ANALYSIS OF SHELL AND TUBE HEAT EXCHANGERS

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Abstract - Heat exchangers have always been an important part to the lifecycle and operation of many systems. A heat exchanger is a device built for efficient heat transfer from one medium to another in order to carry and process energy. Typically one medium is cooled while the other is heated. They are widely used in petroleum refineries, chemical plants, and petrochemical plants**.** The purpose of this thesis work is to design an Oil Cooler, especially for shell and tube heat exchange which is the majority type of liquid to liquid heat exchanger with baffle for induced turbulence and higher heat transfer coefficient. Modeling is done by using PRO-Engineer, and analysis carried out in Ansys software 14.5. General design consideration and design procedure are also illustrated in this thesis in design calculation; the Ansys software 14.5 and HTRI software are used. Within the project work the analysis are done for heat exchanger with baffle and without baffle also used four material for tubes (brass, nickel, carbon steel ,stainless steel) and observed the heat transfer rate is increased for heat exchanger with baffle and when we used brass material. From the theoretical modeling the convection heat transfer coefficient along with the bulk temperature are found out and imposed as boundary condition to predict the. Temperature distribution, heat flux and thermal gradient in heat transfer analysis. By comparing the result for four materials, the stress is less when brass material is used.

Keywords: Oil Cooler, Temperature, Heat Flux, Heat Exchanger.

I. INTRODUCTION

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 Transfer of heat from one fluid to another is an important operation from most of the chemical industries.

II. TYPES OF HEAT EXCHANGERS

The three main types of heat exchangers are

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.

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.

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.

III. THERE ARE MAINLY THREE TYPES OF SHELL AND TUBE HEAT EXCHANGERS

Fixed tube sheet type: temperature during service may cause a differential expansion between them, which if xcessive might loosen the tube sheet joints.

U-tube type: 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.

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.

A. Description Of Oil Cooler

Tubes: Heat exchanger tubes are available in variety of materials, which include both ferrous and non-ferrous materials such as carbon steel, stainless steel, copper, admiralty brass, 90-10 copper-nickel, etc. They are vailable in a number of wall thickness defined by BWG. The tubes are made with the strict tolerance on the outside diameternd as per specification of ASME, BS, IS standards.

Tube Pitch: The tube pitch is the shortest distance between two adjacent tubes. Tube holes cannot be drilled very close together since too small width of metal between the adjacent tubes structurally weakens the tube sheet as shown in Fig.1. The shortest distance between the two tube holes is the clearance.
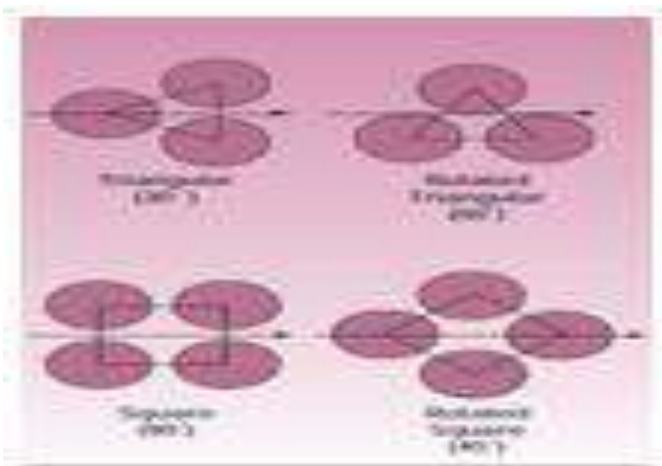

Fig.1. Tube layouts.

Tube Sheet: They are used to hold the tubes at the ends.

A tube sheet is generally a circular metal plate with holes drilled through for the desired tube pattern, holes for the tie rods, grooves for the gaskets and bolt holes for flanges to the shell and channel.

Baffles: It is apparent that higher heat transfer coefficient results when the liquid is maintained in the state of turbulence. To induce turbulence outside the tube it is customary to employ baffles, which cause the liquid to flow through the shell at right angles to the exit of the tubes.

Nozzles: The entrance and exit ports for the shell fluid and tube fluid are referred to as "Nozzles". These nozzles are pipes of constant cross section welded to the shell and channels. They are used to distribute or collect the fluid uniformly on shell and tube sides.

Front-End And Rear End Covers: They are containers for tube fluids for every pass. In many rear end head designs, a provision has been made to take care of thermal expansion of whole tube bundle. The front-end head is stationery while the rear end head could be either stationary or floating depending upon the thermal stresses between the tubes and shell.

Tie Rods And Spacers: Tie rods and spacers are other equivalent means of tying baffle system together. They should be provided to retain all transverse baffles and tube support plates securely in position. They serve two purposes; one to maintain the spacing between the baffles and second function is to reduce the fluid by-passing.

Shell: The cylindrical shell made of rolled carbon steel plate or pipe carries flanged connection for water inlet, water outlet, plug and couplings for shell drain and vent. Suitable provisions are made for pressure and temperature measurement.

Water Chambers: Both the inlet and outlet and rear end water chambers are fabricated from rolled carbon steel plate or a pipe and are of adequate proportions to minimize pressure drop and turbulence.

Tube Plates: The tube plate material is selected depending on the type of cooling water application. Both the tube plates are drilled and tapped to receive the bolts securing water chamber. The tube holes are internally reamed to a finish suitable for the roller expansion into tube plates.

B. Design Methodology

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 analyzed using ANSYS software. In this system oil is taken as hot fluid and cold fluid is water. Where no phase change occurs.

Calculation:

Perform energy balance and find out the heat duty

$$(Q). \; Q = m * cp * (t_2 - t_1) = m * cp * (T_1 - T_2) \quad \text{(1)}$$

Determine the Logarithmic mean temperature difference (LMTD).

$$\text{LMTD} = (\Delta T_1 - \Delta T_2)/\text{Ln } (\Delta T_1/\Delta T_2) \quad \text{(2)}$$

Correction Factor based on R & S Overall heat transfer coefficient (U). $1/U = 1/h_{0f} + (1/h_i + \text{water side fouling factor})(A_0/A_i) + \text{oil side fouling factor} + \text{Tube wall esistance}$.

Basic relation of heat transfer from TEMA book. Surface area calculations (Ao).

$$A_o = Q / U*MTD \quad \text{(3)}$$

Pressure drop calculation for shell side (p_s).

$$\Delta P_{s1} = (B_0 * 2f^1 * N_r * G_s^2)/(g_{0*}\rho_0) \quad \text{(4)}$$

Pressure drop calculation for tube side (p_t).

$$\Delta P_t = B_i \left[(2f_i G^2 L n_p)/(g_c \rho_i D_i \phi_i) \right] \quad \text{(5)}$$

IV. ANALYSIS OF SHELL AND TUBE COMPONENT STRUCTURAL ANALYSISBRASS ALLOY WITHOUT BAFFLE

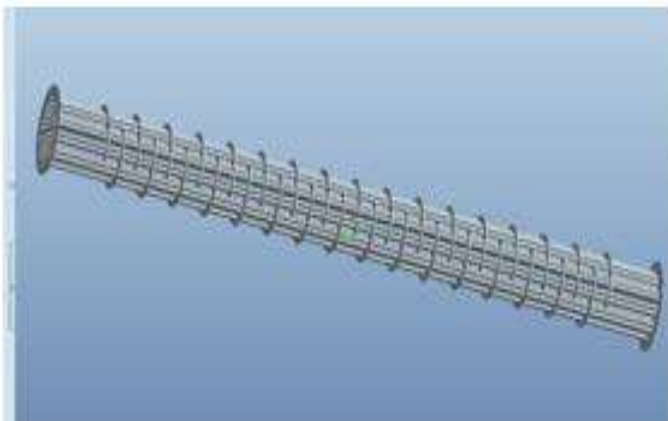Analysis of shell and tube component Structural analysis brass alloy without baffle as shown in Figs.(2-4)
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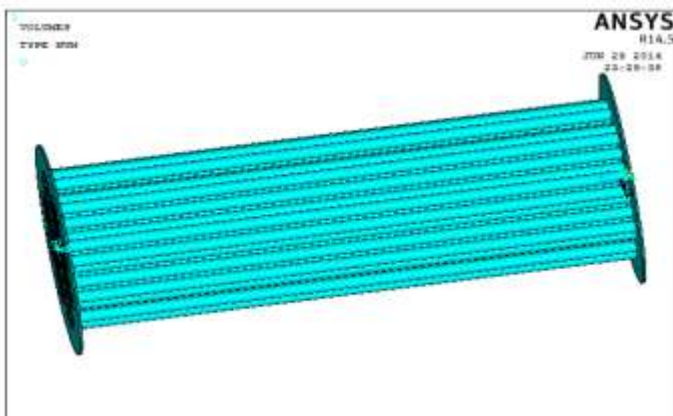**Fig.2. Model of a heat exchanger without outer shell.**

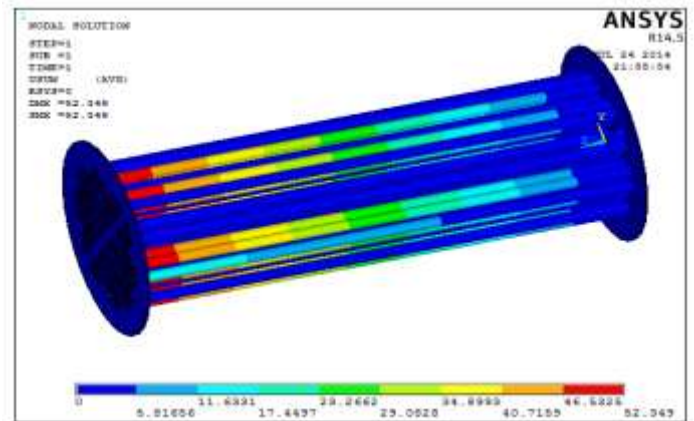**Fig.3. The finite element model of brass alloy without baffle.**

Fig.4. Displacement Vector Sum for brass alloy without baffle (mm).

A. Structural Analysis brass Alloy with Baffle

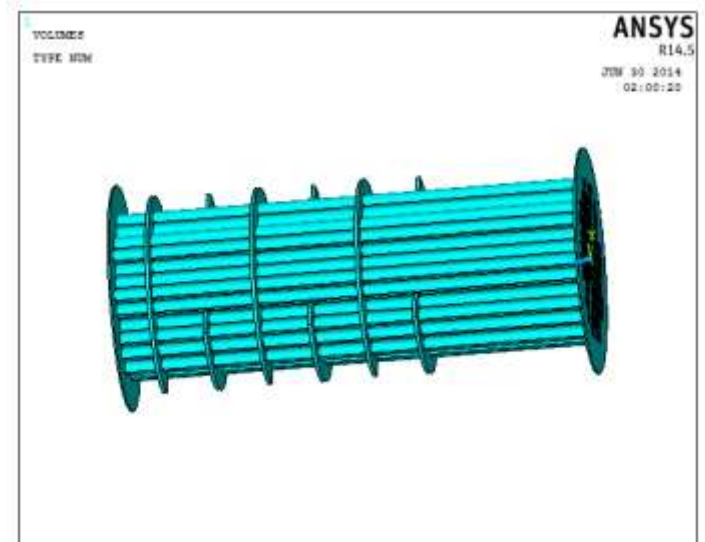Structural Analysis brass Alloy with Baffle As shown in Figs.5-7)
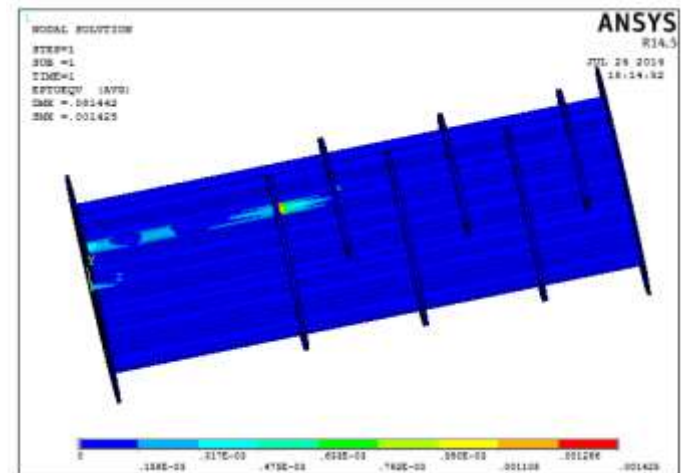

Fig.5. Model for brass alloy with baffle

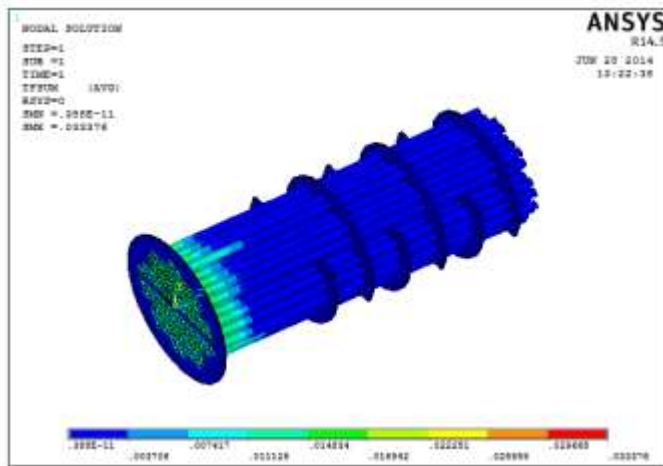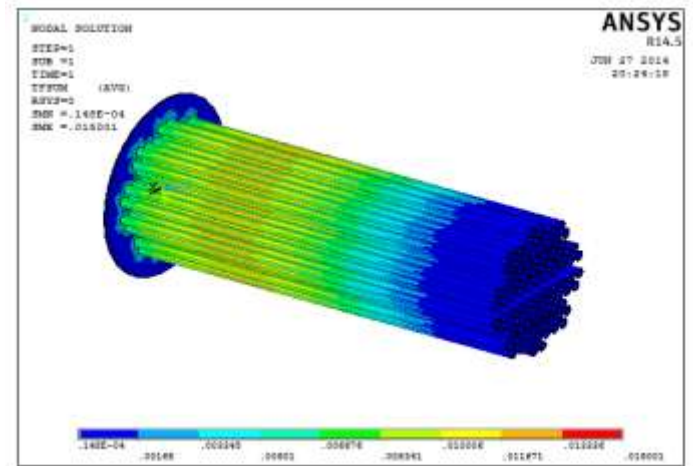**Fig.6. strain for Brass alloy with baffle.**

Fig.7. thermal flux for Brass alloy with baffle (w/mm2).

B. Thermal Analysis Brass Alloy without Baffle

Thermal Analysis brass Alloy Without Baffle As shown in Figs.(8-10)

Fig.8. Nodal temperature for brass alloy without baffle (k).

Fig.9. thermal gradient for brass alloy without baffle (k/mm).

Fig.10. thermal flux for brass alloy without baffle (w/mm2).

TABLE I: Results of Structural Analysis by Ansys For Four Materials with and Without Baffle

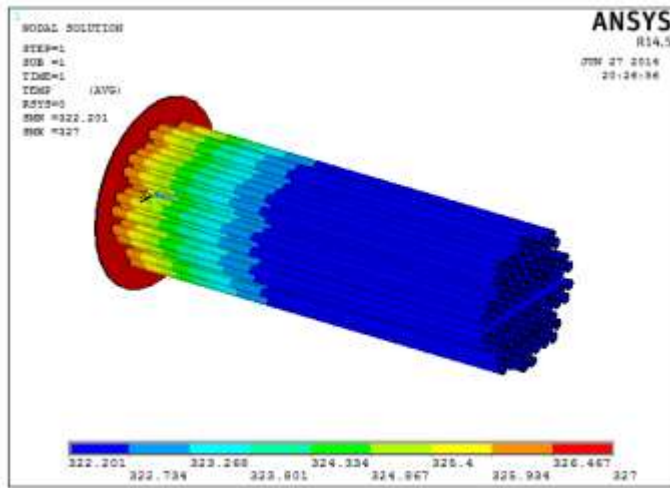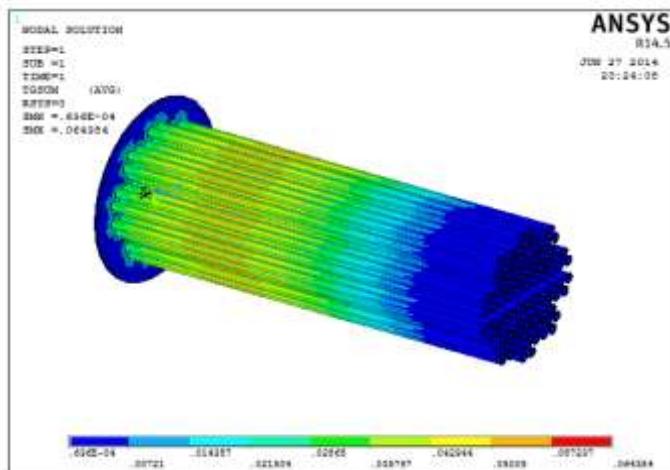| DESPRECTION	MATERIALS	RESULTS		
		DISPLACEMENT (mm)	STRESS (N/mm²)	STRAIN
WITH BAFFLES	nickel	0.031375	118.36	0.574E-03
	brass	0.081442	116.40	0.14E-03
	Carbon steel	0.047063	118.36	0.861E-03
	Stainless steel	0.08504	117.34	0.0015
WITHOUT BAFFLES	nickel	19.42	9296.7	0.4513
	brass	52.349	9794.5	0.1200
	Carbon steel	29.8863	9296.7	0.0677
	Stainless steel	54.7963	9552.2	0.1246

TABLE II: Results of Thermal Analysis by Ansys For Four Materials With and Without Baffle

DESPRECTION	MATERIALS	RESULTS		
		NODAL TEMPERATURE (K)	THERMAL GRADIENT (K/mm)	THERMAL FLUX (W/mm²)
WITH BAFFLES	nickel	327	0.234464	0.014232
	brass	327	0.143246	0.033376
	Carbon steel	327	0.24965	0.012982
	Stainless steel	327	0.300082	0.010293
WITHOUT BAFFLES	nickel	327	0.16716	0.010147
	brass	327	0.064384	0.015001
	Carbon steel	327	0.186198	0.009682
	Stainless steel	327	0.247507	0.008489

V. CONCLUSIONS

By comparing the result for four material ,the stress is less when brass is used .

We find the more heat transfer rate when we used brass material.

By observing the thermal analysis result, the heat transfer rate is increased for heat exchanger with baffle.

When we observing the structural analysis result the displacement and stresses are less when baffle are used than heat exchanger without baffle.

The pressure drop values on shell side and tube side at the same time, overall heat transfer coefficient values are with a variation of 4.4%, 6.3%, and 2.72 % respectively and matching with the HTRI software.

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 thermal and pressure drop calculations are done by using the empirical formula, as per TEMA and verified with HTRI software package.

VI. REFERENCES

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