THOMSON REUTERS
ENDNOTE

[Nimankar , 3(12): December 2016] ISSN 2348 – 8034
DOI- 10.5281/zenodo.223816 Impact Factor- 4.022

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

REVIEW OF HEAT EXCHANGERS

Mr. Sachchidanand J. Nimankar*[1] and Prof. Sachin K. Dahake[2]
*[1]Mechanical, MET's Institute of Engineering Bhujbal Knowledge City, India,
[2]Mechanical, MET's Institute of Engineering Bhujbal Knowledge City, India

ABSTRACT

This paper is a review of heat exchangers. Starts with the introduction of heat exchangers and is concerned with the detailed classification of heat exchangers according to contact types, surface compactness, number of fluids, flow arrangement and construction features including their applications. The study of shell and tube heat exchanger along with the comprehensive description of all the components of shell and tube heat exchanger. The factors affecting the performance of shell and tube heat exchanger is studied and its detailed discussion is given. Some research papers are studied in details and then review from those papers and the conclusions are described in this paper.

***Keywords**: Shell, tube, nozzle, channel, baffle.*

I. INTRODUCTION

A heat exchanger is a device built for efficient heat transfer from one medium to another in order to carry and process energy. Typically one medium is cooled while the other is heated. In most heat exchangers, the fluids are separated by a heat transfer surface and ideally they do not mix. They are widely used in petroleum refineries, chemical plants, petrochemical plants, natural gas processing, air conditioning, refrigeration and automotive applications. A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat and work interactions. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single- or Multi component fluid streams. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or control a process fluid. In a few heat exchangers, the fluids exchanging heat are in direct contact. In most heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix or leak. Such exchangers are referred to as direct transfer type, or simply recuperators. In contrast, exchangers in which there is intermittent heat exchange between the hot and cold fluids—via thermal energy storage and release through the exchanger surface or matrix— are referred to as indirect transfer type, or simply regenerators. Such exchangers usually have fluid leakage from one fluid stream to the other, due to pressure differences and matrix rotation/valve switching. Common examples of heat exchangers are shell-and tube exchangers, automobile radiators, condensers, evaporators, air preheaters, and cooling towers. If no phase change occurs in any of the fluids in the exchanger, it is sometimes referred to as a sensible heat exchanger. There could be internal thermal energy sources in the exchangers, such as in electric heaters and nuclear fuel elements. Combustion and chemical reaction may take place within the exchanger, such as in boilers, fired heaters, and fluidized-bed exchangers. Mechanical devices may be used in some exchangers such as in scraped surface exchangers, agitated vessels, and stirred tank reactors. Heat transfer in the separating wall of a recuperator generally takes place by conduction. However, in a heat pipe heat exchanger, the heat pipe not only acts as a separating wall, but also facilitates the transfer of heat by condensation, evaporation, and conduction of the working fluid inside the heat pipe. In general, if the fluids are immiscible, the separating wall may be eliminated, and the interface between the fluids replaces a heat transfer surface, as in a direct-contact heat exchanger. A heat exchanger consists of heat transfer elements such as a core or matrix containing the heat transfer surface, and fluid distribution elements such as headers, manifolds, tanks, inlet and outlet nozzles or pipes, or seals. Usually, there are no moving parts in a heat exchanger; however, there are exceptions, such as a rotary regenerative exchanger (in which the matrix is mechanically driven to rotate at some design speed) or a scraped surface heat exchanger.

II. CLASSIFICATION OF HEAT EXCHANGER

Heat Exchangers are classified according to;

Contact types:

- *Indirect-Contact Heat Exchangers:*

In an indirect-contact heat exchanger, the fluid streams remain separate and the heat transfers continuously through an impervious dividing wall or into and out of a wall in a transient manner. Thus, ideally, there is no direct contact between thermally interacting fluids. This type of heat exchanger also referred to as a surface heat exchanger.

- *Direct-Contact Heat Exchangers:*

In a direct-contact exchanger, two fluid streams come into direct contact, exchange heat, and are then separated. Common applications of a direct-contact exchanger involve mass transfer in addition to heat transfer, such as in evaporative cooling and rectification; applications involving only sensible heat transfer are rare. Compared to indirect contact recuperators and regenerators, in direct-contact heat exchangers, very high heat transfer rates are achievable, the exchanger construction is relatively inexpensive, and the fouling problem is generally nonexistent, due to the absence of a heat transfer surface (wall) between the two fluids.

Surface Compactness:

Compared to shell-and-tube exchangers, compact heat exchangers are characterized by a large heat transfer surface area per unit volume of the exchanger, resulting in reduced space, weight, support structure and footprint, energy requirements and cost, as well as improved process design and plant layout and processing conditions, together with low fluid inventory. The ratio of the heat transfer surface area of a heat exchanger to its volume is called the **area density** or **surface compactness β**. A heat exchanger with $\beta = 700\ m^2/m^3$ (or $200\ ft^2/ft^3$) is classified as being compact. Examples of compact heat exchangers are car radiators ($1000\ m^2/m^3$) and the human lung ($20{,}000\ m^2/m^3$).

Number of fluids:

Most processes of heating, cooling, heat recovery, and heat rejection involve transfer of heat between two fluids. Hence, two-fluid heat exchangers are the most common. Three fluid heat exchangers are widely used in cryogenics and some chemical processes (e.g., air separation systems, a helium–air separation unit, purification and liquefaction of hydrogen, ammonia gas synthesis). Heat exchangers with as many as 12 fluid streams have been used in some chemical process applications.

Flow arrangement:

The choice of a particular flow arrangement is dependent on the required exchanger effectiveness, available pressure drops, minimum and maximum velocities allowed, fluid flow paths, packaging envelope, allowable thermal stresses, temperature levels, piping and plumbing considerations, and other design criteria. Basically there are two types of heat exchangers as Single passing and multi passing. In single passing there are four different subtypes as parallel flow, counter flow, cross flow and split flow. In multi passing there are three different subtypes as cross flow, Shell and tube heat exchanger and plate heat exchanger.

Construction features:

Heat exchangers are frequently characterized by construction features. Four major construction types are tubular, plate-type, extended surface, and regenerative exchangers. Heat exchangers with other constructions are also available, such as scraped surface exchanger, tank heater, cooler cartridge exchanger etc.

- *Tubular exchangers:*

These are generally built of circular tubes, although elliptical, rectangular, or round/flat twisted tubes. Tubular exchangers can be designed for high pressures relative to the environment and high-pressure differences between the fluids. Tubular exchangers are used primarily for liquid-to-liquid and liquid-to-phase change (condensing or evaporating) heat transfer applications.

- *Plate-type heat exchangers:*

These are usually built of thin plates (all prime surface). The plates are either smooth or have some form of corrugation, and they are either flat or wound in an exchanger. Generally, these exchangers cannot accommodate very high pressures, temperatures, or pressure and temperature differences. Plate heat exchangers (PHEs) can be classified as gasketed, welded (one or both fluid passages), or brazed, depending on the leak tightness required.

- *Extended Surface Heat Exchangers:*

One of the most common methods to increase the surface area and exchanger compactness is to add the extended surface (fins) and use fins with the fin density (fin frequency, fins/m or fins/in.) as high as possible on one or both fluid sides, depending on the design requirement. Addition of fins can increase the surface area by 5 to 12 times the primary surface area in general, depending on the design. The resulting exchanger is referred to as an extended surface exchanger. The heat transfer coefficient on extended surfaces may be higher or lower than that on unfinned surfaces. Generally, increasing the fin density reduces the heat transfer coefficient associated with fins.

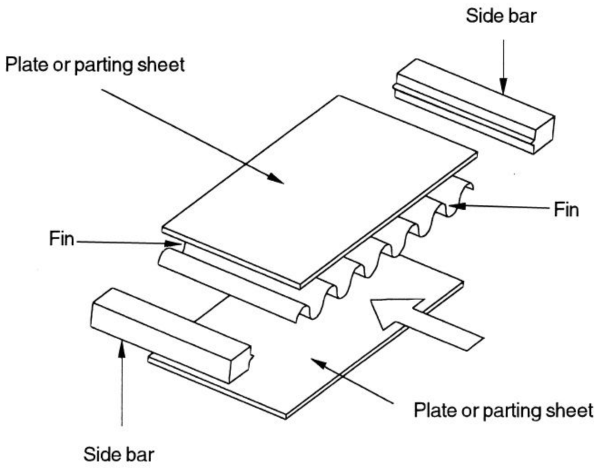

Fig:1 Basic components of plate-fin type heat exchanger

- *Regenerators:*

The regenerator is a storage-type heat exchanger. The heat transfer surface or elements are usually referred to as a matrix in the regenerator. To have continuous operation, either the matrix must be moved periodically into and out of the fixed streams of gases, as in a rotary regenerator or the gas flows must be diverted through valves to and from the fixed matrices as in a fixed matrix regenerator. The latter is also sometimes referred to as a periodic-flow regenerator, a swing regenerator, or a reversible heat accumulator.

III. SHELL AND TUBE HEAT EXCHANGER

In present days shell and tube heat exchanger is the most common type heat exchanger widely use in oil refinery and other large chemical process, because it suits high pressure application.[6] The shell and tube heat exchangers are also widely used in different industries because of its easy in maintenance and low in cost. The major components of shell-and-tube exchangers are briefly described below;

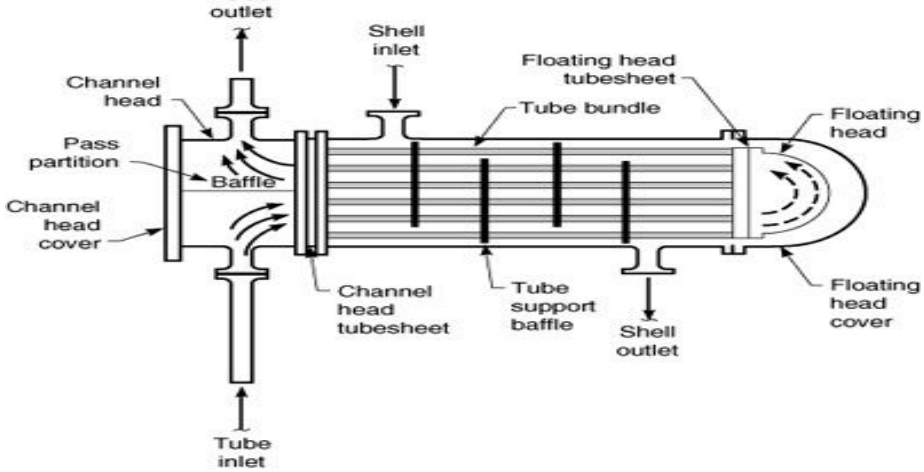

Fig:2 Shell and tube heat exchanger

Shell:

The shell is a container for the shell fluid. Usually, it is cylindrical in shape with a circular cross section, although shells of different shapes are used in specific applications and in nuclear heat exchangers to conform to the tube bundle shape. The shell is made from a circular pipe if the shell diameter is less than about 0.6m (2 ft) and is made from a metal plate rolled and welded longitudinally for shell diameters greater than 0.6m (2 ft). The E shell is the most common, due to its low cost and simplicity, and has the highest log-mean temperature-difference correction factor F. Although the tubes may have single or multiple passes, there is one pass on the shell side. To increase the mean temperature difference and hence exchanger effectiveness, a pure counter flow arrangement is desirable for a two-tube-pass exchanger. This is achieved by use of an F shell having a longitudinal baffle and resulting in two shell passes. Split- and divided-flow shells, such as G, H, and J , are used for specific applications, such as thermosiphon boiler, condenser, and shell-side low pressure drops. The K shell is a kettle reboiler used for pool boiling applications. The X shell is a cross flow exchanger and is used for low pressure drop on the shell side and/or to eliminate the possibility of flow-induced vibrations.

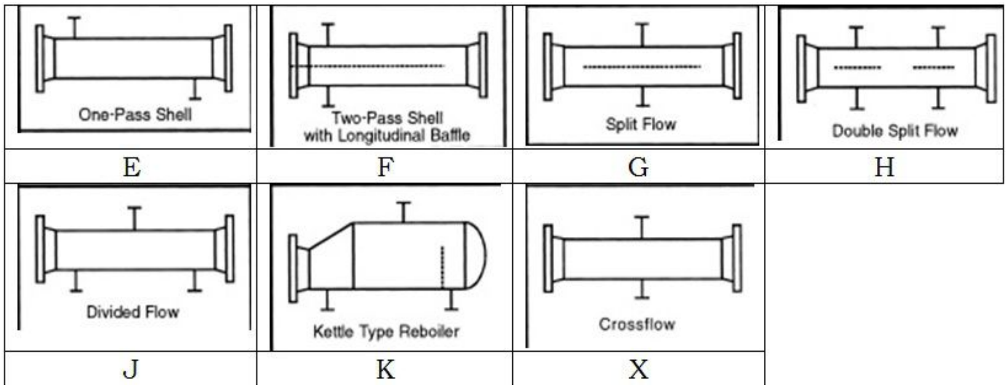

Fig:3 Standard shell types (From TEMA, 1999)

Nozzles:

The entrance and exit ports for the shell and tube fluids, referred to as nozzles, are pipes of constant cross section welded to the shell and channels. They are used to distribute or collect the fluid uniformly on the shell and tube sides. Note that they differ from the nozzle used as a fluid metering device or in jet engines, which has a variable flow area along the flow length.

Tubes:

Round tubes in various shapes are used in shell-and-tube exchangers. Most common are the tube bundles with straight and U-tubes used in process and power industry exchangers. However, sine-wave bend, J-shape, L-shape or hockey sticks, and inverted hockey sticks are used in advanced nuclear exchangers to accommodate large thermal expansion of the tubes. In most applications, tubes have single walls, but when working with radioactive reactive, or toxic fluids and potable water, double-wall tubing is used. In most applications, tubes are bare, but when gas or low-heat-transfer coefficient liquid is used on the shell side, low-height fins (low fins) are used on the shell side. Also, special high-fluxboiling surfaces employ modified low-fin tubing. These are usually integral fins made from a thick-walled tube, Tubes are drawn, extruded, or welded, and they are made from metals, plastics, and ceramics, depending on the applications.

Front and Rear-End Heads:

These are used for entrance and exit of the tube fluid; in many rear-end heads, a provision has been made to take care of tube thermal expansion. The front-end head is stationary, while the rear-end head could be either stationary (allowing for no tube thermal expansion) or floating, depending on the thermal stresses between the tubes and shell. The major criteria for selection of the front-end head are cost, maintenance and inspection, hazard due to mixing of shell and tube fluids, and leakage to ambient and operating pressures. The major criteria for selection of the rear-end head are the allowance for thermal stresses, a provision to remove the tube bundle for cleaning the shell side, prevention of mixing of tube and shell fluids, and sealing any leakage path for the shell fluid to ambient.

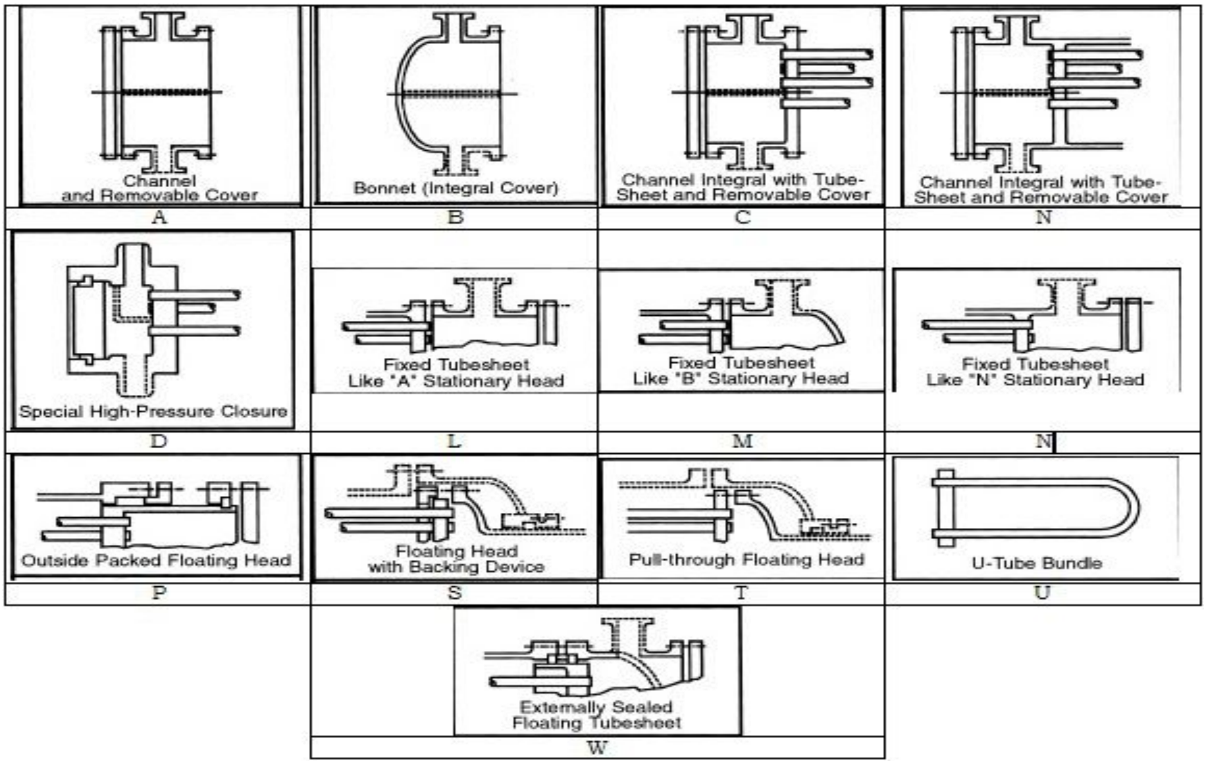

Fig:4 Standard front- and rear-end head types (From TEMA, 1999)

Baffles:

Baffles may be classified as transverse and longitudinal types. The purpose of longitudinal baffles is to control the overall flow direction of the shell fluid such that a desired overall flow arrangement of the two fluid streams is achieved. For example, F, G, and H shells have longitudinal baffles. Transverse baffles may be classified as plate baffles and grid (rod, strip, and other axial-flow) baffles. Plate baffles are used to support the tubes during assembly and operation and to direct the fluid in the tube bundle approximately at right angles to the tubes to achieve higher heat transfer coefficients. Plate baffles increase the turbulence of the shell fluid and minimize tube-to-tube temperature differences and thermal stresses due to the cross flow. The choice of baffle type, spacing, and cut is determined largely by flow rate, desired heat transfer rate, allowable pressure drop, tube support, and flow-induced vibrations. Disk and doughnut baffles/support plates are used primarily in nuclear heat exchangers. These baffles for nuclear exchangers have small perforations between tube holes to allow a combination of cross flow and longitudinal flow for lower shell-side pressure drop. The combined flow results in a slightly higher heat transfer coefficient than that for pure longitudinal flow and minimizes tube-to-tube temperature differences. Rod (or bar) baffles, the most common type of grid baffle, used to support the tubes and increase the turbulence of the shell fluid. The flow in a rod baffle heat exchanger is parallel to the tubes, and flow-induced vibrations are virtually eliminated by the baffle support of the tubes. One alternative to a rod baffle heat exchanger is the use of twisted tubes. Twisted tubes provide rigidity and eliminate flow-induced tube vibrations, can be cleaned easily on the shell side with hydro jets, and can be cleaned easily inside the tubes, but cannot be retubed. A helical baffle shell-and-tube exchanger with baffles as shown in Fig:5 also has the following advantages: a lower shell-side pressure drop while maintaining the high heat transfer coefficient of a segmental exchanger, reduced leakage and elimination of dead spots and recirculation zones (thus reducing fouling). Every shell-and-tube exchanger has transverse baffles except for X and K shells, which have support plates because the sole purpose of these transverse baffles is to support the tubes.

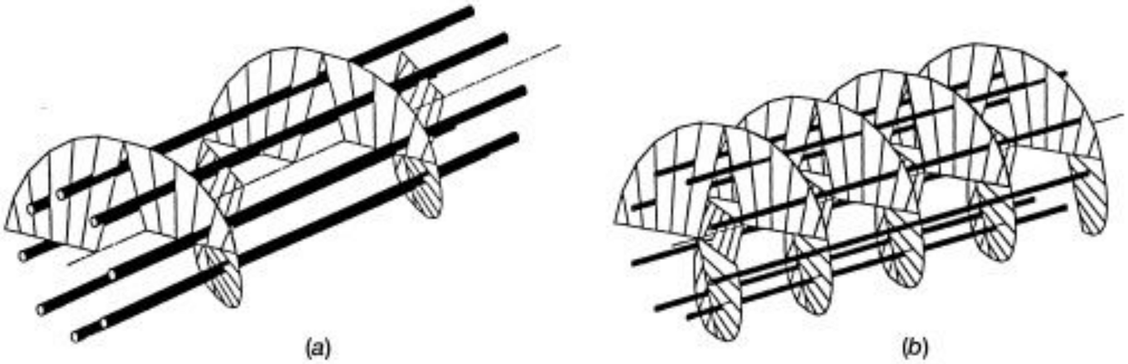

Fig:5 Helical baffle shell-and-tube exchanger: (a) single helix; (b) double helix.

Tubesheets:

These are used to hold tubes at the ends. A tubesheet is generally a round metal plate with holes drilled through for the desired tube pattern, holes for the tie rods (which are used to space and hold plate baffles), grooves for the gaskets, and bolt holes for flanging to the shell and channel. To prevent leakage of the shell fluid at the tubesheet through a clearance between the tube hole and tube, the tube-to-tubesheet joints are made by many methods, such as expanding the tubes, rolling the tubes, hydraulic expansion of tubes, explosive welding of tubes, stuffing of the joints, or welding or brazing of tubes to the tubesheet.

Channel covers:

The channel covers are round plates that bolt to the channel flanges and can be removed for tube inspection without disturbing the tube side piping. In smaller heat exchangers, bonnets with flanged nozzles or threaded connections for the tube side piping are often used instead of channels and channel covers.

IV. LITERATURE REVIEW

Jorge A.W. Gut, Jos_e M. Pinto[1]: In this paper a mathematical model is developed in algorithmic form for the steady-state simulation of gasketed plate heat exchangers with generalized configurations. The configuration is defined by the number of channels, number of passes at each side, fluid locations, feed connection locations and type of channel-flow. The main purposes of this model are to study the configuration influence on the exchanger performance and to further develop a method for configuration optimization. The main simulation results are: temperature profiles in all channels, thermal effectiveness, distribution of the overall heat transfer coefficient and pressure drops. Moreover, the assumption of constant overall heat transfer coefficient is analyzed. He concluded that, The configuration of a plate heat exchanger (PHE) was characterized by a set of six parameters and a methodology to detect equivalent configurations was presented. Based on this parameterization, a detailed mathematical model for the simulation of a PHE in steady-state with a general configuration was developed in algorithmic form. This assembling algorithm made the simulation and comparison of different configurations more flexible. An important feature of the proposed algorithm is that it may be coupled to any procedure to solve the system of differential and algebraic equations. The assumption of constant overall heat transfer coefficient throughout the exchanger, often used for the mathematical modeling, was tested and showed little influence over the main simulation results for heat exchange (thermal effectiveness and outlet temperatures). The presented assembling algorithm is an important tool for the study of the influence of the configuration on the exchanger performance, and can be further used to develop optimization methods for selecting the plate heat exchanger configuration.

Amey Shirodkar and Sangita Bansode[2]: This paper is concerned with the thermo-mechanical issue that is thermal expansion of tubesheet due to high temperature. It is necessary to make a optimize design which is safe, economical and accurate. Due to high temperature and high pressure fluids tubesheet of heat exchanger expands which results expansion of shell which causes deformation of heat exchanger. To avoid this deformation, analysis of effect of temperature variation and associated stresses in the tubesheet is necessary. Objective of this paper is to analyse the temperature variation at the junction of shell to tubesheet junction in shell and tube heat exchanger and optimization of tubesheet thickness. It concludes that due to high temperature and pressure large stresses are generated at the junction of shell and tubesheet junction of heat exchanger. These stresses are validated with Software (PVElite, ANSYS) and Mathematical (ASME Code, Section VIII, Division I) method. Optimized thickness of tubesheet is achieved and the stresses produced in the optimize case is also validated with the PVEite and ANSYS software. So it is economical as well as it ensures safety of heat exchanger.

Manoj Kumar Pandita, Prof Ashok Kumar Gupta, Kailash Kumar Lahadotiya[3]: This paper gives the study to predict the performance of a shell and tube heat exchanger. The performance of the heat exchanger has been evaluated by using the CFD package Fluent for different baffle angles. An attempt has been made to calculate the performance of the heat exchanger by varying the baffle angles and the results obtained have been compared. The baffles inclination dependencies of the heat transfer coefficient and the pressure drop are investigated by numerically modelling a small heat exchanger. The flow and temperature fields inside the shell are resolved using a commercial CFD software tool ANSYS FLUENT. Also the attempts were made to investigate the impacts of various baffle inclination angles on fluid flow and the heat transfer characteristics of a shell-and-tube heat exchanger for three different baffles inclination angles namely 0°, 45° and -45°. The simulation results for shell and tube heat exchangers, one with segmental baffles perpendicular to fluid flow and two with segmental baffles inclined to the direction of fluid flow are compared for their performance. The results are observed to be sensitive to the baffle angles. The steady state heat transfer is found to be more in the case of 45 degrees as compared to the -45 degrees case. He concluded that, There were minor differences in the steady state temperature distribution of the counter flow heat exchanger modelled with +45 degree baffles and -45 degrees baffles. The steady state heat flux comes out to be more in the case of +45 degree baffles case than -45 degrees baffles case. The heat flux comes of 0 degree baffles come out intermediate between 45 and -45 degrees cases. Thus any inclination of the baffles in the positive direction will increase the heat transfer and any angle or inclination in the negative direction will reduce the heat flux.

Patel Dharmik Aa, V. D. Dhimanb, Jignesh J. Patelc, Ravi Engineer[4]: In this paper the study involves CFD analysis of triple concentric tube heat exchanger by using previous research's mathematical model, experimental model and correlation. The comparison is carried out between CFD result and literature result. Effectiveness of heat exchanger increases with increased inner tube diameter. Effectiveness of heat exchanger increases with increased inner annulus diameter at the beginning and decreases when flow becomes laminar. The study concludes that, for triple concentric tube heat exchanger parameters which affect the performance should be relative in sizes or radius of inner tube, inner annulus and outer annulus, mass flow rate, material of tube. With the increase in inner tube diameter heat transfer rates of hot fluid, inner cold fluid and outer cold fluid increased, heat transfer coefficient of hot fluid was increased and heat transfer coefficient of inner cold fluid was decreased. Heat transfer coefficient of outer cold fluid remains constant. Overall heat transfer coefficient based on inner diameter of inner annulus and effectiveness was increased with the increase in inner tube diameter. With the increase in inner annulus diameter heat transfer rate of hot fluid and inner cold fluid increased up to 26 mm after that it decreased due to decrease in temperature difference and flow became laminar. Heat transfer coefficient of hot fluid decreased whereas heat transfer coefficient of outer cold fluid was increased. Overall heat transfer coefficient based on inner diameter of inner annulus was also increased. Effectiveness of triple concentric tube heat exchanger was increased up to 26 mm and after that it was decreased.

G.V.N.Santhosh, Y.V.RamanaMurty, S.SwethaRadha[5]: In this study, the hot fluid will be cooled using seawater with the help of shell and tube heat exchanger. A characteristic of heat exchanger design is the procedure of specifying a design heat transfer area and pressure drops and checking whether the assumed design satisfies all requirement or not. The purpose of this project is how to design the heat exchanger which is the majority type of liquid-to-liquid heat exchanger. General design considerations and design procedure are also illustrated in this project. This study gives an opportunity and experience, to use our limited knowledge. It is a good solution to bridge the gates between institution and industries. Through this project a "**shell and Tube heat exchanger**" is developed which is working satisfactorily under standard conditions and which is helped to know how to achieve low cost semi automation application.

Anil Kumar Samal, Prof. Basudeb Munshi[6]: The study deals with the design of shell and tube heat exchanger with helical baffle and study the flow and temperature field inside the shell using ANSYS software tools. The heat exchanger contains 7 tubes and 600 mm length shell diameter 90 mm. The helix angle of helical baffle will be varied from 00 to 200. In simulation will show how the pressure vary in shell due to different helix angle and flow rate. The flow pattern in the shell side of the heat exchanger with continuous helical baffles was forced to be rotational and helical due to the geometry of the continuous helical baffles, which results in a significant increase in heat transfer coefficient per unit pressure drop in the heat exchanger. The study model predicts the heat transfer and pressure drop with an average error of 20%. Thus the model can be improved. The assumption worked well in this geometry and meshing expect the outlet and inlet region where rapid mixing and change in flow direction takes place. Thus improvement is expected if the helical baffle used in the model should have complete contact with the surface of the shell, it will help in more turbulence across shell side and the heat transfer rate will increase. If different flow rate is taken, it might be help to get better heat transfer and to get better temperature difference between inlet and outlet. Moreover the model has provided the reliable results by considering the standard k-e and standard wall function model, but this model over predicts the turbulence in regions with large normal strain. Thus this model can also be improved by using Nusselt number and Reynolds stress model, but with higher computational theory. Furthermore the enhance wall function are not use in this project, but they can be very useful. The heat transfer rate is poor because most of the fluid passes without the interaction with baffles. Thus the design can be modified for better heat transfer in two ways either the decreasing the shell diameter, so that it will be a proper contact with the helical baffle or by increasing the baffle so that baffles will be proper contact with the shell. It is because the heat transfer area is not utilized efficiently. Thus the design can further be improved by creating cross-flow regions in such a way that flow doesn't remain parallel to the tubes. It will allow the outer shell fluid to have contact with the inner shell fluid, thus heat transfer rate will increase.

Thundil Karuppa Raj R, Srikanth Ganne[7]In this study, attempts were made to investigate the impacts of various baffle inclination angles on fluid flow and the heat transfer characteristics of a shell-and-tube heat exchanger for three different baffle inclination angles namely 0°,10° and 20°. The simulation results for various shell and tube heat exchangers, one with segmental baffles perpendicular to fluid flow and two with segmental baffles inclined to the direction of fluid flow are compared for their performance. The shell side design has been investigated numerically by modeling a small shell-and-tube heat exchanger. The study is concerned with a single shell and single side pass parallel flow heat exchanger. The flow and temperature fields inside the shell are studied using non-commercial CFD software tool **ANSYS CFX 12.1**. For a given baffle cut of 36 %, the heat exchanger performance is investigated by varying mass flow rate and baffle inclination angle. From the CFD simulation results, the shell side outlet temperature, pressure drop, recirculation near the baffles, optimal mass flow rate and the optimum baffle inclination angle for the given heat exchanger geometry are determined. The shell side of a small shell-and-tube heat exchanger is modeled with sufficient detail to resolve the flow and temperature fields. It concludes, The shell side of a small shell-and-tube heat exchanger is modeled with sufficient detail to resolve the flow and temperature fields. For the given geometry the mass flow rate must be below 2 kg/s, if it is increased beyond 2 kg/s the pressure drop increases rapidly with little variation in outlet temperature. The pressure drop is decreased by 4 %, for heat exchanger with 10° baffle inclination angle and by 16 %, for heat exchanger with 20° baffle inclination angle. The maximum baffle inclination angle can be 20°, if the angle is beyond 20°, the centre row of tubes are not supported. Hence the baffle cannot be used effectively. Hence it can be concluded shell and tube heat exchanger with 20° baffle inclination angle results in better performance compared to 10° and 0° inclination angles.

Vindhya Vasiny Prasad Dubey, Raj Rajat Verma, Piyush Shanker Verma, A.K.Srivastava[8]: This paper gives extensive thermal analysis of the effects of severe loading conditions on the performance of the heat exchanger. To serve the purpose a simplified model of shell and tube type heat exchanger has been designed using kern's method to cool the water from 55˚C to 45˚C by using water at room temperature. Then we have carried out steady state thermal analysis on ANSYS 14.0 to justify the design. After that the practical working model of the same has been fabricated using the components of the exact dimensions as derived from the designing. We have tested the heat exchanger under various flow conditions using the insulations of aluminium foil, cotton wool, tape, foam, paper etc. We have also tested the heat exchanger under various ambient temperatures to see its effect on the performance of the heat exchanger. Moreover we have tried to create the turbulence by closing the pump opening and observed its effect on its effectiveness. All these observations along with their discussions have been discussed in detail inside the paper. On the basis of above study it is clear that a lot of factors affect the performance of the heat exchanger and the effectiveness obtained by the formulas depicts the cumulative effect of all the factors over the performance of the heat exchanger. It may be said that the insulation is a good tool to increase the rate of heat transfer if used properly well below the level of critical thickness. Amongst the used materials the cotton wool and the tape have given the best values of effectiveness. Moreover the effectiveness of the heat exchanger also depends upon the value of turbulence provided. However it is also seen that there does not exists direct relation between the turbulence and effectiveness and effectiveness attains its peak at some intermediate value. The ambient conditions for which the heat exchanger was tested do not show any significant effect over the heat exchanger's performance.

Che´rif Bougriou, Khireddine Baadache[9]: This study concerns a new type of heat exchangers, which is that of shell-and-double concentric tube heat exchangers. These heat exchangers can be used in many specific applications such as air conditioning, waste heat recovery, chemical processing, pharmaceutical industries, power production, transport, distillation, food processing, cryogenics, etc. The case studies include both design calculations and performance calculations. It is demonstrated that the relative diameter sizes of the two tubes with respect to each other are the most important parameters that influence the heat exchanger size. The shell-and-double concentric-tube heat exchanger is characterized with the heat transfer between three fluids, with its compactness and can be widened to the cross flow heat exchangers (simple-flow, parallel-flow and counter flow). It can also have risen with concentric tubes under shape; helical, in serpentine or in spiral in a shell. This heat exchanger can be in simple or corrugated tubes, with fins of different forms. This device can be used in all the domains of applications of the heat exchangers. It can work in simple phase (heater or cooler) or with phase change of fluids, such as condensers and evaporators. The performance and/or the heat exchanger length are strongly dependent upon the tube radii that form the heat exchanger. Optimizing a shell-and-double concentric tube heat exchanger lengthwise provides a considerable amount of savings in space and material when compared with a shell and-tube heat exchanger with the same outer tube diameter of the double concentric-tubes and the shell diameter.

Andre´ L.H. Costa a,*, Eduardo M. Queiroz[10]: This paper presents a study about the design optimization of shell-and-tube heat exchangers. The formulated problem consists of the minimization of the thermal surface area for a certain service, involving discrete decision variables. Additional constraints represent geometrical features and velocity conditions which must be complied in order to reach a more realistic solution for the process task. The optimization algorithm is based on a search along the tube count table where the established constraints and the investigated design candidates are employed to eliminate non optimal alternatives, thus reducing the number of rating runs executed. The performance of the algorithm and its individual components are explored through two design examples. The obtained results illustrate the capacity of the proposed approach to direct the optimization towards more effective designs, considering important limitations usually ignored in the literature. The study concludes the optimization of the design of shell-and-tube heat exchangers. The formulation of the problem seeks the minimization of the thermal surface of the equipment, for certain minimum excess area and maximum pressure drops, considering discrete decision variables. Important additional constraints, usually ignored in previous optimization schemes, are included in order to approximate the solution to the design practice. The optimization algorithm applied to the formulated problem involves a tube count table search based on a controlled path along the decision variable space. The definition of variable bounds, feasibility tests and fathoming procedures allow a sensible reduction of computational costs. The algorithm can be associated to any desired rating code for the necessary thermal and hydraulic evaluations.

O. García-Valladares[11]: A detailed one-dimensional steady and transient numerical simulation of the thermal and fluid-dynamic behaviour of triple concentric tube heat exchangers has been developed. The governing equations (continuity, momentum and energy) inside the inner tube and the annulus (inner and outer), together with the energy equations in the inner, intermediate and outermost tube wall and insulation, are solved iteratively in a segregated manner. The discretized governing equations in the zones with fluid flow are coupled using an implicit step by step method. This formulation requires the use of empirical information for the evaluation of convective heat transfer, shear stress and void fraction. An implicit central difference numerical scheme and a line-by-line solver was used in the inner and intermediate tube walls and the outermost tube wall with insulation. All the flow variables (enthalpies, temperatures, pressures, mass fractions, velocities, heat fluxes, etc.) together with the thermo physical properties are evaluated at each point of the grid in which the domain is discretized. Different numerical aspects and comparisons with results obtained from the technical literature are presented in order to verify and validate the model. In this study a numerical model for analyzing the behaviour of triple concentric-tube heat exchangers has been developed by means of a transient one-dimensional analysis of the fluid flow governing equations and the heat conduction in solids. The empirical coefficients used in the model to evaluate the shear stress and heat flux have been chosen after a comparison of different options proposed in the technical literature. The simulation has been implemented on the basis of an implicit step by step numerical scheme for the fluid flow inside the inner tube and annulus, and an implicit central difference numerical scheme in the solids. The six zones that form the triple-tube heat exchanger are solved iteratively in a segregated way until convergence is reached. The model considers heat transfer in solids, local thermo physical properties and local empirical coefficients in each CV. The discretized governing equations allowed extension of this numerical model to cases where evaporation or condensation appeared inside this type of heat exchanger, considering adequate empirical correlations for these zones and also with the knowledge of the thermo physical properties of the fluid or fluids for these conditions. The model presented considers realistic situations, such as transient effects, heat conduction within the tube walls and insulation, temperature dependent fluid properties and the possibility of two-phase flow conditions. Analytical approaches cannot consider these possibilities. The models for solid walls and insulation developed have been validated with analytical solution of heat conduction. In general, the flexibility and generality of the detailed simulation model is demonstrated in this paper by comparison with different cases. The model developed can be an excellent tool to optimize the efficiency of triple concentric-tube heat exchangers, and consequently the energy consumption.

Abdalla Gomaa, M. A. Halim, Ashraf Mimi Elsaid[12]: In this study the experimental and numerical investigations of the triple concentric-tube heat exchanger are presented with particular reference to double tube heat exchanger. The purpose is to present a clear view on the thermo-fluid characteristics of this type of heat exchangers with different key design parameters leading to design optimization. Three fluids being considered which are chilled water in inner tube, hot water in inner annulus, and normal tap water in outer annulus. Numerical CFD model is developed using a finite volume discretization method. The numerical model is validated and then extended to cover more extra design parameters. Four flow patterns are conducted of counter current, co-current, counter current with co-current and co-current with counter current flow. Correlations of Nusselt number, friction factor and heat exchanger effectiveness with the dimensionless design parameters are also presented. The triple tube heat exchanger contributes higher heat exchanger effectiveness and more energy saving compared with double tube heat exchanger per unit length. In the present investigation, the thermo-fluid performance criterion of the triple concentric-tube heat exchanger has been addressed. Experimental and numerical investigations through the triple and double concentric-tube heat exchanger are carried out. The experiments are done for a range of Reynolds number $1720 \leq Reim \leq 6260$. The validated numerical model is extended to cover more design parameters. The investigation covers the effect of key design parameters of hot fluid temperature, hot fluid velocity, flow patterns and inner annulus spacing. The heat transfer per unit pumping power and the heat exchanger effectiveness are presented. Correlations for Nusselt number, friction factor and effectiveness based on dimensionless design parameters are also presented. The main conclusions are summarized as, The effectiveness of triple tube heat exchanger is higher that of the double tube heat exchanger for both parallel and counter flow by *51.4%* and *53.8%* respectively. At different flow arrangements, the Nusselt number and the effectiveness of the triple tube heat exchanger are higher than that of the double tube heat exchanger. The higher values of the Nusselt number and heat exchanger effectiveness are obtained at counter current flow pattern. At a low velocity region ($Re \leq 3000$), the heat transfer per unit pumping power for double tube heat exchanger is higher than that of triple tube heat exchanger, while it is lower than that of the triple tube heat exchanger with flow velocity range ($Re \geq 3500$). At a fixed mass flow rate, the effectiveness of the triple tube heat exchanger is enhanced at lower values of the inner annulus spacing. Higher values of the performance index are obtained at lower values of both Reynolds number and inner annulus spacing. The triple tube heat exchanger contributes higher heat exchanger effectiveness and more energy saving compared with double tube heat exchanger per unit length.

V. CONCLUSION

Heat exchanger is one of the most efficient device to transfer heat from one fluid to other fluid. In this field considerable developments have driven in the past few years. As a result of which there are varieties of heat exchangers available in the market depending on the different use and different applications. In present day shell and tube heat exchanger is the most common type heat exchanger widely used in oil refinery and other large chemical process, because it suits high pressure application. The shell and tube heat exchangers are also widely used in different industries because of its easy in maintenance and low in cost. A Computational fluid dynamics can be used as design tool in the preliminary stage of design of shell and tube heat exchanger.

VI. ACKNOWLEDGEMENTS

I have worked with many people around, without whom this work would never have been completed. It is a pleasure to convey my gratitude to all of them in my humble acknowledgment.

First & foremost, I would like to record my gratitude to my project guide, Prof. S. K. Dahake (MET-BKC), who has supported me throughout my work with his patience and knowledge and always allowed me to think in my way and try out my ideas. I would also like to record my gratitude to Prof. S. V. Ingale, HOD, Mechanical Engineering Department, MET-BKC, for giving me this opportunity to present my work.

Many thanks go to all the friends and all teaching and non-teaching staff of Mechanical Engineering Department, who supported me throughout the year.

Finally, I thank my parents for supporting me throughout all my studies and for making me able to reach at the place where I am.

REFERENCES

1. *Jorge A.W. Gut, Jos_e M. Pinto "Modeling of plate heat exchangers with generalized configurations" International Journal of Heat and Mass Transfer 46 (2003) 2571–2585.*
2. *Amey Shirodkar and Sangita Bansode "Optimization of Tubesheet Thickness of Shell and Tube Heat Exchanger" IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 6, August 2014.*
3. *Manoj Kumar Pandita, Prof. Ashok Kumar Gupta, Kailash Kumar Lahadotiya "CFD analysis of a single shell and single tube heat exchanger and determining the effect of baffle angle on heat transfer" International journal of engineering sciences & research technology [Pandita*, 4.(6): June, 2015] ISSN: 2277-9655.*
4. *Patel Dharmik A, V. D. Dhiman, Jignesh J. Patel, Ravi Engineer "CFD analysis of triple concentric tube heat exchanger" University Journal of Research ISSN (Online) 0000–0000, ISSN (Print) 0000–0000.*
5. *G.V.N.Santhosh, Y.V.RamanaMurty, S.SwethaRadha "Performance Analysis of Shell And Tube Heat Exchanger" International Journal of Mechanical Engineering and Computer Applications, Vol 2, Issue 2, March- April 2014, ISSN 2320-6349.*
6. *Anil Kumar Samal "Shell and tube heat exchanger design using CFD tools".*
7. *Thundil Karuppa Raj R, Srikanth Ganne "Shell side numerical analysis of a shell and tube heat exchanger considering the effects of baffle inclination angle on fluid flow using CFD".*
8. *Vindhya Vasiny Prasad Dubey, Raj Rajat Verma, Piyush Shanker Verma, A.K.Srivastava "Performance Analysis of Shell & Tube Type Heat Exchanger under the Effect of Varied Operating Conditions" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 3 Ver. VI (May- Jun. 2014), PP 08-17.*
9. *Che´rif Bougriou, Khireddine Baadache "Shell-and-double concentric-tube heat exchangers" Heat Mass Transfer (2010) 46:315–322 DOI 10.1007/s00231-010-0572-z.*
10. *Andre´ L.H. Costa , Eduardo M. Queiroz "Design optimization of shell-and-tube heat exchangers" Applied Thermal Engineering 28 (2008) 1798–1805.*
11. *O. García-Valladares "Numerical simulation of triple concentric-tube heat exchangers" International Journal of Thermal Sciences 43 (2004) 979–991.*
12. *Abdalla Gomaa, M.A. Halim, Ashraf Mimi Elsaid "Experimental and numerical investigations of a triple concentric-tube heat exchanger" PII: S1359-4311(15)01434-9 DOI: http://dx.doi.org/doi: 10.1016/j.applthermaleng.2015.12.053 Reference: ATE 7467.*