THERMAL ANALYSIS OF TUBULAR HEAT EXCHANGERS USING ANSYS BY USING ALLOY MATERIALS AS TUBE MATERIALS

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Abstract

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 UGNX8.0 by taking the Inner Diameter of shell is 600 mm, length of the shell is 1000 mm and Outer diameter of tube is 12.5mm, length of Tube is1000mm and Shell material as Steel 1008, Tube material as alloy materials to resist corrosive effect TP439and AL29-4.

By using modeling procedure Assembly Shell and Tube with water as medium is done. By using ANSYS software, the thermal analysis of Shell and Tube heat exchangers is carried out by varying the layout. 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. This paper presents the variations in lay out with water as medium with significant flow at the top level of exchanger and equal distribution of tubes pitch. Analysis comparison with before layout and materials are observed.

Extensions-material used for tubes, tubes layout, corrosion resistance, higher thermal heat conductive.

1.0 Introduction

Heat transfer is a discipline of thermal engineering that concerns the generation, use, conversion, and exchange of thermal energy and heat between physical systems. Heat transfer is classified into various mechanisms, such as thermal conduction, thermal convection, thermal radiation, and transfer of energy by phase changes.

1.1 Mode Of Heat Transfer:

On a microscopic scale, heat conduction occurs as hot, rapidly moving or vibrating atoms and molecules interact with neighboring atoms and molecules, transferring some of their energy (heat) to these neighboring particles. In other words, heat is transferred by conduction when adjacent atoms vibrate against one another, or as electrons move from one atom to another.

Convective-, or convection, is the transfer of heat from one place to another by the movement of fluids, a process that is essentially the transfer of heat via transfer. Thermal radiation is electromagnetic radiation generated by the thermal motion of charged particles in matter.

Tubular heat exchangers are widely used, and they are manufacture in many Sizes, flow arrangements, and types. They can accommodate a wide range of operating Pressures and temperatures. The ease of manufacturing and their relatively low cost have Been the principal reason for their wide spread using engineering applications. A Commonly used design, called the shell-and-tube exchanger, consists of round tubes Mounted on a cylindrical shell with their axis parallel to that of shell.

1.2 Process Design Of Shell And Tube Exchanger For Single Phase Heat Transfer

1.2.1Classification of heat exchangers

Transfer of heat from one fluid to another is an important operation for most of the chemical industries. The most common application of heat transfer is in designing of heat transfer equipment for exchanging heat from one fluid to another fluid. Such devices for efficient transfer of heat are generally called Heat Exchanger. Heat exchangers are normally classified depending on the transfer process occurring in them.

Amongst of all type of exchangers, shell and tube exchangers are most commonly used heat exchange equipment. The common types of shell and tube exchangers are: **Fixed tube-sheet exchanger (non-removable tube bundle)**: The simplest and cheapest type of shell and tube exchanger is with fixed tube sheet design. In this type of exchangers the tube sheet is welded to the shell and no relative movement between the shell and tube bundle is possible.

Removable tube bundle: Tube bundle may be removed for ease of cleaning and replacement. Removable tube bundle exchangers further can be categorized in floating-head and U-tube exchanger.

Floating-head exchanger: It consists of a stationery tube sheet which is clamped with the shell flange. At the opposite end of the bundle, the tubes may expand into a freely riding floating-head or floating tube sheet. A floating head cover is bolted to the tube sheet and the entire bundle can be removed for cleaning and inspection of the interior.

U-tube exchanger: This type of exchangers consists of tubes which are bent in the form of a „U" and rolled back into the tube sheet .

1.3 Problem definition

Corrosion of the tubes is one of the most significant problem find in the present days because of medium becoming polluted with the chemicals mixed with water. Because of this effect normal materials like copper and aluminum also undergoing chemical reaction and becoming corrosive.

Using of alloy materials instead of normal metals are analyzed to decrease the corrosive effect on tubes to make the heat exchanger more reliable.

By observing before thesis lay-out also one of the consideration to improve the efficiency of the heat exchanger. As water as medium, thermal calculations are analyzed to get the efficiency comparison with before papers.

Fig 1.1 shows the classification of heat exchangers.

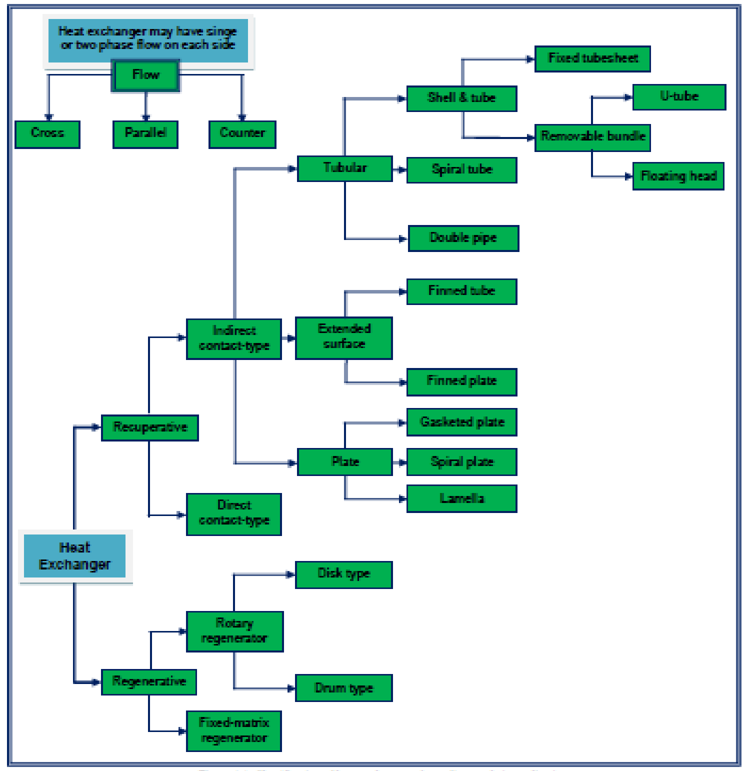

Figure 1.1. Classification of heat exchangers depending on their applications.

1.4 Objectives of present research

1. To decrease corrosive effect alloy materials are introducing instead of market strategies.

2. Heat transfer and thermal analysis will be compared with the before thesis.

3. Tube arrangement will be consider in design for liquid flow.

4. Rate of heat transfer can be improved by varying the tube diameter, length and no of tubes.

5. By changing the pitch lay out rate of heat transfer compare with before layout.

Chapter 2

Litarature Riview

Summary of Literature Review

Heat exchangers have been classified according to transfer processes, number of fluids, degrees of surface compactness, construction features, flow arrangements, and heat transfer mechanisms. A summary is provided in Fig. 1.1. The major emphasis in this chapter is placed on introducing the terminology and concepts associated with a broad spectrum of commonly used industrial heat exchangers (many specialized heat exchangers are not covered in this chapter). To acquaint the reader with specific examples, major applications of most types of heat exchangers are mentioned. With a thorough understanding of this broad overview of different types of exchangers, readers will be able to apply the theory and analyses presented in the succeeding chapters to their specific needs.

Papers Verified Before Approach

B.Jayachandriah1 et al., stated that 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 Shell and Tube heat exchangers 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.

The observations of this project concluded that after performing all the analysis work for shell & tube heat exchangers the following observation had been done. From the study of the result as mentioned in table 1 , after performing the calculation the fluid water for bass output temperature is 310 °k which is nearer to the value mentioned in output temperature of ansys. As we change the tube material from the brass to the copper, temperature difference between output temperature of copper & brass had been varied.[1]

The Tubular heat exchangers are generally built of circular tubes, although elliptical, rectangular or round/flat twisted tubes have also been used in some applications. There is considerable flexibility in design because the core geometry can be varied easily by changing the tube diameter, length, and arrangement. Tubular 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 and liquid to phase change (condensing or evaporating) heat transfer applications. There are used for gas-to liquid and gas- to-gas heat transfer applications primarily when the operating temperature and /or pressure is very high or fouling is a severe problem on at least one fluid side and no other types of exchangers work.CFD analysis has been carried out for different material and on the basis of results made which one give the best heat.[2]

J. A. Guirao Silvia concluded the following statement. Because of the number of parameters involved, heat exchangers are mainly designed by approximate approach, following the TEMA standards. The method here presented cuts down the empirical components by applying ANSYS to typical heat transfer formulations; the length of the apparatus is divided in as many sections as desired; then a point is selected in each fluid and internal and external faces; those points are joined with a conductive or convective element of heat transfer, depending of its position. All physic and thermal properties are made dependent of temperature. The iterative calculations give the energy flow between points and sections, together with pressure and temperature distributions. Testing prototypes will allow to adjust constants. A previous work of data base fluids' properties is needed. The parameters which influence design and dimensions of the exchanger are so calculated much more precisely, resulting in better efficiency and lower prices. The example here presented is liquid-liquid tube and casing exchanger. Other types and flows are being analyzed.[3]

Vindhya Vasiny Prasad Dubey et all., presented a paper which 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 shell and tube type heat exchanger 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 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 aluminum 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.[4]

Jainender Dewatwal has done his research on Plate fin heat exchangers, because of their compactness, low weight and high effectiveness are widely used in aerospace and cryogenic applications. This device is made of a stack of corrugated fins alternating with nearly equal number of flat separators known as parting sheets, bonded together to form a monolithic block. Appropriate headers were welded to provide the necessary interface with the inlet and the exit streams. While aluminum is the most commonly used material, stainless steel construction is employed in high pressure and high temperature applications.

The laminar flow model under predicts **j** and **f** values at high Reynolds number, while the 2-Layer k-e turbulence model over predicts the data throughout the range of interest. Because most industrial heat exchangers operate with Re less than 3000, and because the j and f data predicted by the laminar and the 2-layer k-e turbulence model differ little from each other at low Reynolds numbers, we have used the laminar flow model up to Reynolds number of 10,000, which is considered to be the limit for plate fin heat exchangers operating with gases. Velocity, pressure and temperature fields have been computed and **j** and **f** factors determined over appropriate range of Reynolds number and geometric dimensions.[5]

Roshan V. Marode1 et all., has conducted experiment on Shell and Tube Heat exchanger. They are the basic types of heat exchanger one of the fluids flow through a bundle of tubes enclosed by a shell. The outer fluid is forced through a shell and it flows over the outside surface of the tubes. Such an arrangement is employed where reliability and heat transfer effectiveness. In order to achieve the maximum heat transfer rate he has made an analysis on single tube with two different fluids (Water and Al2O3-water based Nano fluid) in a shell and tube heat exchanger. With relate to same to have a maximum heat transfer rate this paper gives various optimal design solutions using computational techniques. To measure the performance of different designs, its model is suitably designed and fabricated so as to perform experimental tests. Thermal analysis has been carried out for different design with two fluids and on the basis of comparative results is made which one give the best heat transfer rates.

They have presented the design and thermal analysis of different tubes. Experimentally, same designs are made and results are evaluated. With relate to same design tubes are thermally analyzed in ANSYS software and compared both the results. After comparing the result for both waterwater(Case-I) and water-Al2O3(Case-II) for four different tubes we are in conclusion that twisted type of tube is giving high heat transfer coefficient as compared to other i.e 1.14 more. Along with effectiveness, twisted tube is at higher side by 1.17.So according to my research one should go for twisted tube. However, a good understanding of the underlying principles of exchanger design is needed to use this software effectively. The possibility to increase in these characteristics using the latest technology and various methods has raised application range of these designs. Modified design tubes are having great applications due to their large heat transfer area and high heat transfer coefficients. They are used in many industrial processes like waste water treatment, refrigeration, wine and beer making, petroleum refining.[6]

AV.Hari Haran et all., has carried out an experiment on a simplified model for the study of thermal analysis of shell-andtubes heat exchangers of water and oil type is proposed..Shell and Tube heat exchangers are having special importance in boilers, oil coolers, condensers, pre-heaters. They are also widely used in process applications as well as the refrigeration and air conditioning industry. The robustness and medium weighted shape of Shell and Tube heat exchangers make them well suited for high pressure operations. In this paper we have shown how to done the thermal analysis by using theoretical formulae for this we have chosen a practical problem of counter flow shell and tube heat exchanger of water and oil type, by using the data that come from theoretical formulae we have design a model of shell and tube heat exchanger using Pro-e and done the thermal analysis by using ANSYS software and comparing the result that obtained from ANSYS software and theoretical formulae. For simplification of theoretical calculations we have also done a C code which is useful for calculating the thermal analysis of a counter flow of water-oil type shell and tube heat exchanger. [7]

Sunil B. Revagade et all., presented paper on a device which is used to transfer of energy between two fluids is named a heat exchanger. A heat Exchanger may be defined as equipment which transfers the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running costs. Shell and Tube heat exchanger are the basic types of heat exchanger one of the fluids flow through a number of tubes enclosed by a shell. The outer fluid is forced through a shell and it flows over the outside surface of the tubes. Such an arrangement is employed where reliability and heat transfer effectiveness. In order to achieve the maximum heat transfer rate an analysis is made on single tube with Water as based fluid in a shell and tube heat exchanger. With relate to same to have a maximum heat transfer rate this project gives various optimal design solutions using computational techniques. To measure the performance of different designs, its model is suitably designed and fabricated so as to perform experimental tests. Thermal analysis has been carried out for different design with base fluids and on the basis of comparative results is made which one give the best heat transfer rates.

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A. K. Srivastava has presented this paper which consists of a simplified model of counter flow shell and tube type heat exchanger having both interacting liquids as water. In this paper we have first designed a shell and tube heat exchanger to cool water from 55°C to 45°C by water at room temperature. The design has been done using Kern's method in order to obtain various dimensions such as shell, tubes, baffles etc. A computer model using ANSYS 14.0 has been developed by using the derived dimensions of heat exchanger. Then the steady state thermal simulation in ANSYS has been performed by applying several thermal loads on different faces and edges. The heat transfer capabilities of several thermal materials has been compared by assigning different materials to various parts such as tubes, baffles, shell.[9]

3.METHODOLOGY

Selection of alloy materials

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cad layout of external and internal layouts

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design of components using U.G. Nx8.0

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Meshing

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Analysis with cosidered parameters

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Comparisons and conclusions

3.1 Selection of alloy materials

Based on the above data, in this paper work has taken steel 1008 material for shell, copper and brass material for tube. Hence these materials have good working properties compared to the other materials such as Silver, Cast Iron, Aluminum etc.

Crevice Corrosion

Crevice corrosion is very similar to pitting corrosion. However, since the tighter crevice allows higher concentrations of corrosion products (less opportunity to flush with fresh water), it is more insidious than pitting. This drives the pH lower. The end result is that crevice corrosion can happen at temperatures 30°-50° Centigrade lower than pitting in the same environment.

Crevice corrosion is commonly measured by the ASTM G 48 test. Kovach and Redmond evaluated a large database of existing crevice corrosion data and compared it to the PREn number described earlier

Comparative Mechanical and Physical Properties of Condenser Tube Materials Property

AL 29-4C Ti-Grade 2 90-10

AL 29-4C alloy is a superferritic stainless steel designed by Allegheny Ludlum for extreme resistance to chloride ion pitting, crevice corrosion and stress corrosion cracking, as well as general corrosion in oxidizing and moderately .

The super ferritic stainless steel AL 29-4C alloy shows excellent resistance to chloride ion pitting, crevice corrosion and stress corrosion cracking. This resistance makes it an ideal choice for battling the corrosive condensate of partially and fully condensing natural gas and propane burning appliances. Its low alloy content, compared to other high-performance alloys, makes it an economical choice as well.

Mechanical and Physical Properties of Condenser Tube Materials Property AL 29-4C.

Yield Strength ksi (MPa)* 80

Ultimate Strength ksi (MPa) 95

Elongation (percent)* 20

Modulus ksi x 103 (GPa)

Thermal Conductivity 121 ºF/in (W/M5 C

Thermal Expansion 5.2

Density lbs/in3 (g/cm3) .277

Mechanical & Physical Properties of Various Heat Exchanger Tube Candidates, Typical Unless Otherwise Noted

Property	Admiralty Brass C44300	Aluminum Brass C68700	90/10 Cu/Ni C70600	70-30 Cu/Ni C71500	TP 439 S43035	TP 304/TP 316 S30400/S31600	AL6XN® N08367	SEA-CURE® S44660	Ti Grade 2
Ult. Strength	53 ksi	60	50	50	60*	75*	100*	85*	50*
Yield St.	22 ksi	27	15	25	30*	30*	45*	65*	40*
Elongation	60%	55%	35%	25%	20%*	35%*	30%*	20%*	20%*
R. Hardness	RF 75	RB 50	RB 30	Rb 20	RB90**	RB 90**	RB 100**	RC 25**	RB 92**
Mod. Of Elast.	16 x 10^6 psi	16.0	18.0	18.0	29.0	28.3	28.2	31.5	14.9
Density	.308 lbs/in^3	0.301	0.323	0.320	0.280	0.29	0.29	0.278	0.16
Thermal Expan.	11.2 x 10^{-6} in/in/degree F	10.3	9.5	9.5	5.6	9.5	8.7	5.38	5.2
Thermal Cond.	64 BTU/ft-hr-F	58	23.0	17.0	12.3	8.6	7.9	9.9	12.5
Fatigue Endur.	20 ksi	20	20	22	20	30	33	35	16 ksi

Cad layout of present work

DIMENSIONS OF MODELLING

Dimensions of shell and tube heat exchangers:

No of tubes = 62

Length of the tubes = 1000mm

Tube diameter(O.D) = 25mm

Tube diameter(I.D)=21mm

Tube pitch = 32mm

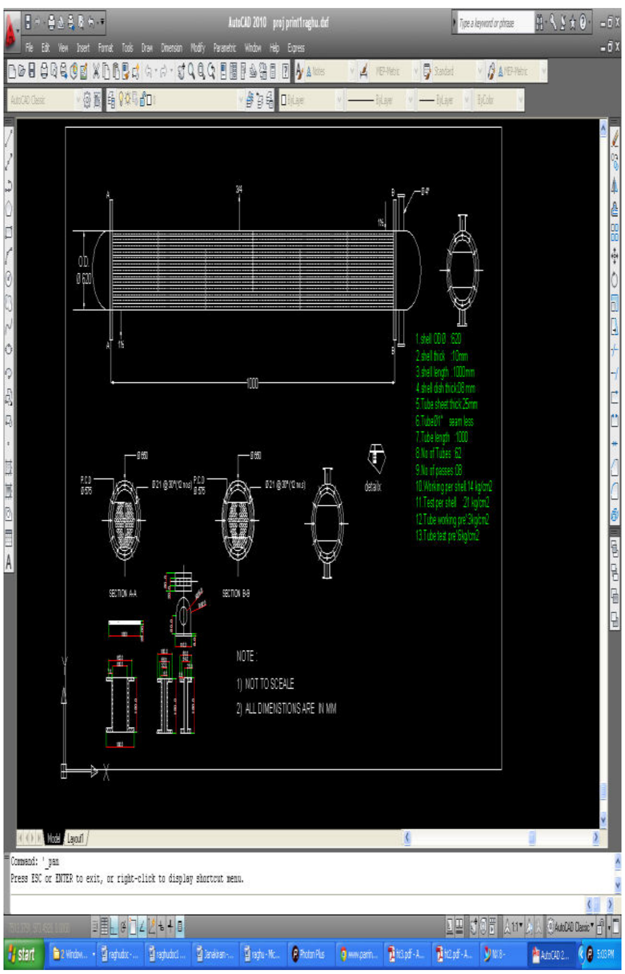
Clearance = Pt – do =32 – 25 =7

Tube layout = 90

Shell length = 1000

Shell diameter (i.d)= 500

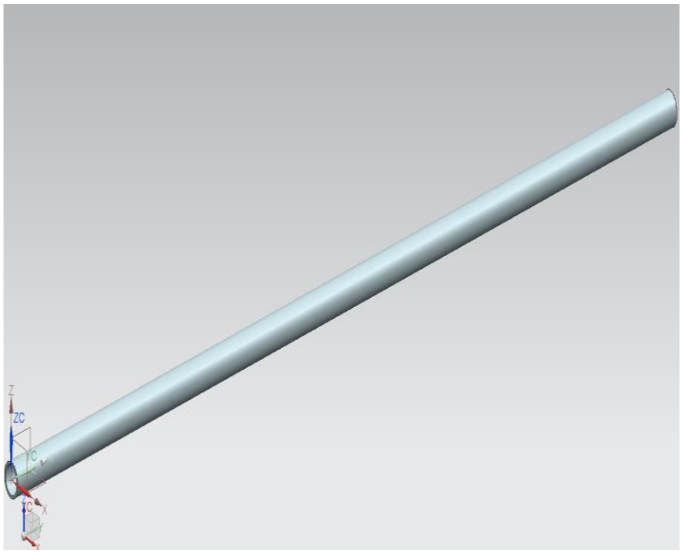
Shell thickness=10



<u>Fig;3.1 shows the lay out of heat exchanger and pipes orientation</u>

<u>Solid modeling</u>

Unigraphics software is one of the world's most advanced and tightly integrated CAD/CAM/CAE software package developed by Siemens PLM Software, offers several pre-packaged Mach Series solutions for NC machining. Available in a range of capability levels, these solutions accelerate programming and improve productivity for a variety of typical manufacturing challenges, from basic machining to complex, multiple-axis and multi-function machining, as well as mould and die manufacturing it also merges solid and surface modeling techniques into one powerful tool set. The packages include complete capabilities for geometry import, CAD modeling and drafting, full associatively to part designs, NC tool path creation, verification and post processing, along with productivity tools that streamline the overall machining process.



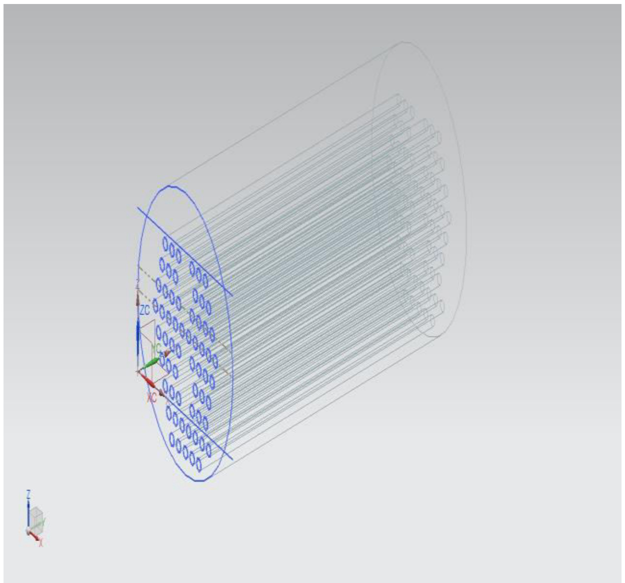
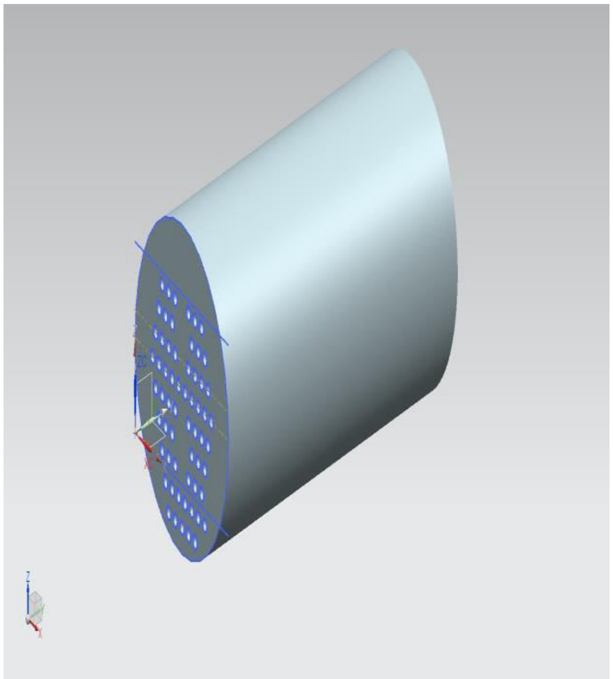


Fig 3.2 shows the tube



Thermal Design Considerations

The flow rates of both hot and cold streams, their terminal temperatures and fluid properties are the primary inputs of thermal design of heat exchangers.

Thermal design considerations: Thermal design of a shell and tube heat exchanger typically includes the determination of heat transfer area, number of tubes, tube length and diameter, tube layout, number of shell and tube passes, type of heat exchanger (fixed tube sheet, removable tube bundle etc), tube pitch, number of baffles, its type and size, shell and tube side pressure drop etc.

Shell: Shell is the container for the shell fluid and the tube bundle is placed inside the shell. Shell diameter should be selected in such a way to give a close fit of the tube bundle. The clearance between the tube bundle and inner shell wall depends on the type of exchanger.

Shells are usually fabricated from standard steel pipe with satisfactory corrosion allowance. The shell thickness of 3/8 inch for the shell ID of 12-24 inch can be satisfactorily used up to 300 psi of operating pressure.

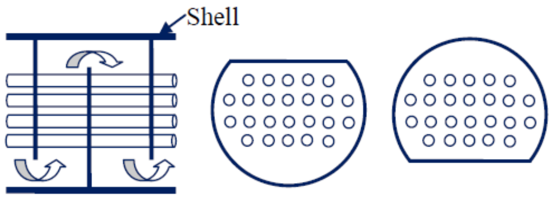
Tube: Tube OD of ¾ and 1"" are very common to design a compact heat exchanger. The most efficient condition for heat transfer is to have the maximum number of tubes in the shell to increase turbulence. The tube thickness should be enough to withstand the internal pressure along with the adequate corrosion allowance. The tube thickness is expressed in terms of BWG (Birmingham Wire Gauge) and true outside diameter (OD). The tube length of 6, 8, 12, 16, 20 and 24 ft are preferably used. Longer tube reduces shell diameter at the expense of higher shell pressure drop. Finned tubes are also used when fluid with low heat transfer coefficient flows in the shell side. Stainless steel, admiralty brass, copper, bronze and alloys of copper-nickel are the commonly used tube materials:

Tube sheet The tubes are fixed with tube sheet that form the barrier between the tube and shell fluids. The tubes can be fixed with the tube sheet using ferrule and a soft metal packing ring. The tubes are attached to tube sheet with two or more grooves in the tube sheet wall by „tube rolling". The tube metal is forced to move into the grooves forming an excellent tight seal. This is the most common type of fixing arrangement in large industrial exchangers. The tube sheet thickness should be greater than the tube outside diameter to make a good seal. The recommended standards (IS:4503 or TEMA) should be followed to select the minimum tube sheet thickness.

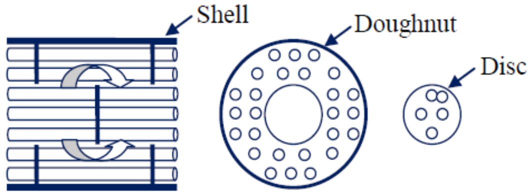
Baffles: Baffles are used to increase the fluid velocity by diverting the flow across the tube bundle to obtain higher transfer co-efficient. The distance between adjacent baffles is called baffle-spacing. The baffle spacing of 0.2 to 1 times of the inside shell diameter is commonly used. Baffles are held in positioned by means of baffle spacers. Closer baffle spacing gives greater transfer co-efficient by inducing higher turbulence. The pressure drop is more with closer baffle spacing. The various types of baffles are shown in

Figure

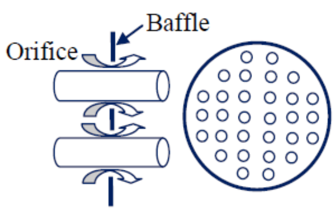
In case of cut-segmental baffle, a segment (called baffle cut) is removed to form the baffle expressed as a percentage of the baffle diameter. Baffle cuts from 15 to 45% are normally used. A baffle cut of 20 to 25% provide a good heat-transfer with the reasonable pressure drop. The % cut for segmental baffle refers to the cut away height from its diameter.



a). Cut-segmental baffle



b). Disc and doughnut baffle



c). Orifice baffle

Different type of heat exchanger baffles: a). Cut-segmental baffle, b). Disc and doughnut baffle, c). Orifice baffle

Selection of fluids for tube and the shell side

Corrosive fluid	Condensing vapor (unless corrosive)
Cooling water	Fluid with large temperature difference (>40°C)
Fouling fluid	
Less viscous fluid	
High-pressure steam	
Hotter fluid	

Thermal Boundry Conditions

Given Data: Hot fluid inlet temperature (T1)= 160°F Hot fluid outlet temperature (T2) = 120°F Cold fluid inlet temperature (t1) = 75°F Cold fluid outlet temperature (t2) = 120°F Fouling factor of hot fluid (Rdg) = 0.0005 (for gasoline) Fouling factor of cold fluid (Rdk) = 0.001 (for kerosene) Pinlet (for hot fluid) = 50 psia Pinlet (for cold fluid) = 50 psia Δpmax (for hot fluid) = 7 psi Δpmax (for cold fluid) = 10 psia Mass flow rate of cold fluid () = 150000 lb.h-1 k m.

Calculation of caloric temperature

For the calculation of caloric temperature please refer

$$r = \frac{\Delta t_c}{\Delta t_h} = \frac{T_2 - t_1}{T_1 - t_2} = \frac{120 - 70}{160 - 120} = 1.25$$

°API of hot fluid=76°; Therefore $K_c = 1$; $F_c = 0.455$

Fluid properties at caloric temperature

Viscosity: 76°API

gasoline, μ_g=0.2cp (0.484 lb.ft-1.h-1) 46°API

kerosene, μ_k =1.6 cp (3.872 lb.ft-1.h-1)

Density: ρ_g=685 kg.m-3 (42.7 lb.ft-3)

ρ_k=800 kg.m-3 (49.8 lb.ft-3)

Thermal conductivity:

k_g=0.075 Btu h-1ft-1 °F-1

k_k=0.083 Btu h-1ft-1 °F-1

Specific heat capacity: C_g = 0.57 Btu lb-1ft-1

C_k = 0.48 Btu lb-1ft-1

Specific gravity:

S_g = 0.685

S_k = 0.80

Mesh files

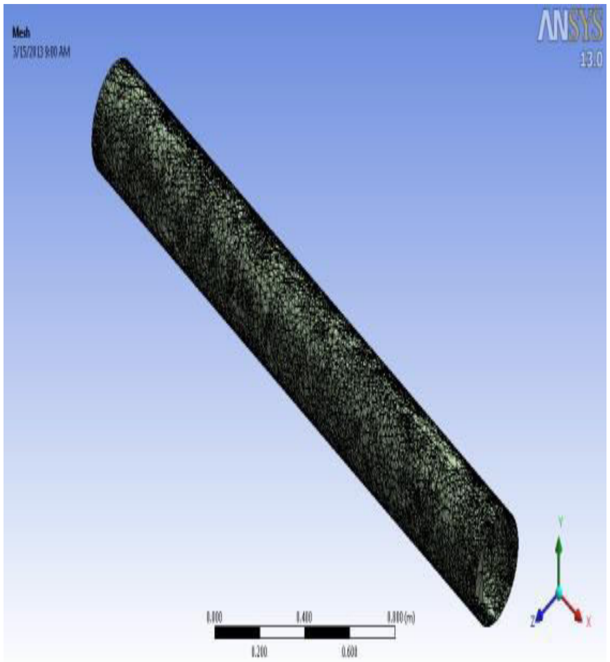
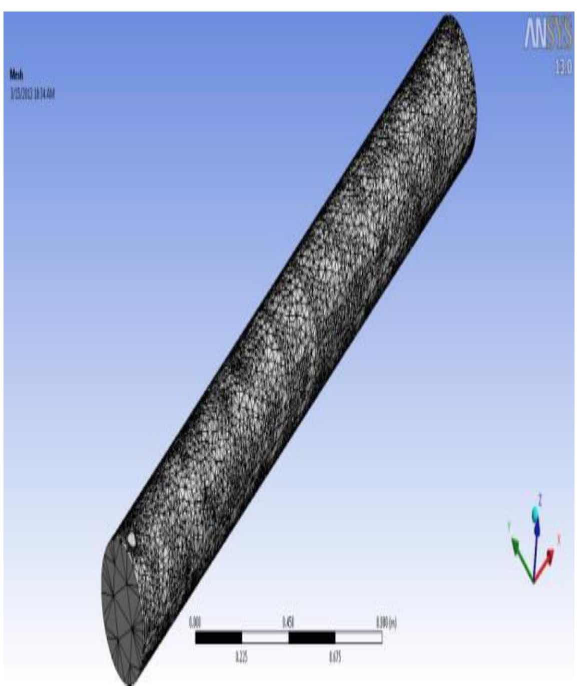


fig. Tube meshing files



Mesh for fresh water

Analytical Analysis:

General formula for calculating heat transfer:

The heat release from the shell and tube heat exchangers was obtained by multiplying over all heat transfer co-efficient, Area of tubes and difference of temperatures.

$$\mathbf{Q = UA\theta_m}$$

Where, A = area of tub, U = Overall heat transfer coefficient

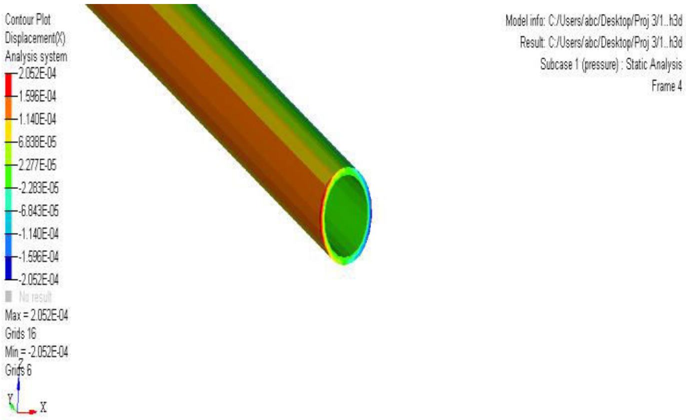
LMTD method:

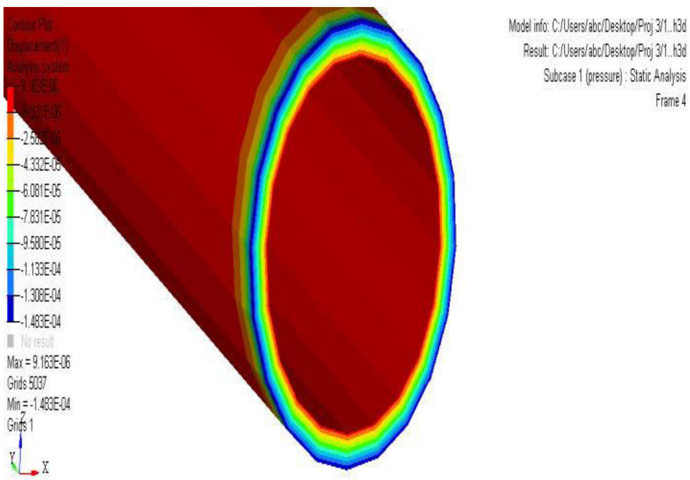
$$\theta_m = \frac{(t_{h1} - t_{c1}) - (t_{h2} - t_{c2})}{ln\,(\frac{t_{h1} - t_{c1}}{t_{h2} - t_{c2}})}$$

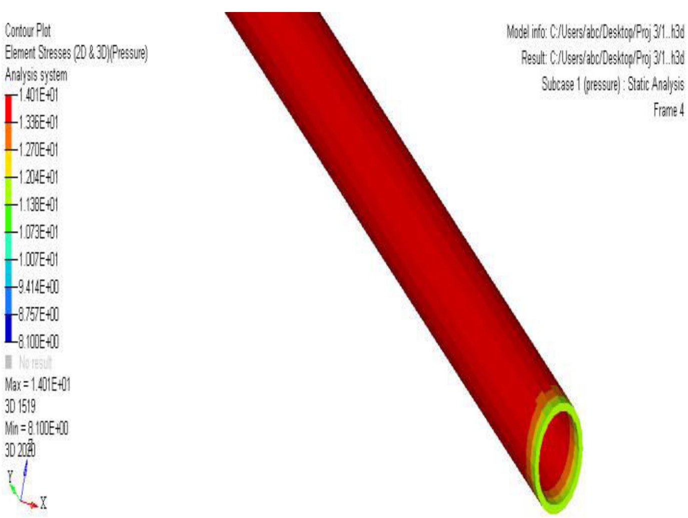
Area of the tubes

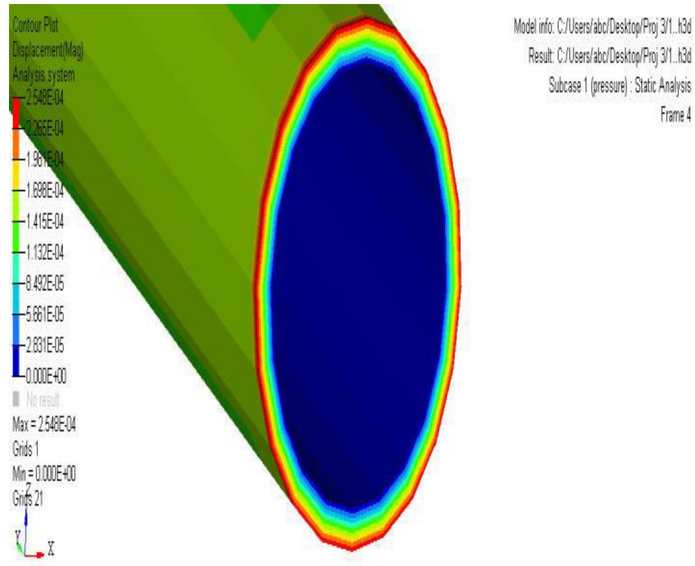
$$\mathbf{A = \pi d_0 L}$$

where, do = outside diameter of tubes, L = length of the tubes.









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