International Journal of
Scientific Engineering and Technology Research

ISSN 2319-8885
Vol.03,Issue.20
September-2014,
Pages:4181-4187

www.semargroup.org,
www.ijsetr.com

Design and Analysis of Heat Exchanger

BAYDAA RASHID ISMAEL[1], DR. ARUNA KUMARI[2]

[1]PG Scholar, Dept of Mechanical Engineering, JNTUH College of Engineering (Autonomous), Hyderabad, India, & Republic of Iraq council of Ministries Shia Endowment Head office, E-mail: hhhbbb_1970@yahoo.com.

[2]Prof, Dept of Mechanical Engineering, JNTUH College of Engineering (Autonomous), Hyderabad, India, E-mail: arunajntu@jntuh.ac.in.

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 soft ware 14.5. General design consideration and design procedure are also illustrated in this thesis in design calculation; the Ansys soft ware 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. Also when we do structural analysis for heat exchanger by using Ansys 14.5 software we observing the analysis result the displacement and stresses are less, when we used heat exchanger with baffle than when we used heat exchanger without baffle. Also by comparing the result for four materials, the stress is less when brass material is used. Thermal and pressure drop calculation are done by using the empirical formula .as per TEMA and verified with HTRI soft ware The pressure drop values on shell side and tube side, overall heat transfer coefficient values are found out and observed that they are with variation of 4.4% ,6.3% and 2.7% respectively and matching with HTRI software.

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. 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 exchangers.

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. 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.

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 excessive 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. 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.

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.

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 available in a number of wall thickness defined by BWG. The tubes are made with the strict tolerance on the outside diameter and 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.

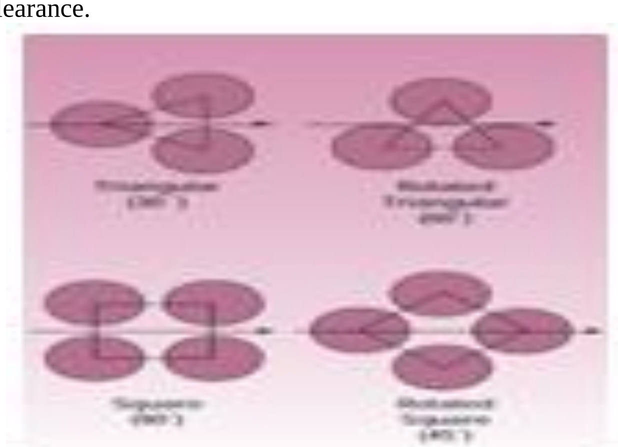

Fig.1. Tube layouts.

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. Baffles are used to support tubes, enable a desirable velocity to be maintained for the shell side fluid, and prevent failure of tubes due to flow-induced vibration.

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. The inlet and outlet water chamber carries water and inspection cover is divided internally into inlet and outlet chambers, each having a flanged connection. The rear end water chamber consists of a simple dished cover or a flat end cover. If the water passes are more than two it is divided accordingly.

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.

Theoretical Calculation: Perform energy balance and find out the heat duty

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

Determine the Logarithmic mean temperature difference (LMTD).

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

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

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

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

Pressure drop calculation for shell side (p_s).

$$\Delta P_{s1} = (B_0{*}2f^1{*}N_r{*}G_s^2)/(g_0{\cdot}\rho_0) \quad (4)$$

Pressure drop calculation for tube side (p_t).

$$\Delta P_t = B_i\,[(2f_iG^2Ln_p)/(g_c\rho_iD_i\phi_i)] \quad (5)$$

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 Figs2 to 7.

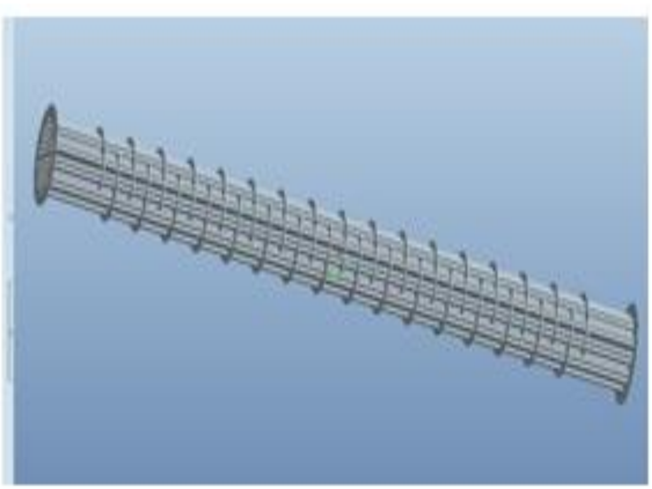

Fig.2. Model of a heat exchanger without outer shell.

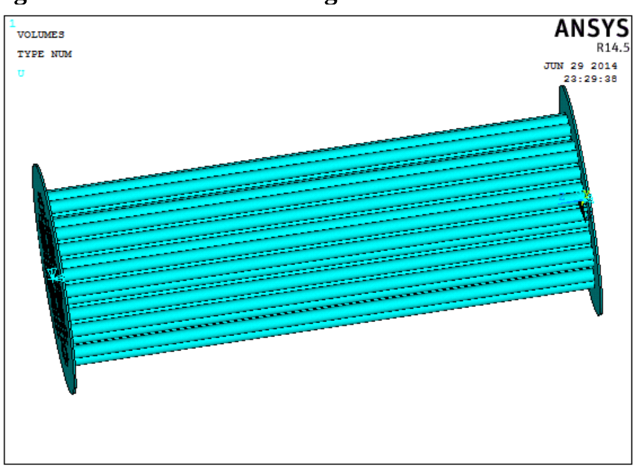

Fig.3. The finite element model of brass alloy without baffle.

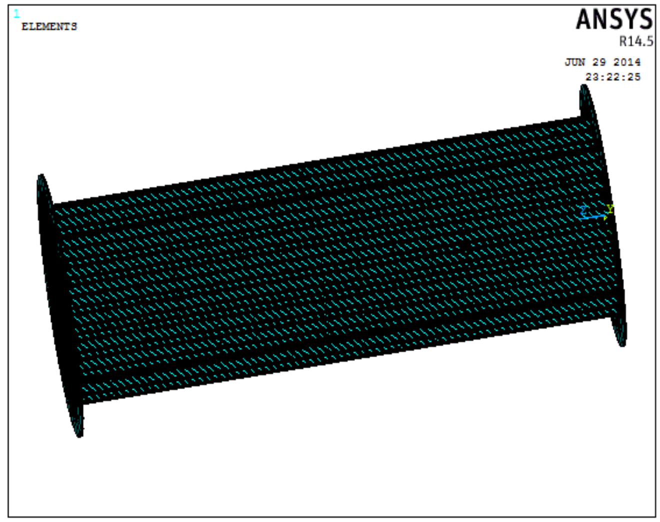

Fig.4. Meshed model for brass alloy without baffle.

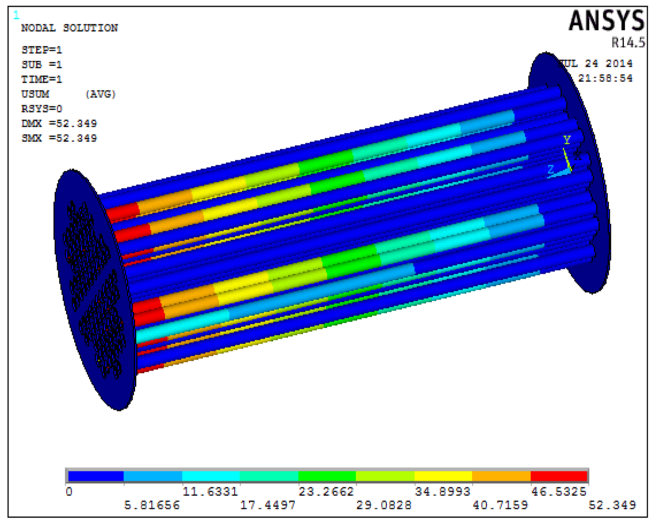

Fig.5. Displacement Vector Sum for brass alloy without baffle (mm).

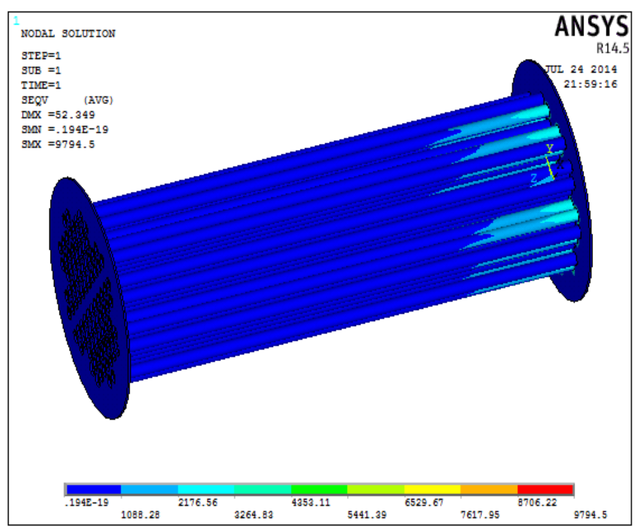

Fig.6. stress for brass alloy without baffle (N/mm^2).

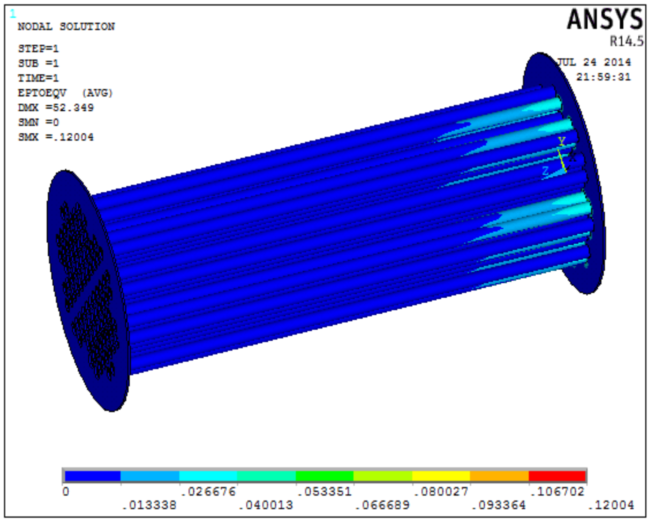

Fig.7. strain for brass alloy without baffle.

A. Structural Analysisbrass Alloy With Baffle

Structural Analysisbrass Alloy With Baffle As shown in Figs.8 to 15.

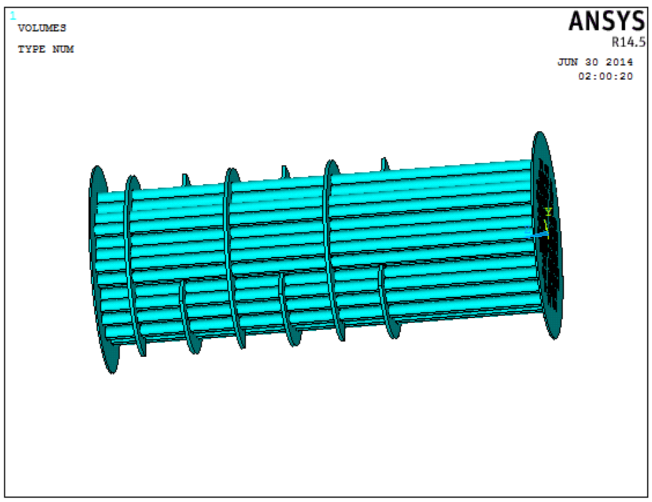

Fig.8. Model for brass alloy with baffle.

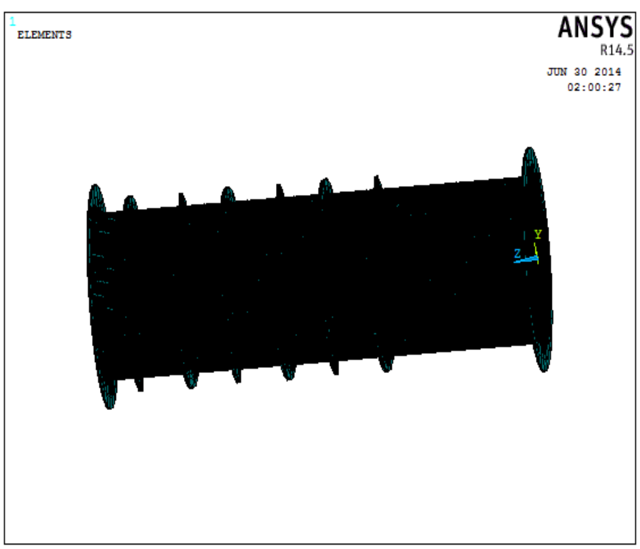

Fig.9. Meshed model for brass alloy with baffle.

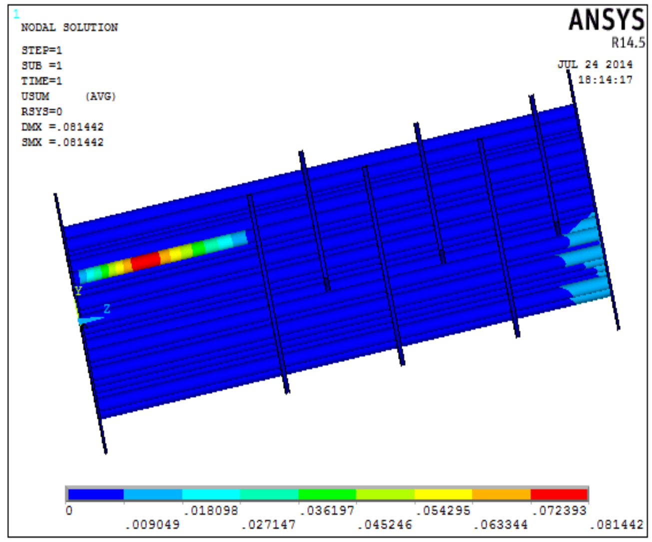

Fig.10. Displacement Vector Sum for brass alloy with baffle (mm).

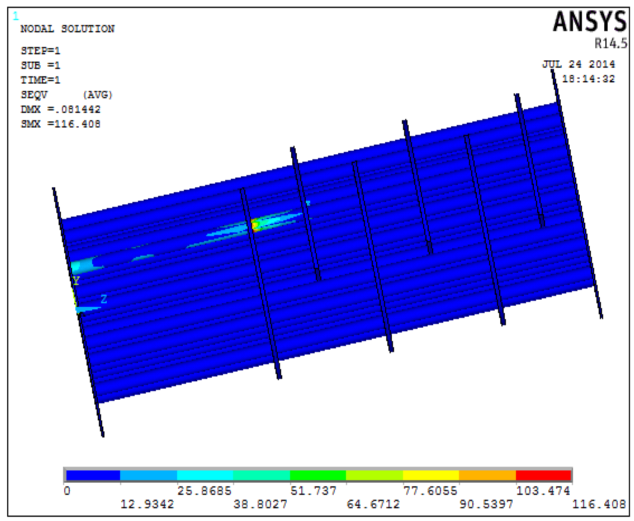

Fig.11. stress for brass alloy with baffle (N/mm^2).

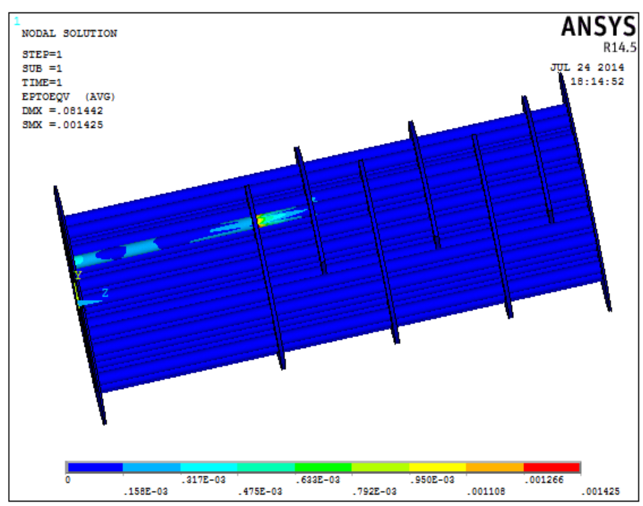

Fig.12. strain for Brass alloy with baffle.

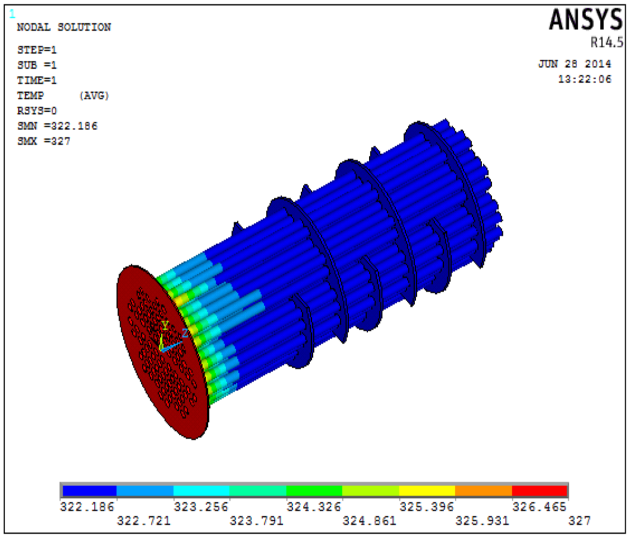

Fig.13. temperature desterbution for brass alloy with baffle (k).

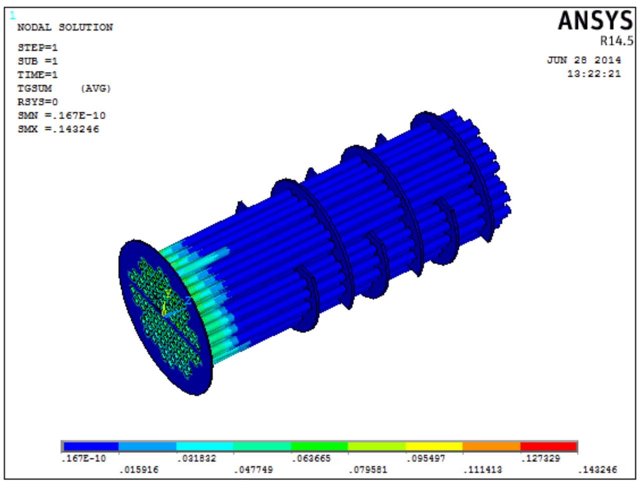

Fig.14. thermal gradient for Brass alloy with baffle (k/mm).

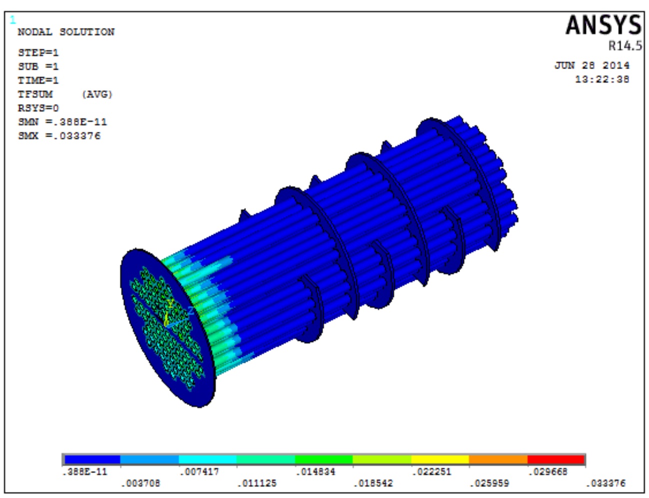

Fig.15. thermal flux for Brass alloy with baffle (w/mm^2).

B. Thermal Analysis Brass Alloy Without Baffle

Thermal Analysis brass Alloy Without Baffle As shown in Figs.16 to 19.

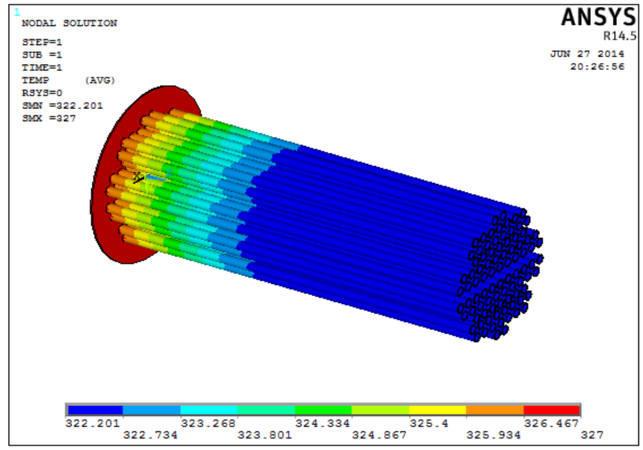

Fig.16. Nodal temperature for brass alloy without baffle (k).

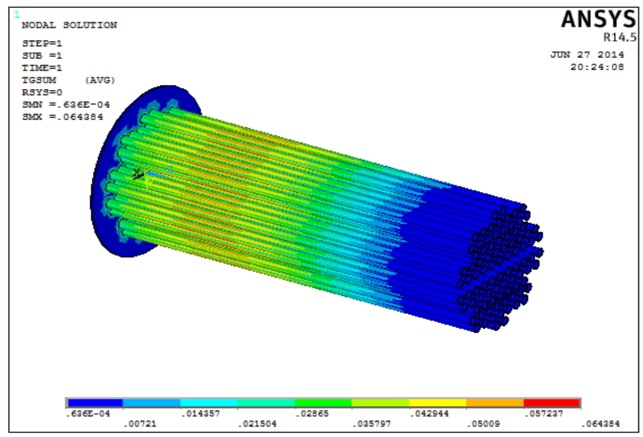

Fig.17. thermal gradient for brass alloy without baffle (k/mm).

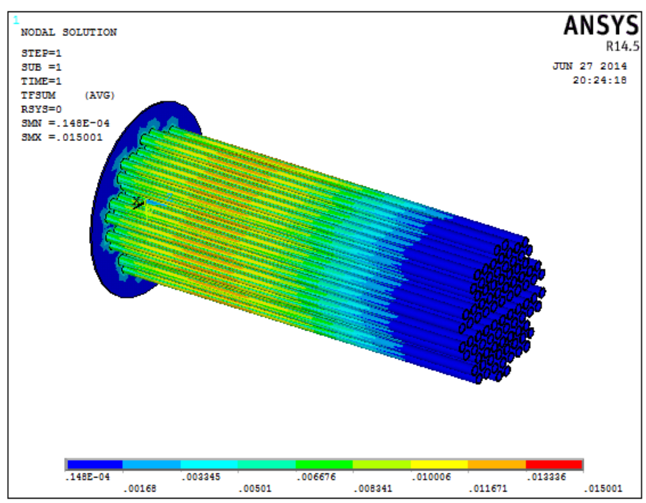

Fig.18. thermal flux for brass alloy without baffle (w/mm^2).

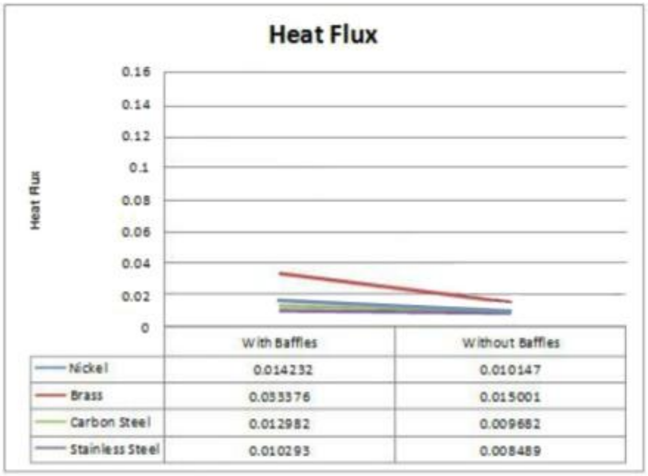

Fig.19. Heat Flux (w/mm^2).

TABLE I: Results Of Structural Analysis By Ansys For Four Materials With And Without Baffle

DESPRECTION	MATERIALS	RESULTS		
		DISPLACEMENT (mm)	STRESS (N/mm^2)	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/mm^2)
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. CONCLUSION

- 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

[1] Sachdeva, R’ Fundamental of Engineering of Heat and Mass Transfer, Wiley Eastern Ltd, 1988.
[2] Donald. Q. Kern, Process Heat Transfer, Mc Graw Hill 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”.
[13] k.S.N RAJU , "Fluid Mechanics Heat Transfer and Mass Transfer" Chemical Engineering.
[14] Heat exchanger design hand book by kuppan thulukkanam (second edition).
[15] Nenad Radojković[1], Gradimir Ilić[1], Žarko Stevanović[2], Mića Vukić[1], Dejan Mitrović[1], Goran Vučković[2].Experimental study on thermal and flow processes in shell and tube heat exchanger - influence of baffle cut on heat exchange efficiency .Series : Mechanical Engineering Vol. 1, No 10,2003,pp.1377-1384.
[16] D. P Naik and V. K. Matawala[1] .An assessment of counter flow shell and tube heat exchanger by entropy generation minimization method World Journal of Science and Technology 2012, 2(4):28-32 .ISSN: 2231-258.
[17] A.R. Moghadassi[1], S.M. Hosseini[1], F. Parvizian[1], F. Mohamadiyon[1], A. Behzadi Moghadam[1] and A Sanaeirad[2]

An expert model for the shell and tube heat exchangers analysis by artificial neural networks ARPN Journal of Engineering and Applied Sciences Vol 6, No. 9, September 2011. ISSN 1819-6608.
[18] K. C. LEONG and K. C. TOH .Shell and Tube Heat Exchanger Design Software for Educational Applications .Int.J.Engng Ed. Vol. 14, No. 3, p. 217-224, 1998.

Author's Profile:

Baydaa Rashid Ismael, Bachelor Degree in Mechanical Engineering & Education from University of Technology -Baghdad, IRAQ. Presently he finished his Master of Technology Thermal Engineering in Jawaharlal Nehru Technological University, Hyderabad, INDIA. His research interest.

Professor of Mechanical Engineering Department JNTUH College of Engineering Hyderabad Mechanical Engineering Internal Combustion Engines, Machine Design Mechanical Engineering Graduate. Her field of research includes IC engines, engineering design.