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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 widely use 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, TubularExchanger Manufacturing Association,Shelland 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 STHE 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.PradipPathade, 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 of

Heattransfer. Fig [4]. the advantage of 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 side pressure drop and low fouling over shell and tube heat exchanger. [1]

B. Vindhya Vasiny Prasad Dubey, Raj RajatVerma, (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 STHEhas 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.[3]

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.VanditaThantharate, 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.[5]

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 heat transfer coefficient per unit pressure drop in the heat exchanger. [6]

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. [7]

H. Kevin m. Lunsford (2006)this paper it is stated that the engineers are continually being asked to improve processes and increase efficiency. 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.[8]

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:

$$Q = U \times A \times \Delta T_m$$

Also,

$$Q = m.Cp.\,(T2 - T1) \text{ --- } \{Joules\}$$

(The log mean temperature difference)

$$\Delta Tm = (T1 - t2) - (T2 - t1) \text{ --- } \{°c\}$$

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.

Thickness of the shell

$$t_s = c\frac{P.ds}{F_J p - 0.6P} + c$$

Where,

ts= Shell thickness

p= Design pressure

Ds= Shell ID

f= Maximum allowable stress of the material of construction

J= Joint efficiency (usually varies from 0.7 to 0.9)

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 be achieved 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 drop constraints may require an increase in the number of tubes and/or a reduction in tube length. Long tube lengths with few tubes may carry shell side distribution problems.

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No. of Tubes calculation,

$A = \pi * 19.05 * length$

No. of Tubes = Q/ A

For Safety, add +2 tubes .

C. Design of tube sheets.

Tube sheets are usually made from a round flat piece of metal with holes drilled for the tube ends in

A precise location and pattern relative to one another. Tubes are attached to the tube sheet by pneumatic or 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.

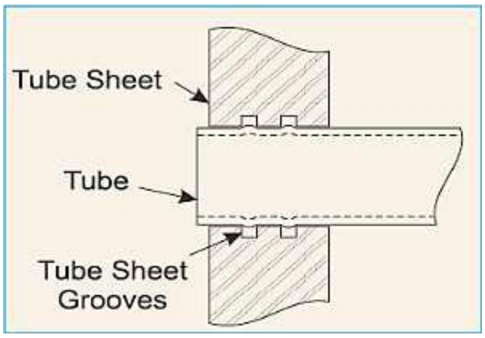

Fig 5.1. Tube Sheet of Heat exchanger

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)

D. Design of baffles.

Baffles are used to support tubes and enable a desirable velocity for the fluid to be maintained at the shell 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= (Di×C×B)/(Pt)

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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 shell Length of shell is larger than diameter of shellbyresearch 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.

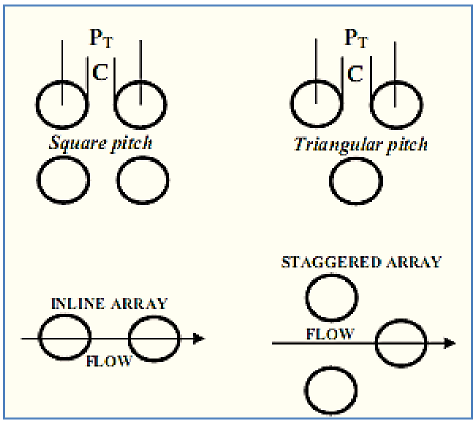

Fig.5.2: Tube arrangement pattern

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.

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 30º layout for turbulent or laminar flow in clean service.

For 90º or 45º 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.

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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:

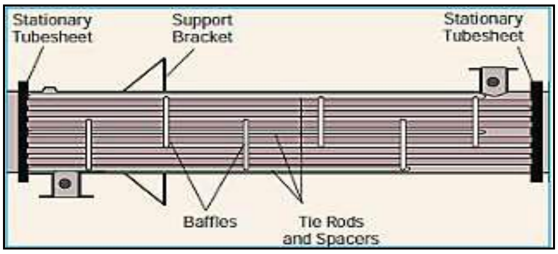

Fig.5.3: Shell & Tube Type Heat Exchanger fixed tube bundle

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.

$$\mathbf{Db = do\ (Nt / K1)^{1/n} = mm}$$

Where:

do= Tube Outside Diameter;

Nt= Number of tubes.

K1 - n = see table below:

H. Design of tube sheets and flanges.

Tube sheets are usually made from a round flat piece of metal with holes drilled for the tube ends in.

Tube sheets are used for supporting the tubes from both end.

Tube sheet is a circular flat plate with regular pattern drilled holes according to the tube sheet layouts. The open end of the tubes is connected to the tube sheet. The tube sheet is fixed with the shell to form the main barrier for shell and tube side fluids. The tube sheet is attached either by welding (called integral construction) or bolting (called gasket construction) or a combination of both types.

The tube sheet thickness should be greater than the tube outside diameter to make a good seal.

Tube Sheet and Flange Thickness:

$$t_{st} = \frac{F * p}{3} \sqrt{\frac{P}{k * f}}$$

But k is calculated as,

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$$K = 1 - \frac{0.907}{\left(\frac{P_t}{d_o}\right)^2}$$

Where,

P= shell inside pressure

F=1 for fixed tube and floating type tube sheet;

Gp=diameter over which pressure is acting (for fixed tube sheet heat exchanger Gp= , shell ID)

f= allowable stress for the tube sheet material

Mean ligament efficiency (k):

$k = 1 - 0.907\ (PT\ /do^{2})$for triangular pitch

$k = 1 - 0.785\ (PT\ /do^{2})$ for square or rotated pitch.

Table 5.2:- factors for tube sheet calculation

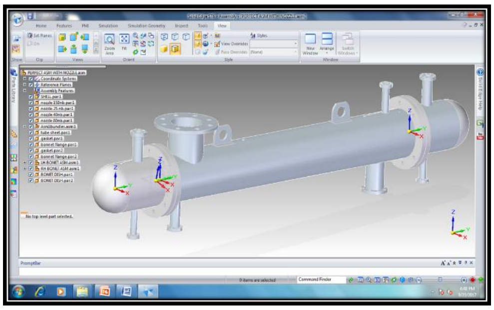
Triangular Pitch p_t = 1.25 d_o					
Number Passes	1	2	4	6	8
K_1	0.319	0.249	0.175	0.0743	0.0365
n	2.142	2.207	2.285	2.499	2.675

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. MODELINGOF HEAT EXCHANGER ON SOLID EDGE

Solid Edge is a 3D CAD, parametric feature (history based) and synchronous technology solid modelling software. It runs on Microsoft Windows and provides solid modeling, assembly modelling and 2D orthographic view functionality for mechanical designers. Through third party applications it has links to many other Product Lifecycle Management (PLM) technologies.

In both ordered and synchronous mode Solid Edge offers very powerful, easy yet stable modelling in hybrid surface/solid mode, An assembly is built from individual part documents connected by mating constraints, as well as assembly features and directed parts like frames which only exist in the Assembly context. Solid Edge supports large assemblies with over 1,000,000 parts.



6.1 Heat exchanger model

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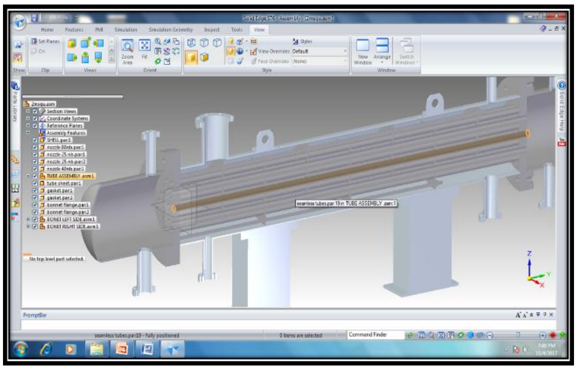


6.2 Sectional view of heat exchanger

VII.STEADY STATE AND TRANSIENT THERMAL ANALYSIS OF HEAT EXCHANGER

Analytical Calculation for heat flux-

$$Q' = K * A * \Delta Tlm$$

= 13 * 4000* 87.98

=4574960.00 joules/ square meter

=4574960/60

= 76,246 w/square meter

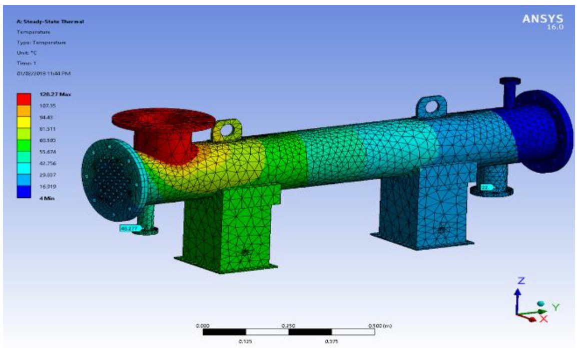
Result by software (Ansys)-

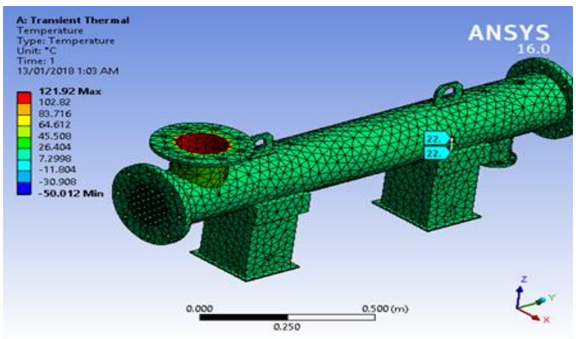
Requirements-

Temperature design = Around 120 degree Celsius

Heat flux must be up to75%-80% of analytical value

i.e. in between 57184-70000 w/square meter





Steady State Thermal

7.1Maximum Temperature = 120.27 degree Celsius 7.2Maximum Heat flux = 60667w/square meter

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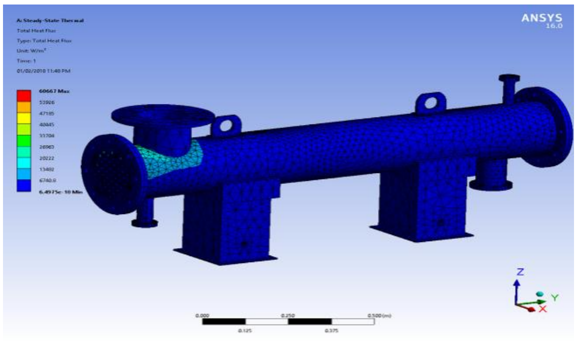
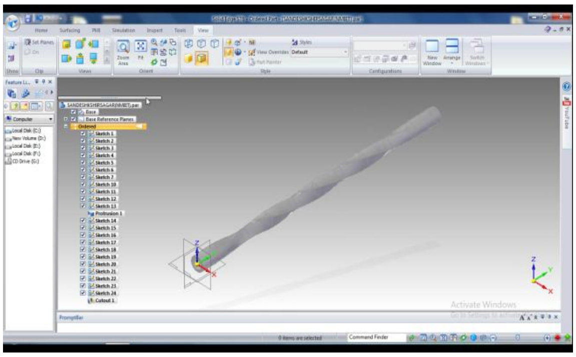


Transient Thermal

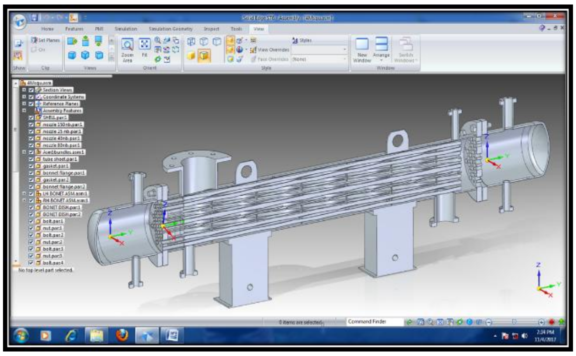
7.3 Temperature = 121.92 degree Celsius

VIII.DEVELOPMENT SUGGESTIONS IN HEAT EXCHANGER

8.1Twisted tube



8.1Use of Twisted tube



8.2 Heat exchanger with twisted tube

IX. 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.

In validation of heat exchanger two – three methods are referred such as steady state thermal, transient thermal and computational fluid dimensional flow (In work) for non-failure results.

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REFERENCES

Journal Papers:

[1] PradipPathade, Anmol Singh *Twisted Type Shell and Tube Heat Exchangers2017 (296 and 299)*

[2] Vindhya Vasiny Prasad Dubey, Raj RajatVerma, *Performance Analysis of Shell & Tube Type Heat Exchanger under the Effect of Varied Operating Conditions pg no (10-14)*

[3] Daniel S. Janikowski *Selecting Reliable Heat Exchanger Tube Materials May 27, 2014*

[4] Prof. Sunil S. Shinde, Mr. Pravinkumar V. Hadgekar *Numerical comparison on Shell side performance of Helixchanger with center tube with different helix angles pg no(2-6)*

[5] Ms.VanditaThantharate,.D.B.Zodpe *Experimental and Numerical Comparison of Heat Transfer Performance of Twisted Tube and Plain Tube Heat Exchangers. (2-4)*

[6] Anil Kumar *Shell and tube heat exchanger design using Samal Roll .pg no (5-22).*

[7] Jurandir Primo *Shell and Tube Heat Exchangers Basic Calculations, PE pg no (2-34)*

[8] Kevin m. Lunsford *Increasing Heat Exchanger Performance,Bryan Research & Engineering, Inc.,Bryan, Texa. pg no (4-5)*