estimate of its efficiency is obtained by calculating over all heat transfer coefficient. Pressure drop and area required for a certain amount of heat transfer, provides an insight about the capital cost and power requirements (Running cost) of a heat exchanger. Usually, there are many theories to design a heat exchanger according to the requirements.

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

Active Technique: This method requires some external power input for the improvement of thermal performance of heat exchanger; examples are mechanical aids, surface vibration, fluid vibration, electrostatic fields, suction and jet impingement.

Passive Technique: This method generally uses amendments to the flow in the tube of heat exchangers by fitting inserts into the tube. Such method does not need any type of external power. Due to these inserts the flow get disturbed and turbulence is created which results in increase in pressure drop, decreasing the tube wall temperature and thereby increase in heat transfer coefficient.

Compound Technique: When two or more methods incorporated simultaneously to obtain improvement in thermal performance of heat exchanger is termed as compound method. Hence obtained thermal performance of heat exchanger is greater than that produced by any one method of them when used individually.

2. LITERATURE REVIEW

Some experimental and numerical work on heat transfer enhancement in heat exchanger has been done in the last decades. Both the industrial and academic people have taken interest in this area. The following is a review of the research that has been completed especially on heat transfer enhancement.

Gül¸sahÇakmak, H. LütfiYücel, ZekiArgunhan and CengizYıldız [1], studied the heat transfer, friction factor, and thermal performance factor characteristics of a concentric-tube heat exchanger are examined experimentally. A wavy inner pipe is mounted in the tube with the purpose of generating swirl flow that would help to increase the heat transfer rate of the tube. The examination is performed for a Reynolds number ranging from 2700 to 8800. An empirical correlation is also formulated to match with experimental data of the Nusselt number using the Wilson plot method. In addition, to obtain the real benefits in using the swirl generator at a constant pumping power, the thermal enhancement factor is also determined. Over the range considered, the increases in the Nusselt number, friction factor, and thermal performance factor are found to be, respectively, about 113%, 81%, and 196%higher than those obtained from a smooth-surface inner pipe.

Feilong Zhan, Jiajun Tang, Guoliang Ding and DaweiZhuang [2], experimentally studied to investigate the particle deposition characteristics of wavy fin-and-tube heat exchangers. Experimental conditions cover fin pitch over a range from 1.6 mm to 3.2 mm, particle concentration over a range from 80 kg m-3 to 280 kg m-3 and air velocity over a range from 1 m s-1 to 3 m s-1. The observation results show that the particles mostly deposit on the leading edge of fins as well as the front part of tubes. The weight measurement results show that fin pitch and particle concentration have a monotonic effect on particle deposition, the maximum particle deposition weight per unit area increases by 13.1% and 6.2% respectively as fin pitch decreases and particle concentration increases; while air velocity has a complicated effect on particle deposition, the maximum particle deposition weight per unit area firstly increases by 6.8% and then decreases by 10.9% as air velocity increases.

FeiDuan, KeWei Song, HouRan Li, LiMin Chang, YongHeng Zhang and LiangBi Wang [3], numerically studied on the flow and heat transfer characteristics in the fin side of the wavy finned flat tube heat exchanger are compared with experimental results. The influence of the fin spacing, the wave spacing, the wave amplitude and Reynolds number on the flow and heat transfer performances is investigated. The correlations of the Nusselt number and friction factor are obtained by fitting the numerical results. The results show that the intermittent wavy fin can significantly increase the heat transfer than straight fin. The longitudinal vortices can enhance heat transfer, but the transversal vortices appear negative effect on heat transfer. Both of the intensities of longitudinal vortices and transversal vortices do not uniquely determine Nusselt number for all configurations.

Gun Woo Kim, Hyun Muk Lim, and GwangHoon Rhee [4], numerically studied on heat transfer enhancement by cross-cut induced flow control in a wavy fin heat exchanger. The concept of cross-cut is cutting fin in a direction perpendicular to the flow direction. The simulation was performed using non dimensional governing equations for a steady laminar flow. The parametric study was conducted to find the optimum position and length of the cross-cut. The results showed that the heat transfer performance of optimized cross-cut wavy fin was enhanced by a maximum of 23.81% greater than a typical wavy fin. The pressure drop also increased by a maximum 7.04% in optimized case.

Young Joo Kim, Minsung Kim, Sangkeun Kim, June Kee Min and Man Yeong Ha [5], studied experimental investigation of the flow and heat transfer characteristics in a Sinusoidal wavy circular tube (SWCT). We solvednumerically the conservation equations of continuity, momentum and energy which govern the steady, three-dimensional, and incompressible fluid flow and the heat transfer in the SWCT. They discussed the effect of the geometry parameters, such as the peak amplitude and wavelength, on the distribution of the local pressure coefficient, fluid flow, wall vorticity and local Nusselt number in the sinusoidal wavy circular tube. The simulations were performed for the different Reynolds numbers of 100, 1000 and 10000

S. Vahidifar and M. Kahrom [6], studied heat transfer characteristics and the pressure drop of a horizontal double pipe heat exchanger with wire coil inserts. They studied the characteristics of the heat transfer and the pressure drop of a double pipe horizontal tube heat exchanger with an inserted wire coil and rings. Wire coil acts as a swirl flow, which increases turbulence and roughness whereas rings increase heat transfer as a promoter of turbulence and roughness. The experimental data sets were extracted from wire coils and rings tested within a geometrical range with a pitch of (P/D=1, 2, 4) and wire diameter of (d/D=0.05, 0.07, 0.11). For wire coil with d/D=0.11, P/D =1 and Reynolds number of 10000, the overall enhancement efficiency amounted to 128%.

DhanrajS.Pimple [7], experimentally studied to investigate the heat transfer and friction factor data for single -phase flow in a shell and tube heat exchanger fitted with a helical tape insert. In the double concentric tube heat exchanger, hot air was passed through the inner tube while the cold water was flowed through the annulus. The influences of the helical insert on heat transfer rate and friction factor were studied for counter flow, and Nusselt numbers and friction factor obtained were compared with previous data (Dittus 1930, Petukhov 1970, Moody 1944) for axial flows in the plain tube. The flow considered is in a low Reynolds number range between 2300 and 8800. A maximum percentage gain of 165% in heat transfer rate is obtained for using the helical insert in comparison with the plain tube.

Bornova, Izmir [8], experimentally investigated on the swirl flow devices like twisted tape, winglet, groove, conical ring, wire coil etc. have been used as passive heat transfer augmentation technique. Heat transfer, friction factor and thermal-hydraulic performance factor characteristics were investigated separately under the same conditions such as same twisted ratios and same Reynolds number values. Twisted tape which gives best heat transfer and friction factor results was determined. Derived empirical correlations which had been found by researchers were used for comparison between twisted tapes.

Prof. ShashankS.Choudhari and Prof. Taji S.G [9], studied heat transfer characteristics and friction factor of horizontal double pipe heat exchanger with coil wire inserts made up of different materials are investigated. The Reynolds numbers are in the range of 4000-13000. The inner and outer diameters of tubes are 17 mm and 21.4 mm respectively. Hot water and cold water are used as working fluid on tube side and annulus side, respectively. The hot water and cold water flow rates are maintained same and in range of .033 to .1 kg/s. Three different materials as copper, aluminum, and stainless steel and different pitches are used. Aluminum, copper, and stainless steel inserts are of pitches 5, 10, and 15 mm respectively. Effect of these coil wire inserts material on enhancement of heat transfer and friction factor are considered. The experimental data obtained from plain tube were verified with the standard correlation to ensure the validation of experimental results. Coil wire has significant effect on heat transfer and friction factor. Cu insert has higher heat transfer enhancement of 1.58 times as compared to plane tube. On other hand Aluminium and stainless steel insert has heat transfer enhancement of 1.41 and 1.31as compared to plane tube respectively. The friction factor found to be increasing with decreasing coil wire pitch.

C.K.Pardhi [10], studied experimentally investigation on performance improvement of double pipe heat exchanger by using tabulator. As compared to conventional heat exchanger the augmented has shown a significant improvement in heat transfer coefficient by 61 % for twisted tape I and 78% for twisted tape II. 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.

DeepaliGaikwad and Kundlik Mali [11], 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 %.

Dr. A. G. Matani and Swapnil A. Dahake [12], studied experimental investigation on the influences of twisted tapes and wire coil on pressure drop, friction factor, heat transfer and thermal enhancement index are experimentally determined. The tests are conducted using the TT with three different twist ratios (y/w = 3.5, 2.66 and 2.25), double twisted tape (y/w=3.5 and 2.66) and WCTT pitch ratio of 0.88 for Reynolds numbers range between 5000 and 18,000 under uniform heat flux conditions.The experimental results indicate that the tube with the various inserts provides considerable improvement of the heat transfer rate over the plain tube. The experimental results demonstrate that friction factor (f) and thermal enhancement index increase with decreasing twist ratio (y/w). The results also show that the WCTT are more efficient than the TT for heat transfer enhancement.

KushalKamboj, Gurjeet Singh, Rohit Sharma, DilbaghPanchal and JaspreetHira [13], experimentally investigated on heat transfer augmentation in double pipe heat exchanger using mechanical tabulators. The Nusselt number is found to be enhanced by 11.46, 17.88 and 26.76 % with DCST-C pitches *P* = 15, 10 and 5 cm, vis-à-vis plain tube. Friction factor and pressure drop characteristics were also studied and evaluated. It reveals that, with an increment in DCST-C pitch, friction factor and pressure drop increases. DCST-C offers a maximum of 20.79, 48.59 and 66.87 % friction factor with 15, 10 and 5 cm respectively, vis-à-vis friction factor generated by plain tube. The experiment for augmentation of heat transfer is successfully performed with DCST-C arrangement in double pipe heat exchanger and heat transfer is enhanced by 26.76 %, Friction factor is increased maximum of 66.87 % for DCST-C pitch 5 cm vis-à-vis plain tube. However, thermal performance factor gives maximum value 1.0525 for DCST-C pitch 15 cm.

ChinarukThianpong, PetpicesEiamsa-ard and Smith Eiamsa-ard [14], experimentally investigated on the heat transfer, pressure loss and thermal performance characteristics. The experiments were performed under uniform wall heat flux condition by using PTs with y/W = 3, 4 and 5, d/W = 0.11, 0.14 and 0.17 and s/W = 0.4, 0.6 and 0.8 where y is a twist length, d is a perforation hole diameter, s is a spacing between holes (pitch) and W is a tape width. The experimental results reveal that Nusselt number increased with decreasing s/W and y/W and increasing d/W. For the present range, the maximum heat transfer was obtained by utilizing the tape with s/W = 0.4, d/W = 0.17 and y/W = 3, which is higher than those obtained from the plain tube with and without typical twisted tape by around 27.4 and 86.7%, respectively.

S. Eiamsa-ard , K. Wongcharee , P. Eiamsa-ard , C. Thianpong [15], 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).

Ye Yao, Xingyu Zhang and YiyingGuo [16], experimentally studied to investigate on the heat transfer enhancement of water-water heat exchanger in shell-and-tube type assisted by power ultrasonic. The acoustic frequency of ultrasound transducer employed is about 21 kHz, and three power levels (40W, 60W and 100W) are used for this study. The impact of water flow rate and inlet water temperature in the tube as well as the ultrasonic power on the enhancement was investigated. It was found that the water flow rate and ultrasonic power levels would produce great influence on the enhancement by power ultrasound which decreased with the increasing water velocity in the tube and the decreasing acoustic power.

Chatter Pal Saini and Sandeep Kumar [17], experimentally studied on Heat transfer characteristics in a horizontal rectangular heat exchanger with five triangular baffles inclined at fixed angle of 20^0 along the channel are investigated experimentally. The same heat exchanger is also investigated with use of vibration. The experiment is done on three different vibration intensities. Effects of different vibration intensities on heat transfer are observed and compared with different heat transfer characteristics like overall heat transfer coefficient, effectiveness and heat transfer rate in absence of vibrations. It is found that with increase in vibration intensities, heat transfer characteristics can be improved to some extent.

Sanjay P. Govindani and Dr. M. Basavaraj [18], 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.

Guo-Yan Zhou, Jingmei Xiao, Lingyun Zhu, Juntao Wang and Shan-Tung Tu [19], 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.

3. PROPOSED WORK

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

Table1. Details of experimental set-up

S.N.	Description	Material	Dimensions/ Range
1.	Outer Tube (1nos.)	Copper	(51 mmOD,48 mm ID)*1000 mm
2.	Inner Plain Tube (1nos.)	Copper	(26 mm OD,23 mm ID)*1500 mm
3.	Inner Wavy Tube (1nos.)	Copper	(26 mm OD,23 mm ID)*1500 mm
4.	Mass Flow Rates	-	80LPH to 120LPH
5.	Hot Water Inlet Temp.	-	50 to 70^0C

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

4. CONCLUSIONS:

This review has considered heat transfer and the performance of heat exchanger under influence of inner plain and wavy tube. For this study counter flow heat exchanger will be used. Experiments will be performed by varying parameters like mass flow rates and hot water inlet temperatures. We will be obtained from the experiment conducted on various hydrodynamic configurations in heat exchanger using plain and wavy tube. From the above review, various way of enhance the heat transfer rate by generating the turbulence flow by active and passive method such as various type of inserts and surface vibration. Hence it is conclude that from the literature review, using inner wavy tube heat transfer rate may increases considerably than that of the plain or smooth tube.

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