Review on Design of Components and Development In Shell And Tube Type Heat Exchanger For Chemical Industry

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Abstract- *This project is mainly focusing on designing and development of one type of heat exchanger which is Shell and Tube type Heat Exchanger, step by step on designing, by LMTD method and calculate Certain Outputs that are needed. The Calculating formulas are referred from TEMA an IS4305 standards and to design this Heat Exchanger many considerations were taken. It consists of designing dimensions of various parts of Heat Exchangers such as Shell, Tubes and Bonnets etc. and to analyze thermal properties of the same.*

In present day shell and tube heat exchanger is the most common type heat exchanger widelyuse in oil refinery and other large chemical process, because it suits high pressure application.

In development stage various trials and Constructional Changes in designing Parameters are to be done and develop system's Analysis is to be compared with original Systems analysis.

Keywords- Log mean temperature difference, Tubular Exchanger Manufacturing Association, Shell and Tube Heat Exchanger

I. INTRODUCTION

A heat exchanger is defined as a device which is used to recover the thermal energy between two or more fluids available at different temperatures. Distinct heat exchangers are in practice for several applications in the industries. The design of heat exchanger includes many geometric and operating parameters for a heat exchanger geometry which fulfils the thermal energy demand and system effectiveness within the given constraints . These are used as process equipment in the process, petroleum, air conditioning, refrigeration, transportation, power, cryogenic, alternate fuels, heat recovery and many other industries.

This exchanger is built of a bundle of round tubes mounted in a large cylindrical shell with the tube axis parallel to the shell to transfer the heat between the two fluids. The fluid flows inside the tubes and other fluid flows across and along the tubes of heat exchanger. But for baffled shell-and-tube heat exchanger the shell side stream flows across between pairs of baffles and then flows parallel to the tubes as it flows from one baffle compartment to the next. Due to which heat transfer is seen in it.

II. OBJECTIVES OF RESEARCH:

i) To select material for a shell and tube heat exchanger.
ii) To obtained the best Dimensions of heat exchangers.
iii) To design and build model of a shell and tube heat exchanger.
iv) To analyze normal STHE model with improved model in software.

III. NEED OF DEVELOPMENT

Heat exchangers are used to transfer heat from one media to another. It is most commonly used in space heating such as in the home, refrigeration, power plants and even in air conditioning. It is also used in the radiator in a car using an antifreeze engine cooling fluid. Heat exchangers are classified according to their flow arrangements where there are the parallel flow, and the counter flow. Apart from this, heat exchangers also have different types depending on their purpose and how that heat is exchanged. Normally in conventional heat exchangers not total heat transferred from one medium to another medium that's why the development in the components of the heat exchanger is essential for improvisation in efficiency.

IV. LITERATURE REVIEW

A. Pradip Pathade, Anmol Singh (2017) This paper stated that many industrial facilities face problem of effective heat transfer due to the performance issues of heat exchangers. optimizing changes in flow regime and redesigning heat exchangers for best possible heat exchange for maximizing profits. twisted tube type shell and tube heat exchanger (shell and tube type heat exchanger) combats nearly all performance drawbacks in conventional heat exchangers. 'twisted tube technology' is the new technology in the era of heat transfer equipment the concept of swirl flow moment of fluid creates turbulence enhancing thermal-hydraulic performance of shell and tube type heat exchanger. the shell and tube type heat exchanger increases the overall efficiency ofheat transfer.fig [4]. the advantageof twisted type shell and tube heat exchanger over conventional heat exchanger are studied in this paper on the basis of economics, performance and material of construction including reactive metals for improved performance, no vibration, and no dead spots etc.The retrofit situation is increased capacity, lower installed cost, lower shell sidepressure drop and low fouling over shell and tube heat exchanger. [7]

B. Vindhya Vasiny Prasad Dubey, Raj Rajat Verma, (2014) This paper consists of 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 STHE has been designed using kern's method to cool the water from 55 to 45 by using water at room temperature. Then we have carried out steady state thermal analysis on ANSYS 14to justify the design. After that the 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 'Al' 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.. All these observations along with their discussions have been discussed in detail inside the paper.[2]

C. Daniel S. Janikowski(2014) This paper helps to identify the factors that need to be considered when selecting a material. Properties compared in this paper include corrosion resistance, stress corrosion, cracking potential, thermal and mechanical properties, erosion resistance, vibration potential, and temperature limitations.

The property comparison guides are intended to be quick tools to assist the user in selecting a cost-effective material for a specific application.[5]

D. Prof. Sunil S. Shinde, Mr. Pravinkumar V. Hadgekar (2013) This paper consists of Computational Fluid Dynamic (CFD) is a useful tool in solving and analyzing problems that involve fluid flows, while STHE is the most common type of heat exchanger and widely use in oil refinery and other large chemical processes because it suite for high pressure application. The numerical simulation of Shell & Tube Heat Exchanger with center tube called Helix exchanger with center tube with different baffle inclination is to be done.[4]

E. Ms.Vandita Thantharate, Dr.D.B.Zodpe (2013) This paper consists of heat exchangers various active and passive techniques have been used over plain tubes to enhance heat transfer. Twisted tube is a passive technique. The main aim of this study is to determine its feasibility for use in applications like automobile radiators, air conditioners or similar type of multi pass applications. In present study, twisted tube is compared with plain tube in multiple tube pass (4 passes) of 0.3 m length each pass for four flow rates of 1.5 lpm, 1.37 lpm, 0.5 lpm and 0.24 lpm resulting in Reynolds number of Re 625 to 7000 covering turbulent and laminar range. The comparison is done analytically, experimentally and numerically. The results showed that for the given mass flow rates and inlet temperature, the performance of plain tube is better than twisted tube in low flow rates.For high Reynolds number range the performance of twisted tube is better, the reason is attached flow through tubes. Thus this study concludes that for multi pass configuration one should always select twisted tubes according to the required flow rate.[3]

F. Anil Kumar and Samal Roll (2013) In present day 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. The process in solving simulation consists of modeling and meshing the basic geometry of STHE using and temperature field inside the shell using ANSYS software tools. 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 heattransfer coefficient per unit pressure drop in the heat exchanger.[8]

G. Jurandir Primo (2012) This paper consists of the intercoolers, boilers, pre-heaters and shell and tube type heat exchangers in inside power plants as well as other engineering processes, heat exchangers are utilized for controlling heat energy. Heat exchangers are devices that regulate efficient heat transfer from one fluid to another. There are two main types of heat exchangers. The first type of a heat exchanger is called the recuperative type, in which heat are exchanged on either side of a dividing wall by fluids, The second type is regenerative type, in which hot and cold fluids are in the same space which contain a matrix of materials which work alternately as source for heat flow. The optimum thermal design of a STHE involves the consideration of many interacting design parameters.[1]

H. Kevin m. Lunsford (2006) This paper it is stated that the 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. Processes which use heat transfer equipment must frequently be improved for these reasons. This paper provides some methods for increasing shell-and-tube exchanger performance. The methods consider whether the exchanger is performing correctly to begin with, excess pressure drop capacity in existing exchangers, the revaluation of fouling factors and their effect on exchanger calculations, and the use of augmented surfaces and enhanced heat transfer. Three examples are provided to show how commercial process simulation programs and shell-and-tube exchanger rating programs may be used to evaluate these exchanger performance issues. The last example shows how novel heat transfer enhancement can be evaluated using basic shell-and-tube exchanger rating calculations along with vendor supplied enhancement factors.[5}

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I. Sanjay Kumar Sharma and Vikas Sharma(2013) This study presents the results of computational numerical analysis of air flow and heat transfer in a lightweight automobile engine, considering three different morphology pin fins. A numerical study using ANSYSfluent was conducted to find the optimum pin shape based on minimum pressure dropand maximizing the heat transfer across the Automobile engine body. The results indicate that the dropshaped pin fins show improved results on the basis of heat transfer and pressure drop by comparing otherfins. The reason behind the improvement in heat transfer by drop shape pin fin was increased wettedsurface area and delay in thermal flow separation from drop shape pin fin.**[9]**

J. Vindhya Vasiny Prasad Dubey, Raj Rajat Verma(2014) This paper is concerned with the study of shell & tube type heat exchangers along
with its applications and also refers to several scholars who have given the contribution in this regard. Moreover the constructional details, design methods and the reasons for the wide acceptance of shell and tube type heat exchangers has been described in details inside the paper.[10]

K. Amol Niphade, Prof. H. A. Chavan, Swapnil.S. Kulkarni (2015) The heat exchanger for 'dairy' calls for an ingenious design for turning around the high volume of milk in short span of time. This work shall be focused on determining the design alternatives for the heat exchanger. The current needs are met with a shell and tube type heat exchanger with support offered for volume of about five thousand liters of milk per day. Mathematical modeling coupled with computational methodology shall be explored for ramping up the volume in excess of twenty thousand liters. ANSYS Fluent shall be deployed for finding solution while mathematical model shall offer alternative methodology for validating the solution.[11]

L. B.Jayachandriah1, K. Rajasekhar(2014) Tubular Heat exchangers can be designed for high pressures relative to environment and high-pressure differences between the fluids. Tubular exchangers are used primarily for liquid-to-liquid. An attempt is made in this paper is for the Design of shell and tube heat exchangers by modeling in CATIA V5 by taking the Inner Diameter of shell is 400 mm, length of the shell is 700 mm and Outer diameter of tube is 12.5mm, length of Tube is 800mm and Shell material as Steel 1008, Tube material as Copper and Brass. By using modeling procedure Assembly Shell and Tube with water as medium is done. By using ANSYS software, the thermal analysis of STHE is carried out by varying the Tube materials. Comparison is made between the Experimental results, ANSYS. With the help of the available numerical results, the design of Shell and Tube heat exchangers can be altered for better efficiency.[12]

V. ANALYTICAL DESIGN OF COMPONENTS DIMENSIONS OF SHELL AND TUBE TYPE HEAT EXCHANGER

A. Design of Shell

Here is a set of steps for the process. Design of a heat exchanger is an iterative (trial & error) process:

Calculate the required heat transfer rate, **Q,** from specified information about fluid flow rates and temperatures.

Make an initial estimate of the overall heat transfer coefficient, **U**, based on the fluids involved.Calculate the log mean temperature difference, **ΔTm**, from the inlet and outlet temperatures of the two fluids.Calculate the estimated heat transfer area required, using: **A = Q/(U*ΔTm).**Select a preliminary heat exchanger configuration.Make a more detailed estimate of the overall heat transfer coefficient, **U**, based on the preliminary heat exchanger configuration.Calculate the mass flow rate again by energy equation after selecting standard area value.The main basic Heat Exchanger equation is:$\mathbf{Q = U \times A \times \Delta T_m}$

also,

Q = m.Cp. (T2 – T1) --- {Joules}

(The log mean temperature difference)

ΔTm = (T1 – t2) – (T2 – t1) ---{°c}

Where:-

U = Overall heat transfer coefficient

M = Mass flow rate

Cp = specific heat of fluids

T1 = Inlet tube side fluid temperature;

t2 = Outlet shell side fluid temperature;

T2 = Outlet tube side fluid temperature;

t1 = Inlet shell side fluid temperature.

Corrosion and fouling consideration-

Fouling is deposit formation, encrustation, deposition, scaling, scale formation, or sludge formation inside heat exchanger tubes.

B. Design of tubes.

The most common sizes used are Ø3/4" and Ø1". Use the smallest diameter for greater heat transfer area with a minimum of Ø3/4" tube due to cleaning considerations and vibration. For shorter tube lengths say < 4ft can be used Ø1/2" tubes.Select the quantity of tubes per side pass to give optimum velocity. For liquids 3-5 ft/s (0.9-1.52 m/s) can be used. Gas velocities are commonly used 50-100 ft/s (15-30 m/s). If the velocity cannot beachieved in a single pass consider increasing the number of passes. The tube length is determined by heat transfer required to process and pressure drop constraints. To meet the design pressure dropconstraints may require an increase in the number of tubes and/or a reduction in tube length. Long tubelengths with few tubes may carry shell side distribution problems.

C. Design of tube sheets.

Tube sheets are usually made from a round flat piece of metal with holes drilled for the tube ends ina precise location and pattern relative to one another. Tubes are attached to the tube sheet by pneumaticor hydraulic pressure or by roller expansion. Tube holes are drilled and reamed and can bemachined with one or more grooves. This greatly increases the strength of the tube joint.

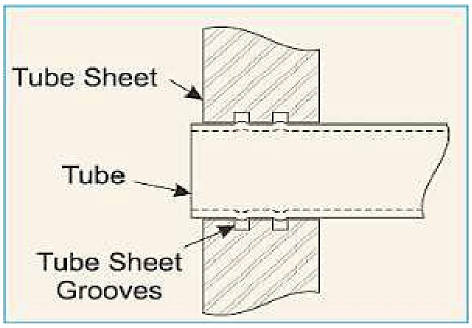

Fig 5.1. Tube Sheet of Shell & Tube Type Heat Exchanger

D. Design of baffles.

Baffles: are used to support tubes and enable a desirable velocity for the fluid to be maintained at theshell side, and prevent failure of tubes due to flow-induced vibration. There are two types of baffles plate and rod.

Plate baffles may be single-segmental, double-segmental, or triple-segmental:

Selecting baffles are single segmental type with 25% area reduction and its design is done by below steps-

As=<u>(Di×C×B)/(Pt)</u>

Where,

As= Shell side cross flow area

Di= Shell inside diameter

C= Clearances

B= Baffle spacing

Pt= Tube pitch

Now , baffle spacing depend on shell diameter & length of shellLength of shell is larger than diameter of shellBy research l/d varies from 5 to 15 generally 6 to 8.

E. Tube Arrangement.

Triangular pattern provides a more robust tube sheet construction.

Square pattern simplifies cleaning and has a lower shell side pressure drop.

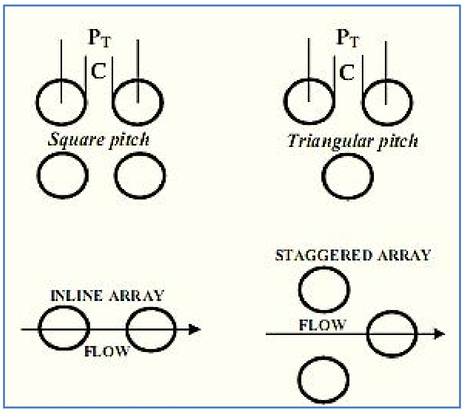

Fig.5.2: Tube arrangement pattern

Tube pitch is defined as:

PT = do+ C

Where:

PT = tube pitch

do = tube outside diameter

C = clearance

Typical dimensional arrangements are shown below, all dimensions in inches and mm.

Table 5.1.:- Dimensional arrangement of triangular pitch

TubeDiameter	SquarePitch	TriangularPitch
5/8"(16 mm)	7/8"(22mm) (Note=1)	25/32"(20 mm)
¾"(19mm)	1"(25mm)	15/16"or1"(24or25mm)
1"(25mm)	1¼"(32mm)	1¼"(32mm)
1¼"(32mm)	19/16"(39mm)	19/16"(39mm)
1½"(38mm)	17/8"(47mm)	17/8"(47mm)

The table above uses minimum pitch 1.25 times tube diameter i.e. clearance of 0.25 times tube diameter, the smallest pitch in triangular 30° layout for turbulent or laminar flow in clean service.

For 90° or 45° layout allow 6.4 mm clearance for tube for ease of cleaning.

F. Bonnet shell

l/d ratio for effective bonnet shell referred as 1-1.5 by selecting suitable diameter as per match to flow rate of fluid it is calculated.

G. Heat Exchanger Bundles

Tube bundles are also known as tube stacks are designed for applications according to customer requirements, including direct replacements for existing units. There are two types of tube bundles:

a) Fixed Tube Sheet. A fixed-tube sheet heat exchanger has straight tubes that are secured at both ends by tube sheets welded to the shell.

b) U-Tube. As the name implies, the tubes of a U-tube heat exchanger are bent in the shape of a U and there is only one tube sheet in a U-tube heat exchanger.

Selecting fixed tube sheet:

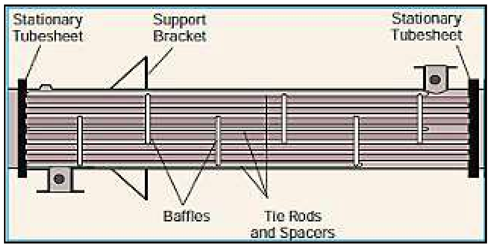

Fig.5.3: Shell & Tube Type Heat Exchanger fixed tube bundle

Bundle diameter, Db, can be estimated using constants shown:

Note :- If the designed bundle diameter is lesser than the shell diameter selected then the design is said to be safer design.

$$D_b = d_o\,(N_t / K_1)^{1/n} = mm$$

Where:

do = Tube Outside Diameter;

Nt = Number of tubes.

K1 - n = see table below:

Table 5.2:- factors for tube sheet calculation

Triangular Pitch $p_t = 1.25\,d_o$					
Number Passes	1	2	4	6	8
K_1	0.319	0.249	0.175	0.0743	0.0365
n	2.142	2.207	2.285	2.499	2.675
Square Pitch $p_t = 1.25\,d_o$					
Number Passes	1	2	4	6	8
K_1	0.215	0.156	0.158	0.0402	0.0331
n	2.207	2.291	2.263	2.617	2.643

VI. CONCLUSION

In Introduction we detailed studied about shell and tube type heat exchanger used to recover the thermal energy between two or more fluids available at different temperatures. Distinct heat exchangers are in practice for several applications in the industries. The design of heat exchanger includes many geometric and operating parameters for a heat exchanger geometry which fulfills the thermal energy demand and system effectiveness. In Methodology of the project we have listed or make the project stages by which we have to work according to it.

Literature review are referred for knowing what is shell and tube type heat exchanger , Its materials and selecting those materials according to various aspects. Also heat exchanger design process according to which heat exchanger must be designed. Modeling of heat exchanger is done under guidelines of industrial experts in which different sizes are referred by standards of ASME,TEMA and also standard pipe sizes charts.

VII. ACKNOWLEDGEMENT

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