ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 5, Issue 7, July 2016

COMPUTER AIDED DESIGN AND ANALYSIS OF A HEAT EXCHANGER

D.AMRUTHA VIJAY, P.SNEHALATHA

Abstract: Heat transfer is the science that deals with the rate of exchange of heat between hot and cold bodies called the source and receiver. When one Kg of water is vaporized or condensed, the energy change in either process is identical. However, the rates at which either process proceeds is different, vaporization being much more rapid than condensation. A Heat Exchanger is a device used for affecting the process of heat exchange between two fluids that are at different temperatures. Heat Exchangers are useful in many engineering processes those in refrigerating and air-conditioning systems, power systems, food processing systems, chemical reactors and space or aeronautical applications .This project deals with the design and analysis of a heat exchanger (oil cooler) by using pro E , hyper mesh and Ansys software's ,so as to satisfy the requirement data collected from the source along with the design considerations of esteemed TEMA & ASME standards. The main objective is to calculate the temperature distribution & stress value by using Ansys.

Keywords: Computer Aided Analysis, Heat Exchanger,oil cooler.

INTRODUCTION

1.1. INTRODUCTION TO PROCESS HEAT TRANSFER

The science of thermodynamics deals with the quantitative transitions and rearrangements of energy as heat in bodies of matter. Heat transfer is the science that deals with the rate of exchange of heat between hot and cold bodies called the source and receiver. When one Kg of water is vaporized or condensed, the energy change in either process is identical. However, the rates at which either process proceed is different, vaporization being much more rapid than condensation.

The major difference between thermodynamics and heat transfer is that the former deals with the relation between heat and other forms of energy, whereas the latter is concerned with the analysis of the rate of heat transfer. Thermodynamics deals with systems in equilibrium so it cannot be expected to predict quantitatively the rate of change in a process, which results from non-equilibrium states. Heat transfer is commonly associated with fluid dynamics and it also supplements the laws of thermodynamics by providing additional rules to establish energy transfer rates.

Process heat transfer deals with the rates of heat exchange as they occur in the heat transfer equipment of the engineering process. This approach brings to better focus the importance of the temperature difference between the source and the receiver, which is, after all, the driving force whereby the transfer of heat is accomplished. A typical problem of process heat transfer is concerned with the quantities of heat to be transferred, the rates at which they may be transferred because of the natures of the bodies, the driving potential, the extent and arrangement of the surface separating the source and the receiver, and the amount of mechanical energy which may be expanded to facilitate the transfer. Since heat transfer involves an exchange in the system, the loss of heat by the one body will equal the heat absorbed by another within the confines of the same system

1.2. PRINCIPLES OF HEAT TRANSFER

The heat exchange process in a heat exchanger can be Described by the principles of conduction, convection, and radiation.

CONDUCTION

Heat conduction is the mode of heat transfer accomplished By the mechanism of molecular interaction. The energy exchange takes place By the kinetic motion or direct impact of molecules. Molecules at relatively Higher energy level impart energy to adjacent molecules at lower energy Levels. This type of heat transfer occurs, as there is a temperature gradient in The system comprising of solid, liquid or gas. Conduction is proportional to the area-measured normal to the direction of heat flow and to the temperature gradient measured in that direction.

$$Q = -KA\,(dt/dx)$$

K= Coefficient of thermal conductivity

CONVECTION

Convection is possible only in the presence of a fluid Medium. When a fluid flows inside a duct or over a solid body and the Temperatures of fluid and solid surfaces are different, heat transfer between the fluid and the solid surfaces takes place. This is due to the motion of the Fluid relative to the surface. The heat transfer by convection is always accompanied by heat transfer by conduction for a fluid flowing at a mean Temperature Tm over a surface of temperature Ts. Newton proposed the Following convection equation

$$q = Q/A = h(T_s - T_m)$$

Where

q= heat flux at the wall in W/m2

h = heat transfer coefficient in W/m2 °c

Ts = surface temperature in °c

Tm = mean temperature in °c

RADIATION

If two bodies at different temperatures are placed in an Evacuated adiabatic enclosure so that they are in contact through a solid or Fluid medium, the temperature of two bodies will tend to become equal. The Mode of heat transfer by which this equilibrium is achieved is called as Thermal Radiation. Radiation is an electromagnetic wave phenomenon and Medium is required for its propagation. According to Stefan-Boltzmann law the radiation emitted by a body is Proportional to the fourth power of absolute temperature.

$$Q = \sigma T_1^4$$

Where,

σ = Stefan-Boltzmann constant
T1= Surface temperature in °Kelvin

HEAT EXCHANGERS

2.1. INTRODUCTION TO HEAT EXCHANGERS

A Heat Exchanger is a device used for affecting the process of heat exchange between two fluids that are at different temperatures. Heat Exchangers are useful in many engineering processes those in refrigerating and air-conditioning systems, power systems, food processing systems, chemical reactors and space or aeronautical applications.

2.2. CLASSIFICATION OF HEAT EXCHANGERS

CLASSIFICATION BASED ON WORKING FEATURES:

The heat exchangers are mainly divided into three categories according to their working features

1. Closed type exchanger
2. Regenerators
3. Open type exchangers or mixed type

(1). CLOSED TYPE EXCHANGER

Closed type exchangers are those in which heat transfer occurs between two fluids, which do not mix, or physically in contact with each other. The fluids involved are separated from each one other by a pipe or a tube wall or any other surface, which may be involved in heat transfer path. Heat transfer will occur by convection from the hotter fluid to the solid surface, by conduction through the solid and again by convection from the solid surface to the cooler fluid. Most of the heat exchangers come under this category. Our discussion will be related to this type.

(2). REGENERATORS

The regenerators are storage type heat exchangers. The heat transfer surface or elements are usually referred to as a matrix in the regenerator. Regenerators are exchangers in which a hot fluid, then a cold fluid, flows through same space alternatively with as little mixing as possible occurring between the two streams. The surface that receives releases thermal energy. Such a device is important.

Material properties of surfaces involved as well as fluid flow properties of the stream along with geometry are qualities that must be known. The analysis needs knowledge of unsteady state convection and conduction. In steam power plants, the air pre-heaters are usually rotor regenerator type.

(3). OPEN TYPE OF EXCHANGERS OR MIXED TYPE

Open type heat exchangers, as the name implies are devices where in the entering fluid stream flow into the open chamber and complete mixing of the two streams occurs. Hot and cold fluids entering such an exchanger will leave as a single stream.

Analysis of open type involves the law of conservation of mass and laws of thermodynamics. Jet condensers used for cooling the water circulated through the condensers in power plants come under this category.

CLASSIFICATION BASED ON FLUID FLOW ARRRANGEMENTS

Mostly heat exchangers are classified on the basis of configuration of the fluid flow paths through the heat exchangers. The choice of particular flow arrangement is dependent upon the required exchanger effectiveness, available pressure drops, minimum and maximum velocities allowed, fluid flow paths, packing envelope, allowable thermal stresses, temperature levels, piping and plumbing considerations, and other design considerations and criteria.

COUNTER FLOW EXCHANGER

In counter flow exchanger the two fluids flow parallel to each other but in opposite directions within the core. The counter flow arrangements are thermodynamically superior to any other flow arrangements. It is the most efficient flow arrangements for given overall thermal conductance (UA), fluid flow rates and inlet temperatures.

PARALLEL FLOW EXCHANGER

In parallel flow exchanger the fluid streams enter together at one end, flow parallel to each other in the same direction and leave together at other end. This arrangement has lowest exchanger effectiveness among the single pass exchanger for given overall thermal conductance and fluid flow rates. In a parallel flow exchanger, a large temperature difference between inlet temperatures of hot and cold fluid exists at the inlet side, which may include high thermal stresses in the exchanger wall at the inlet. This flow arrangement is not used for applications requiring high temperature effectiveness.

CROSS FLOW EXCHANGER

In this type of exchanger the fluids flow normal to each other. Thermodynamically, the effectiveness of the cross flow exchanger falls between the parallel and counter flow exchangers. This is one of the most common flow arrangements used for extended surface heat exchanger, because it greatly simplifies the header design at the exit of each fluid.

ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
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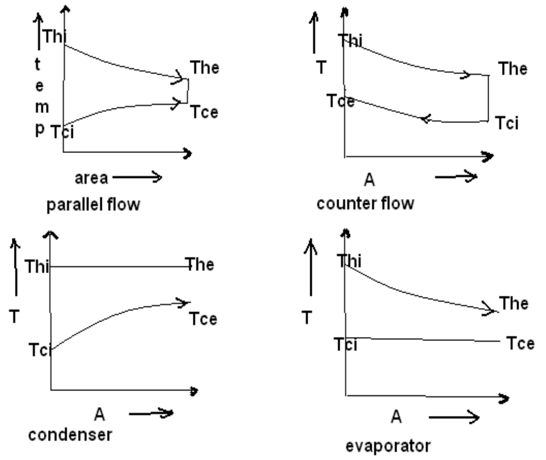


FIGURE 2.2.A CLASSIFICATION BASED ON FLUID FLOW ARRANGEMENTS

CLASSIFICATION BASED ON APPLICATIONS

Heat exchangers are classified on the basis of the applications for which they are intended and special terms are employed for major types.

These terms include

Boiler
Condenser
Oil cooler

BOILERS

Steam boilers have been used to produce power and constitute one of earliest applications of the engineering principles to heat exchangers. They consist of a number of small diameter tubes interconnected to the boiler drum. Water is allowed to flow through these tubes. The head from the flue gases passing over the tubes is transferred to the water through the tube surface.

CONDENSERS

Condensers are used in power plants, chemical plants and refrigeration systems. Large power plant condensers are called surface condensers. Steam condensers consist of a bundle of small diameter tubes laced inside a metal shell. The exhaust steam from the turbines passes over the tubes and cooling water in the tubes.

COOLERS

When a fluid at high temperature is to be cooled to a lower temperature, coolers are used. For example oil coolers and air coolers are used to cool the lube oil that is to cool the bearings and other surfaces of the large machinery like turbines. The most common type used is the shell and tube type of heat exchanger.

2.3. TYPES OF HEAT EXCHANGERS

The three main types of heat exchangers are,

(1). AIR COOLED HEAT EXCHANGER

It is tubular heat transfer equipment in which ambient air passes over the tubes and thus acts as the cooling medium. Air is available in unlimited quantities compared to water. The airside fouling is frequent problem. But the heat transfer coefficient of air is less than that of water.

(2). PLATE TYPE HEAT EXCHANGER

The plate type of heat exchanger consists of a thin rectangular metal sheet upon which a corrugated pattern has been formed by precision pressing. One side of each plate mounted on the frame and clamped together. The space between adjacent plates forms a flow channel. The cold and hot fluids flow through channels.

(3). SHELL AND TUBE TYPE HEAT EXCHANGER

Shell and tube type heat exchangers are the most versatile and suitable for almost all applications, irrespective of duty, pressure and temperature. Shell and tube type exchanger consists of a cylindrical shell containing a nest of tubes that run parallel to the longitudinal axis of the shell and are attached to perforated flat plates called tube sheets at each end. There are a number of perforated plates, through which the tube passes called as baffles. This assembly of tubes and baffles is called a tube bundle and is held together by tie rods and spacer tubes for spacing the baffles.

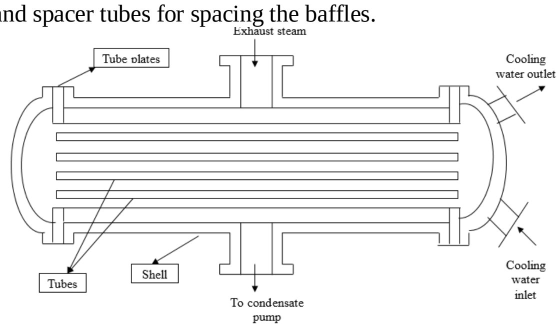


FIGURE: 2.3.A SHELL AND TUBE HEAT

There are mainly three types of shell and tube heat exchangers.

1. Fixed tube sheet
2. U-tube type
3. Floating tube sheet type

(1). FIXED TUBE SHEET TYPE

Tube sheets are welded to shell to form a box. Inside of the tubes may be mechanically cleaned after removing the channel cover, but because the tube bundle cannot be removed, cleaning of the outside tubes can only be achieved by chemical means. The combination of the thermal expansion coefficient of the shell tubes and temperature during service may cause a differential expansion between them, which if excessive might loosen the tube sheet joints. The principle advantage of the fixed tube sheet construction is its low cost because of the simple construction.

(2). U-TUBE T YPE

U-tube type heat exchanger has only one tube sheet and as each tube is free to move with respect to shell, the problem of the differential movement is eliminated. Tubes can be cleaned mechanically, in applications where the tube side fluid is virtually non-fouling fluid. The advantage of U-tube heat exchanger is, as one end is free the bundle can expand or contract in response to the stress differentials. The disadvantage of U-tube construction is that the inside of the tube cannot be cleaned effectively since the U bends require flexible end drill shafts for cleaning.

(3). FLOATING HEAD TYPE

The floating head type heat exchanger is the most versatile type of heat exchanger. In this type of heat exchanger one tube sheet is fixed relative to the shell, while the other is free to float thus permitting differential movement between shell and tube and also complete tube bundle withdrawal for easy cleaning. Although this type of exchanger is widely used, it has an internal joint at the floating head and careful design is asserted to prevent the leakage of one fluid to another. Also, the design accommodates a smaller number of tubes than the fixed tube sheet or U-tube type having the same shell inside diameter.

2.4. TYPES OF SHELL AND TUBE HEAT EXCHANGERS

1. Surface condenser
2. Steam jet air ejector condenser
3. Gland steam condenser
4. Drain cooler
5. LP heaters
6. Deaerators
7. HP heaters
8. Oil cooler

Surface condenser (rectangular):-

The condenser is surface type, fabricated construction and single shell. The condenser is mounted on saddles. A set of springs at the support or an expansion bellow at the condenser neck is provided to take care of thermal expansion in vertical direction. The condenser is firmly connected to the exhaust side of the turbine.

Ejector condenser: - The ejector condenser extracts non-condensable gases from condenser and there by creates and maintains vacuum in the system.

Gland steam condenser: - The gland steam condenser is used to condense the gland steam extracted from turbine glands, in a regenerative cycle, this besides condensing the glands steam, heats the condensate from the condenser. In case of very low condensate flows or non-condensing sets, GSC steam will be cooled by cooling water the condensate or cooling water passes through the tubes and steam/drain passes over the tubes. The gland steam condenser is of surface, horizontal/vertical mounting type.

Drain cooler: - This sub cools the drain from the low-pressure heater to improve the cycle efficiency by heating the feed water flowing in the drain cooler.

L.P Heater: - The low-pressure heaters are used to heat the condensate from the condenser, by extracting steam from turbine in a regenerative heat cycle. This, besides effecting an improvement in the thermal efficiency removes moisture from the low-pressure stage of the turbine there reducing the problems of blade corrosion in the turbine. The condensate passes through the u tubes and steam/drain passes over the tubes. The LP heaters are of surface type with either horizontal or vertical mounting.

H.P. Heater: - The high pressure feed water heaters are employed to increase the overall efficiency of the regenerative cycle by heating the feed water by the steam extracted from suitable stages of the turbine.

Deaerators: - Deaerators are used to remove oxygen (corrosive gases) mechanically from the water used for generating steam in the boilers. The oxygen is reduced to 0.005cc/liter or less.

Oil cooler: - Oil cooler is basically a heat exchanger and is an essential equipment to cool the lube oil that is to cool the bearings and other surfaces of the large machinery like turbines.

SELECTION OF HEAT EXCHANGERS

From the design point of view, Heat exchangers are complicated equipment's. For example, if the overall heat transfer coefficient U is kept throughout the heat exchanger, and that the convection heat transfer coefficient can be predicted using the convection correlation's, however, the uncertainty in the predicted value of U can even exceed 30 percent. Thus it is natural to tend to over design the heat exchanger in order to avoid unpleasant surprises.

Heat transfer enhancement in heat exchangers is usually accompanied by increasing pressure drop and thus higher pumping power. Therefore any gain in the enhancement in heat transfer should be weighed against the cost of the accompanying pressure drop. Also, some thought should be given to which fluid should pass through the tube side and which should pass through the shell side. Usually, the more viscous fluid passes is for the shell side (larger passage area and thus lower pressure drop) and the fluid with higher pressure for the tube side. The rate of heat transfer in the prospective heat exchanger is

$$Q_{max} = m. C_p.(T1 – T0)$$

Which gives the heat transfer requirement of the heat exchanger before having any idea about the heat exchanger itself.

The proper selection depends on several factors. They are:

- Heat transfer rate:

This is the most important quantity in the selection of heat exchanger. A heat exchanger should be capable of transferring heat at the specified rate in order to achieve the desired temperature change of the fluid at the specified mass flow rate.

- Cost:

Budgetary limitation usually plays the most important role in the selection of heat exchanger, except for some specialized cases where "money is no object". An off the shell heat exchanger has a definite advantage over those made to order. However, in some cases, none of the existing heat exchangers will do, and it may be necessary to undertake the expensive and time-consuming task of designing and manufacturing a heat exchanger to suit the needs. This is often the case when the heat exchanger is an integral part of the overall device to be manufactured.

- Pumping power:

In a heat exchanger, both fluids are usually forced by pumps, which consume electrical power. The annual cost of electricity associated with the operation of the pumps can be determined. Minimizing the pressure drop and the mass flow rate of the fluid will minimize the operating cost of the heat exchanger, but will maximize the size of the heat exchanger and thus the initial cost.

- Size and weight:

Normally, the smaller and lighter the heat exchanger, the better is it. The space available for the heat exchanger in some cases limits the length of the tubes that can be used.

- Type:

The type of heat exchanger to be selected depends primarily on the type of fluid involved, the size and weight limitations, and the presence of any phase change processes. A heat exchanger is suitable to cool a liquid by the gas if the surface area on the gas side is many times that on the liquid side. On the other hand, a shell and tube heat exchanger is very suitable for cooling a liquid by another liquid.

- Materials:

The materials used in the construction of the heat exchanger may be and important consideration in the selection of heat exchanger. A temperature difference of 50oC or more between the tubes and the shell will probably pose differential thermal expansion problems and the need to be considered. The case of corrosive fluids, corrosive-resistant materials such as stainless steel can be selected.

Tube Plate Material: In general the tube plate should be of a harder material than the tube so that it does not deform and affect the tightness of completed joints adjacent to it. It should however be ductile enough to take up discrepancies in orality of the hole or tubes during expansion. After expansion the material shall be still within its elastic limits.

Tube expansion:

In surface condensers, the tubes are normally roller expanded in the tube plate to form a leak proof joint. The strength of the roller-expanded joint shall be sufficient to overcome the pressure of water acting over the tubes. The expansion joint should therefore be strong and carried with meticulous care.

- Tube-to-Tube sheet joint: - Tubes are secured to tube plates by roller expansion, which form a tight joint between tube and tube plate. This will provide a good sealing arrangement against the penetration of circulating water into the steam space. The strength of the tube to tube sheet joint is such that an expansion bellow on shell side due to differential expansion between tube and shell is not required (i.e.) the force exerted by the tube due to differential expansion with shell will be less than the strength of the joint.

- Other considerations: There are other considerations in the selections of heat exchanger depending on their applications like being leak tight is an important consideration when toxic or expensive fluids are involved. Ease of service and low maintenance cost and safety and reliability are some other important considerations in the selection process

DESIGN OF OIL COOLER

5.1. DESIGN METHODOLOGY

The first criterion that a heat exchanger should satisfy is the fulfillment of the process requirement. The design specifications may contain all the necessary detailed information on flow rates of fluids; operating pressures; pressure drop limitations for both streams, temperatures size, length and other design constraints such as cost, type of material, heat exchangers types and arrangements .The heat exchanger design provides missing information based on experience, judgment and the requirements of the customer.

The selection criterion is that the heat exchanger must withstand the service conditions of the plant environment therefore all thermal design analysis; the mechanical design is conducted, which includes the calculation of plate, tube, shell and arrangements. The exchanger must resist corrosion by the service and process streams and by the environment; this is mostly a matter of proper material selection. A proper design of inlet nozzles and connections, supporting materials, location of pressure and temperature and measuring devices and manifolds are to be made. Thermal stress calculation must be performed under steady state and transit operating conditions. The addition important factors to be considered are checked in the design are flow vibrations and level of velocities to minimize or eliminate fouling and erosion

5.2. GENERAL DESIGN CONSIDERATIONS

For designing any water-cooled heat exchanger, several parameters are usually fixed. These parameters include heat duty, inlet and outlet process steam temperatures and ambient inlet temperature of water. The key variable parameter that controls the heat exchanger design is the cooling water flow rate. An increase in the cooling water flow rate increases the overall heat transfer coefficients and the mean temperature difference, thereby decreasing the size of the heat exchanger. The increase in water velocity also increases the waterside pressure drop through the exchanger, thus increasing the necessary pump capacity. Erosion problems, vibrations, flow stability and tube materials also restrict the velocity of water.While designing a heat exchanger, values of certain design parameters like number of tubes and water quantity are assumed initially. Therefore, a trial and error is required to find the optimum values of the design parameters. Sometimes, this may lead to too much iteration and thus the design becomes cumbersome. However, with the advent of personal computer this process is simplified. HTRI (Heat Transfer Research Institute of USA) has developed a powerful software package for designing heat exchangers with the help of which the designing becomes very simple and optimum.

The design of heat exchangers can be broadly classified into three separate but interrelated activities:

- Thermal Design
- Pressure drop characteristics
- Mechanical Design

In the present project, the methodology used in the design of the heat exchanger is studied and presented. The thermal design involves the calculation of shell side and tube side heat transfer coefficients, heat transfer surface area and pressure drops on the shell side and tube side.

The mechanical design involves the calculations of thickness of pressure parts of the heat exchanger such as the shell, channel, tube etc. to evaluate the rigidity of part under design pressures. The design of the heat exchanger is then modeled in PRO-Engineer and finally analysed using ANSYS software.

In this system oil is taken as hot fluid and cold fluid is water.

Where no phase change occurs, the following factors will determine the allocations of fluid streams to the shell or tubes.

Corrosion: This will reduce the cost of expensive alloys components.

Fouling:

The fluid has greatest tendency to foul the heat transfer surface should be placed in the tubes. This will give better control over the design fluid velocity, and the allowable velocity in the tubes will reduce fouling. Alsothe tubes will be easier to clean.

Fluid temperature:

If the temperatures are high enough to require the use of special alloys placing the higher temperature fluid in the tubes will reduce the overall cost. At moderate temperatures, placing the hotter fluids in the tubes will reduce the shell surface temperatures, and hence the need for lagging to reduce heat loss, or for safety reasons. The inlet temperature of hot fluid is taken as 54.45 C.

Pressure drop: For the same pressure drop, higher heat transfer coefficient will be obtained on the tube-side than the shell side and fluid with the lowest allowable pressure drop should be allocated to the tube side
.

Viscosity: Generally, a higher heat transfer coefficient will be obtained by allocating the more viscous material to the shell side, providing the flow is turbulent. If turbulent flow cannot be achieved in the shell side, providing the flow is turbulent. If turbulent flow cannot be achieved in the shell it is better to place the viscous fluid in the tubes, as the tube side heat transfer coefficient can be predicted with more certainty. In this project, the hot fluid is in the shell side and the cold fluid is allocated in the tube side.

5.3. THERMAL DESIGN DATA (PROVIDED BY B.H.E.L)

Heat duty =65000 kcal/hr (Input data)
Quantity of water = 50m3/hr (Assumed)
Quantity of oil = 14.75m3/hr (Input data)
Water inlet temperature = 33°c (Input data)
Oil outlet temperature = 45°c (Input data)
Allowable pressure drop on water side = 0.6 kg/cm2 (Input data)
Allowable pressure drop on oil side = 0.6 kg/cm2 (Input data)
Fouling factor on water side = 0.0004 hr-m2-°c/kcal
Fouling factor on oil side = 0.0002 hr-m2-°c/kcal (Input data)
Tube material =Admiralty brass
Thermal conductivity of tube material = 66 BTU/hr-ft2 0F (From TEMA)
Number of tubes = 90
Number of tube passes = 2
Length of tube = 3300mm=3.300 m
Outside diameter of the tube = OD=19.05mm=0.01905m

ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 5, Issue 7, July 2016

Thickness of tube = 1.650mm=0.00165m
Inside diameter of tube = OD-2*Thk = 15.75mm=0.01575m
Tube type = Plain type
Tube pitch = 25.4mm=0.0254m
Ratio of outside to inside surface area=Ao/Ai =πdoL/πdiL = 1.2095
Number of baffles = 33
Baffle cut =22%
Type of heat exchanger = Shell and tube AEW type heat exchanger (floating rear tube sheet)
Baffle thickness = 6mm=0.006m
Shell inside diameter = 307mm=0.307m
Shell outside diameter =323.8mm=0.3238m
Shell thickness = 8.4mm=0.0084m
Baffle spacing = 86mm=0.086m

Properties of Oil:

$\mu 0$ = 25.6375cp = 0.0256357 kg/m-sec=92.295 Kg/m-hr

Cp0 = 0.4663 kcal/kg-°c
K0 = 0.1295 kcal/m-hr-°c
$\rho 0$ = 851.85 kg/m3

Properties of Water:

μw = 0.7496cp = 0.0007496 kg/m-sec=2.6985 kg/m-hr

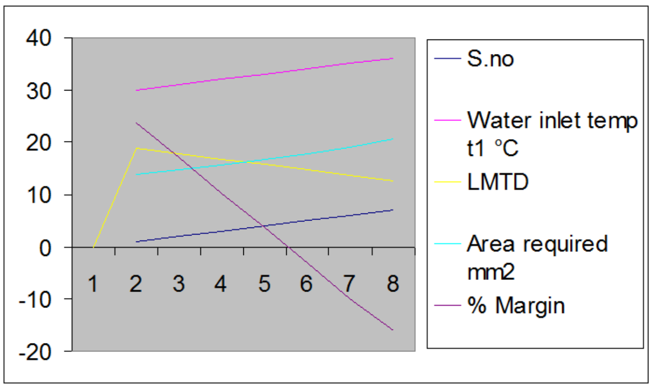
Cpw = 0.9992 kcal/kg-°c
Kw = 0.54275 kcal/m-hr-°c
ρw = 992.945 kg/m3

Table.1 Comparison of pressure drop &overall heat transfer coefficient values with HTRI

S.NO	Pressure drop				Overall heat transfer coefficient, Kcal/hr-m²/⁰C		
		Theoretical	HTRI	% Error	Theoretical	HTRI	% Error
1	Shell Side	0.336	0.335	0.29	244.9	249.035	1.68
2	Tube Side	0.2629	0.229	1.4			

Table.2Variation of LMTD and surface area with water inlet temperature

S.no	Water inlet temp t1 °C	LMTD °C	Area required mm2	% Margin
1.	30	18.78	13.887	23.73
2.	31	17.76	14.684	17.01
3.	32	16.74	15.57	10.32
4.	33	15.72	16.586	3.59
5.	34	14.7	17.7	-3.10
6.	35	13.67	19.07	-9.90
7.	36	12.64	20.632	-16.0



Variation of LMTD and surface area with water inlet temperature

Table.3 Variation of overall heat transfer coefficient with fouling factor of oil

S.no	Fouling factor of oil Hr-m2-°c/kcal	Heattransfer coefficient of oil Kcal/hr-m2-°C	Overall heat transfer coefficient Kcal/hr-m2-°C
1.	0.0001	331.196	276.595
2.	0.0002	320.578	249.035
3.	0.0003	310.620	237.228
4.	0.0004	301.263	226.479

ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
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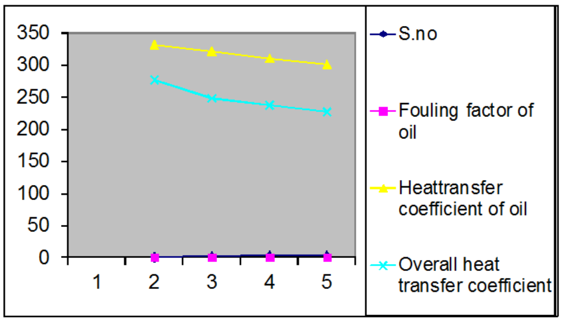
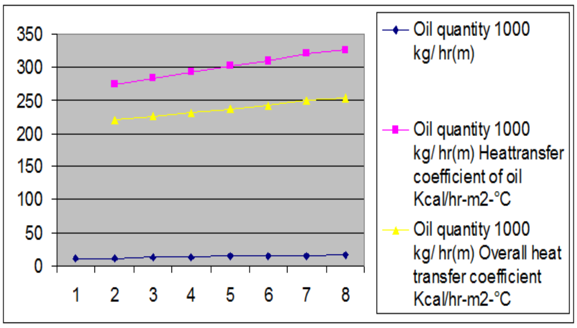


Variation of overall heat transfer coefficient with fouling factor of oil

Table.4 Variation of heat load and overall heat transfer coefficient with oil quantity

S.no	Oil quantity 1000 kg/ hr(m)	Heat load Q_s Kcal/hr	Reynolds No	Heat transfer coefficient of oil Kcal/hr-m²-°C	Overall heat transfer coefficient Kcal/hr-m²-°C
1.	11.0655	48760.513	154.83	273.898	219.971
2.	11.8032	52011.213	165.125	283.207	225.885
3.	12.5409	55261.914	175.472	292.274	231.616
4.	13.2766	58512.615	185.79	301.048	237.092
5.	14.0163	61763.331	196.119	309.572	242.347
6.	14.754	65014	209.873	320.578	249.035
7.	15.4917	68264.71	216.757	325.944	252.267
8.	16.2294	71515.419	227.085	333.831	256.966



Variation of heat load and overall heat transfer coefficient with oil quantity

MODELLING OF HEAT EXCHANGER USING PRO-E

INTRODUCTION TO PRO-E:

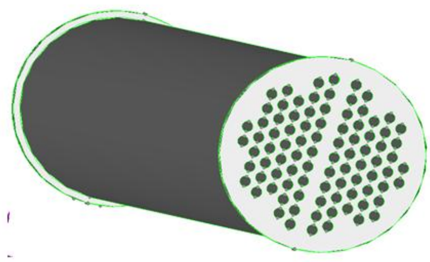
With the advances in computer technology and cad system, complex programs can be modeled with relative ease. Several alternative configurations can be tried out on a computer before the first prototype is built .of the various design packages available in the market ,Pro-Engineer is a parametric feature based package which is very flexible and versatile and hence is widely used .also it has an additional advantage of direct interface with a CNC machine.

It is one of the very few design packages which incorporates a wide range of modules required by the industry like :

Sketcher
Part drawing
Advanced part
Assembly
Manufacturing
Sheet metal
Surface
Drawing

In the present project, the components of heat exchanger are modeled using part drawing features and then using assembly modules, the assembly of the heat exchanger is generated. The part drawing is a versatile module where in the whole heat exchanger can be modeled as a single unit as opposed to the assembly module where each part is modelled separately and finally assembled to get the required component using the various options available. The geometric model of heat exchanger is shown in Fig.6.1

Fig.6.1.The model of a heat exchanger



FINITE ELEMENT MODELING ANALYSIS

7.1. Introduction

It is very difficult for human brain to examine critically the behaviour of a complex structure subjected to different conditions. To overcome this, scientists started to divide the complex structure into individual components, whose behaviour can be understood intuitively. This individual component is then assembled to study the behavior of the entire structure. This

ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 5, Issue 7, July 2016

method of discretising a complex structure and then making analysis on it is termed as Finite Element Method.

7.2. Need for Finite Element Analysis:

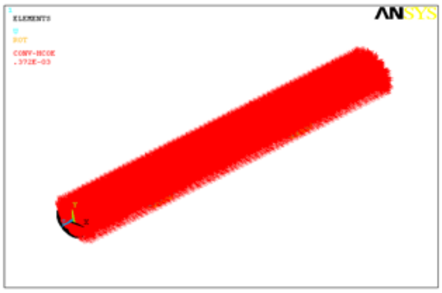
The tendency of structure or a component in a machine to fail increased with the complexity of structure. This necessitated the analysis of the machine during design, a building before and after construction, to ensure proper functioning and reduce production losses. The analysis becomes difficult and time consuming as the complexity of the model increases. This dictated the need for an efficient method that gives a reasonably good result and require less time. Finite element methods give plausible solutions to such problems and are much widely in use because the techniques can be adapted to digital computers.

In many situations, an adequate model is obtained by dividing it into a finite number of well-defined components called elements. Such problems are termed discrete. Whereas in some cases the discretisation is finite and can only be defined by fictional mathematics equations. Such problems are termed continuous. It becomes difficult to solve such equations even by fast digital computers. This imposed the need for finite element methods, which uses equations that can be solved easily by the computers.

All these factors called for a need for Finite Element Methods.

7.3. Advantages of Finite Element Methods

There are certain advantages of Finite Element Methods, which made it a widely used method. They are as follows:



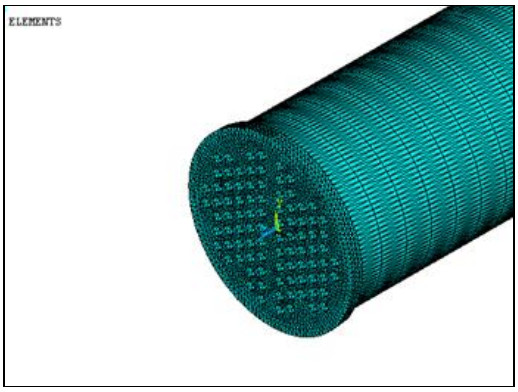
The thermal boundary conditions

1. With the advent of digital computers the analysis became cheaper, easier and faster.

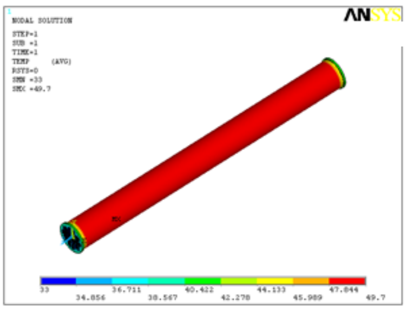
2. Finite Element Analysis makes it possible to evaluate a detailed and complex structure in a computer during the planning stage itself. The demonstration in computer of the adequate strength of the structure and the possibility of improving the design during the planning stage justify the cost of analysis.

3. In the absence of Finite Element Analysis (or any numerical methods), designing and analysis of structures are based on hand calculations. Certain assumptions have to be made to reduce the complexity of calculations. This reduces the accuracy of solution. FEA makes effective use of numerical techniques, and even though some assumptions are made, the desired degree of accuracy can be achieved.

8.3. ANALYSIS OF SHELL AND TUBE COMPONENT



finite element model of heat exchanger



Nodal solution for Temperature Distribution Condition

ISSN: 2278 – 7798
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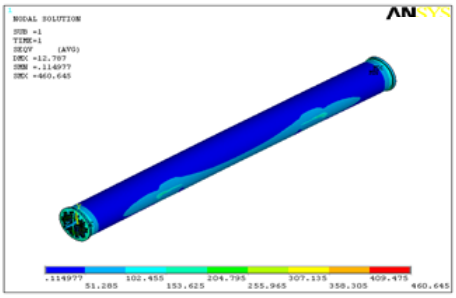
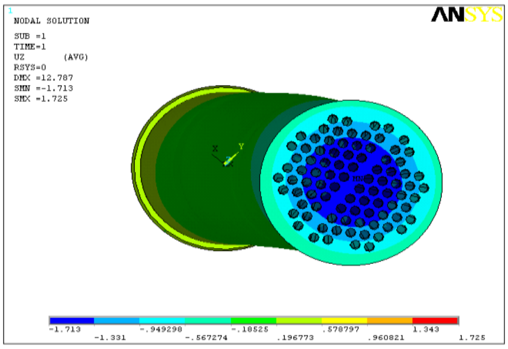
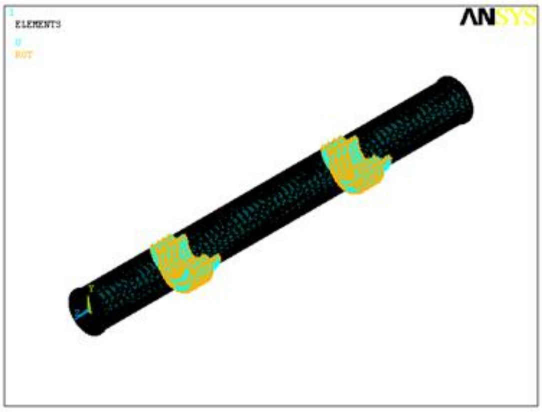
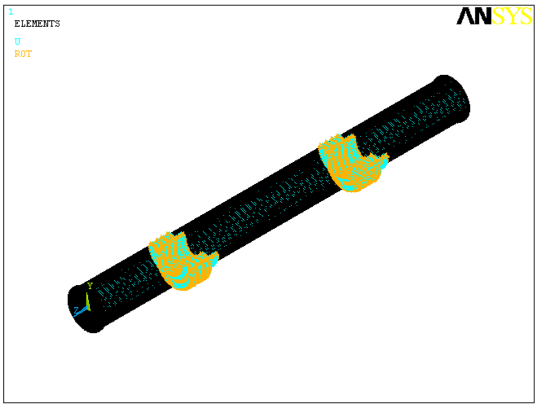


Fig.8.3. Nodal solution for Von Mises Stress



Nodal solution for Deformation in z-direction





8.4. RESULT AND DISCUSSIONS

The thermal and pressure drop calculations for a given heat exchanger are done using theoretical equations. These results are evaluated with the world-renowned software package for design of heat exchanger "HTRI"(Heat Transfer Research Institute of USA). This is shown in Table 1.The calculated results were found to be closely matching with program output values. Hence the heat balance and the provided heat transfer surface areas are matching with power plant requirements.

In mechanical design, important minimum dimensions of different parts of the equipment to suit the design pressures and temperatures. The design standard ASME code for pressure vessel constructions are used.

The surface area required by calculations is adequately provided in the tube; the pressure drops calculated for the flows through the heat exchanger are within the permissible limits; the critical components have been designed for sufficient mechanical strength as per ASME .The performance of the given geometry is tabulated (Table 2,3,4) and graphically analysed by varying the parameters Hence, the present design of oil-to-water heat exchanger is in order. As the inlet temperature of water increases, LMTD decreases due to increase in surface area. shows the variation. As the fouling factor increases over all heat transfer coefficient decreases as shown in

The variation of temperature are shown in the heat exchanger, where the maximum temperature of 49 degree centigrade at and the minimum temperature is observed 33 degree centigrade as shown in figure

Stress Analysis:

The thermal solution is coupled with structural analysis for the deflection and the stresses .the maximum displacement is observed 1.725mm whereas the maximum stresses is observe red to be 460.645 MPa.

CONCLUSION

Within the present project, the thermal and pressure drop calculations are done by using the empirical formula, as per TEMA and verified with HTRI software package (USA).

The pressure drop values on shell side and tube side at the same time, overall heat transfer coefficient values are with a variation of 0.29%. 1.4% and 1.68% respectively and matching with the HTRI software.

The variation of LMTD and surface area with water inlet temperature decreases and increases respectively and

variation in overall heat transfer coefficient decreases with the increase of fouling factor of oil. As the quantity of oil is varied increasingly the heat load and the overall heat transfer coefficient also increases.
From the theoretical modeling the convection heat transfer coefficients along with the bulk temperature and imposed as a boundary conditions to predict the temperature distribution in heat transfer analysis in both the shell and tube.
The maximum Von Mises stress induced is 460.645Mpa, which is less than allowable stress. Hence the design is safe based on the strength.

REFERENCES

[1] Sachdeva, R' Fundamental of Engineering of Heat and Mass Transfer,
Wiley Eastern Ltd, 1988.

[2] Donald. Q. Kern, Process Heat Transfer, Mc Graw Hill7 Publications.

[3] Holman, J.P, Heat Transfer, Mc Graw Hill Publications,1986.

[4] TEMA Standards

[5] ASME Standards-Boilers and Pressure Vessels Code

[6] ASME Standards-Section –VIII Division –I

[7] ASME Standards- Section-II Part-A,B & D

[8] Cook, R.D.Taylor M 'Concept of Finite Elements in Engineering'
John Wiley International, 1985.

[9] ANSYS user manual.

[10] Reddy.J.N.'Introduction to FEM' Tata Mc Graw Hill, Education3,
1995

[11] Domukundwar, Heat and Mass transfer, Dhanpat Rai & sons
Publications.

[12] Dr. P. Ravinder Reddy, "Computer Aided Design and Analysis"

Author's Profile:

D Amrutha Vijay is a student pursuing M.Tech (CAD/CAM) in Eswar College of Engineering, Narasaraopet, Guntur, India.

P.SNEHALATHA P M.Tech (P.hD), is having 6+ years of experience in the field of teaching in various Engineering Colleges and PG colleges. At present she is working asAsst.Prof.in Eswar College of Engineering, Narasaraopet, Guntur, India.She published 1 international journal i.e SCI Journal and attend 1 national conference and 2 international conferences. She also guided many B.Tech, & M.Tech projects. She attended five day workshop on –Student Evaluation conducted by NITTTR, Chennai. And one day seminar on teaching and learning process at Stanns Engineering College, Chirala.
Her interested areas are CAD, Composite Materials, Machine Drawing, Machine Tools, Production Planning And Control.