A Review on Optimal Design of Single Tube in a Heat Exchanger using FEA Tool

Roshan V. Marode **Ashok J. Keche**

Abstract:- **The performance of heat exchangers can be improved to perform a certain heat-transfer duty by heat transfer enhancement techniques. In general, these techniques can be divided into two groups: active and passive techniques. The active techniques require external forces, e.g. electric field, acoustic or surface vibration, etc. The passive techniques require fluid additives or special surface geometries. As Heat exchangers is one of the most important heat transfer apparatus that find its use in industries like oil refining, chemical engineering, electric power generation etc. In order to achieve the maximum heat transfer rates an analysis of single tube of shell and tube heat exchanger. With relate to same to have a maximum heat transfer rate this project gives various optimal design solutions using computational techniques. To measure the performance of different designs, its model is suitably designed and fabricated so as to perform experimental tests. FEA analysis has been carried out for different design and on the basis of results made which one give the best heat transfer rates.**

Keywords:- **Heat Exchanger, Optimal Design, Computational Techniques, FEA analysis.**

I. INTRODUCTION

Conventional shell and tube heat exchangers with segmental baffles have low heat transfer co-efficient due to the segmental baffle arrangement causing high leakage flow bypassing the heat transfer surface and high pressure drop that poses a big problem for industries as the pumping costs increases. The hydrodynamic studies testing the heat transfer (mean temperature difference) and the pressure drop; with the help of research facilities and industrial equipment have shown much better performance of helical baffle heat exchangers as compared to the conventional ones. This results in relatively high value of shell side heat transfer coefficient, low pressure drop, and low shell side fouling.

One of the important processes in engineering is the heat exchange. The means of heat exchanger that to transfer the heat between flowing fluids. A heat exchanger is the process to transfer heat from one fluid to another fluid. The heat exchanger is devise that used for transfer of internal thermal energy between two or more fluids at different temperatures. In most heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix. Heat exchangers are used in the process, power, petroleum, transportation, air conditioning, refrigeration, Cryogenic, heat recovery, alternate fuels, and other industries. Common examples of heat exchangers familiar to us in day-to-day use are automobile radiators, condensers, evaporators, and oil coolers. Heat exchangers could be classified in many different ways.

II. LITERATURE REVIEW

ALA HASAN[1] investigated five oval tubes experimentally and compared with that for

a circular tube in a cross-flow of air. The nominal axis ratios R (major axis / minor axis) for three of the investigated oval tubes are 2, 3, and 4.Two other configurations of oval tubes are also tested, an oval tube R = 3 with two wires soldered on its upper and lower top positions, and a cut-oval tube. The measurement results show that the mean Nusselt numbers Nu D for the oval tubes are close to that for the circular tube for Re D < 4000. For a higher Re D , the Nu D for the oval tubes is lower than that for the circular tube and it decreases with the increase in the axis ratio R. The drag coefficients C d for the tubes are measured and the combined thermal-hydraulic performance is indicated by the ratio Nu D / C d , which shows a better combined performance for the oval tubes.

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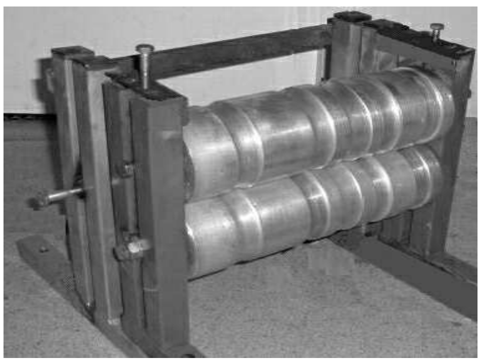

Fig 2.1

Oval Tube or Elliptical Tube	Major Axis(c),mm	Minor Axis(y),mm	c/y
R=2	22.2	11.7	1.9
R=3	24	8.6	2.8
R=4	25.1	6.3	4

RAMCHANDRA PATIL et al.[2] they gives a design procedure for complete helical coil heat exchangers it gives complete procedure for designing coil type tubes. Heat transfer coefficient of fluid flowing in side of coil can be determined by usual conventional methods and obtained by straight tube -one of the Sieder-Tate relationships a plot of colburn factor Jh. Team work predicted that optimal design of coil type tube gives high colburn factor at high reynolds number for tube side heat transfer.

ABDULKAREEM ABBAS et al[3] in this paper heat transfer augmentation due to twisting parameter was investigated in a twisted tube of square cross sectional area. Twisting parameter is defined as the ratio of the length of the tube where it completed twisting of360 degrees to its hydraulic diameter. Four twist parameters were chosen;5, 10, 25 and 50, and a comparison is made with a straight untwisted duct. It was observed that the heat transfer coefficient increases with decreasing twist parameter. This is interpreted to the nature of span wise swirling flow generated. The swirling increases cross flow velocity vectors as it becomes far from tube center towards walls. At tube wall the thickness of boundary layer becomes thinner as near wall velocity become larger which leads to a boundary layer of good thermal characteristics. Also swirling increases internal mixing process which enhances internal thermal equilibrium. The heat transfer coefficient also increases as Reynolds number increased as velocity components are increased.

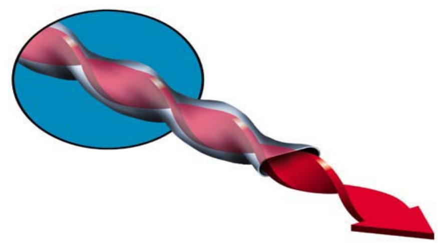

Fig 2.2

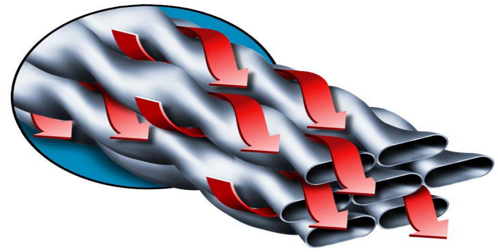

Fig. 2.3

G. E. KONDHALKAR et al [4] gives the performance analysis of spiral tube heat exchanger over the shell and tube type heat exchanger. They found that the cost saving using spiral tube heat exchanger is around 15 –20 % as compared to shell and tube type heat exchanger and to establish that improvement in overall heat transfer coefficient as compared to shell and tube type heat exchanger from 400 to 650W/m2K. The process at higher velocity was not suitable. So it is decided to keep the low velocity with more turbulence which is reduced fouling and increases the heat transfer rate as well as oil will not stick to the inner surface of the tubes.

J.P. HARTNETT et al [5] they are investigates the average in tube heat transfer co-efficient in spiral coil heat exchanger. The test section is spiral coil heat exchanger which consists of six layer of concentric spiral coil tube. They obtain the experiment result of tube heat transfer coefficient in spiral coil heat exchanger under dehumidifying conditions. They give the experimental equation and compare with the present correlation and to obtain new correlation.

P. Naphon [6] proposed that the heat exchanger consists of a shell and helically coiled tube unit with two different coil diameters. Cold and hot water are used as working fluids in shell side and tube side. The cold and hot water mass flow rates ranging between 0.10 and 0.22 kg/s, and between 0.02 and 0.12 kg/s. He concludes that Outlet cold water temperature increases with increasing hot water mass flow rate. An average heat transfer rate increases as hot and cold water mass flow rates increase. The friction factor decreases with increasing hot water mass flow rate. Inlet hot and cold water mass flow rates

and inlet hot water temperature have significant effect on the heat exchanger effectiveness.

P. M. DESHPANDE et al. [7] studied horizontal spiral coil tube (HSTC) for various forces (viscous, buoyancy and centrifugal force) acting on fluid element in coil; of which the centrifugal force is predominant and results in secondary flow. This phenomenon also depends on the physical properties of fluid at a given temperature. They also concluded that as the coil diameter reduces the curvature ratio increase that increases the pressure drop.

DR. M. S. TANDALE et al [8] provided analytical model to design of spiral tube heat exchanger and experiments were performed. The experimental results show that the deviation between calculated values of overall heat transfer coefficient from the experimental results and theoretical values obtained from the analytical model are within 12%. Also, the accuracy is found to be within ±8 % in approximation. The pressure drop estimated is also Design and Experimental Analysis of Spiral Tube Heat Exchanger 40 compared with actual values observed during experimentation, which is found in acceptable range.

Mauro A. S. S. Ravagnani et al. [9] have presented various studies in the field of design of heat exchangers. Two optimization models will be considered to solve the problem of designing shell and tube heat exchangers. The first one is based on a General Disjunctive Programming Problem (GDP) and reformulated to a Mixed Integer Nonlinear Programming (MINLP) problem and solved using Mathematical Programming and GAMS software. The second one is based on the Meta-Heuristic optimization technique known as Particle Swarm Optimization (PSO).

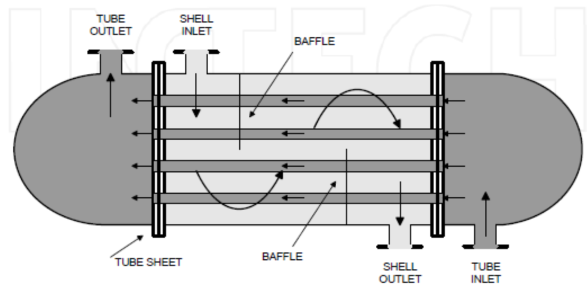

Figure 2.2 Heat exchanger with one passes at the tube side

Yang-gu Kim et al. [10]A computational study for the optimal design of heat exchangers (HX) used in a high temperature and high pressure system is presented. Two types of air to air HX are considered in this study. One is a single-pass cross-flow type with straight plain tubes and the other is a two-pass cross-counter flow type with plain U-tubes. These two types of HX have the staggered arrangement of tubes.

Paresh Patel, et al(2012) [11] In this paper a CFD analysis has been carried out for different material and on the basis of results made which one give the best heat transfer rates. This paper is to analyze the inlet and outlet temperature of two different materials viz. aluminium and copper with that of analytical calculations. From study it was cleared that after performing the calculation the fluid water the output temperature is near to the value mentioned in output temperature of ansys. As we change the material from the aluminum to the brass, temperature difference between input temperature and output temperature.

JAY J. BHAVSAR, et al(2013)[12 The objective of this paper is to design and analyse of spiral tube heat exchanger. In this newly proposed design hot fluid flows in axial path while the cold fluid flows in a spiral path. The presented work concluded that spiral tube heat exchanger has high heat transfer rate compared with helical coil heat exchanger and spiral plate heat exchanger.

Professor Sunilkumar Shinde et al (2012)[18] This paper analyses the conventional heat exchanger thermally using the Kern method. The paper also consists of thermal analysis of a heat exchanger with helical baffles using the Kern method, which has been modified to approximate results for different helical angles. Lastly, an attempt has been made to modify the existing Kern method for continuous helical baffle heat exchanger, which is originally used for Segmental baffle Heat Exchangers and proven that the Helical baffle heat exchanger has far more better Heat transfer coefficient than the conventional segmental Heat Exchanger.

III. PROPOSED DESIGN FOR TUBE OF HEAT EXCHANGER

Fig3. 1.a) Circular Cross- Section Tube- Front View

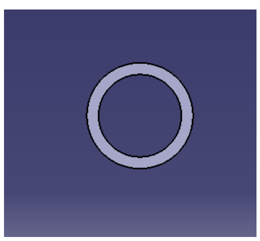

Fig3.1.b Circular Cross- Section Tube- Side View

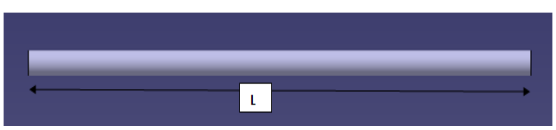

Fig3.2 a Elliptical cross-section tube-Front View.

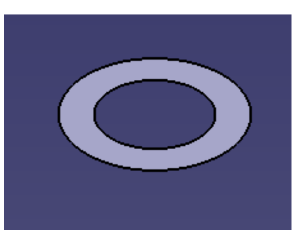

Fig3. 2 b Elliptical cross-section tube-Side View

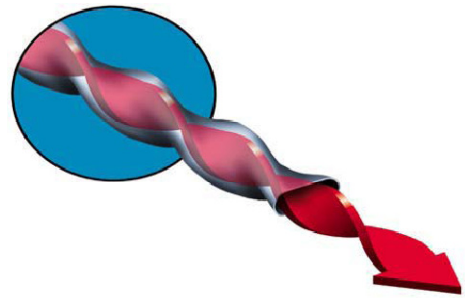

Fig.3. 3 Twisted Type Tube

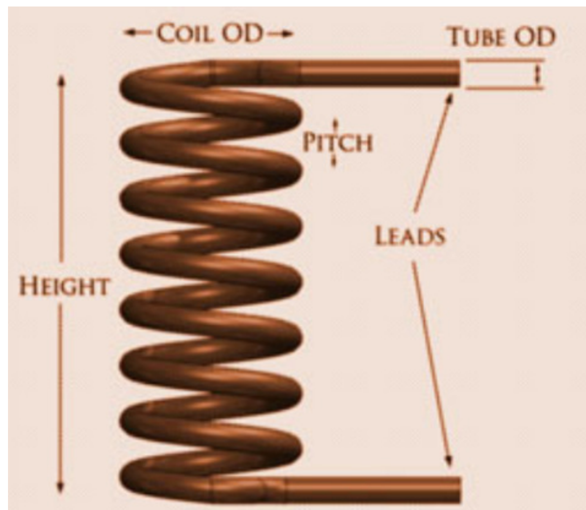

Fig. 3.4 Coil type tube

All design tubes are having same effective length say 'L'

IV. PROCEDURE

Thermal modeling

I. Analysis type - Thermal h-method.

II. Steady state or Transient State.

III. Properties of the material or Isotropic

IV. Objective of analysis- to find out the temperature distribution in a tube at various cross sections for different design when the process of shell and tube is done.

V. CONCLUSION

This study will show the design and thermal analysis of different tubes. Experimentally, same designs are going to made and results to be evaluated. With relate to same design tubes are thermally analyzed in ANSYS software. We will compare both the results and heat transfer rate is being studied viz. which design having high heat transfer rate/performance. Widely circulated design tubes are having great applications due to their large heat transfer area and high heat transfer coefficients .In commercial aircraft heat exchangers are used to take heat from engine's oil system to heat cold fuel.The possibility to increase in these characteristics using the latest technology and various methods has raised application range of these designs.

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