

Comparative Analysis of Admiralty and Red Brass Materials for a Shell and Tube Heat Exchanger

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ABSTRACT: In the present scenario Shell and Tube Heat Exchanger (STHE) is the most common type of heat exchanger that is widely used in oil refinery and other large chemical process industries, as it suits for high pressure applications. Admiralty Brass has many desirable properties for thermally efficient and durable heat exchangers but to get optimal efficiency and high performance we go over another material i.e. Red Brass, is excellent for its resistance to dezincification and season cracking for which the high copper brasses. The objective of this paper is to design a STHE and analyze the temperature distribution, heat flux and total deformation of the STHE using ANSYS software tool and also we compared and analyzed Admiralty Brass and Red Brass materials for the STHE. The present heat exchanger is an oil cooler which contains 90 tubes of 3300 mm inside a shell diameter of 323.8 mm. From the simulation experimentation result the performance and efficiency of heat exchanger is increased by replacing Red Brass instead of Admiralty Brass.

KEYWORDS: Shell and Tube Heat Exchanger, Admiralty Brass, Red Brass, Dezincification, ANSYS, Oil Cooler.

NOMENCLATURE

k	-	Coefficient of thermal conductivity w/mk	A	-	Surface area m ²
q	-	Heat flux at the wall in W/m ²	h	-	Heat transfer coefficient in W/m ² °C
T	-	Surface temperature in °C	T _m	-	Mean temperature in °C
K	-	Stefan-Boltzmann constant	T ₁	-	Surface temperature in Kelvin
E	-	Young's Modulus in GPa	r	-	Poisson's Ratio

I. INTRODUCTION

Heat exchangers are one of the most important devices of mechanical systems in modern society. It is a device which transfers the heat energy from hot fluid to cold fluid, with maximum rate and minimum investment with less running cost. These are useful in many engineering processes such as refrigerating and air-conditioning systems, power systems, food processing systems, chemical reactors, space or aeronautical applications [1]. Most industrial processes involve the transfer of heat and more often, it is required that the heat transfer process be controlled.

Shell and tube heat exchangers have the ability to transfer large amounts of heat in relatively low cost, serviceable designs. They can provide large amounts of effective tube surface while minimizing the requirements of floor space, liquid volume and weight. Shell and tube exchangers are available in a wide range of sizes. They have been used in industry for over 150 years, so the thermal technologies and manufacturing methods are well defined and applied by modern competitive manufacturers. These are a simple but effective type of heat exchanger, consisting of a cylindrical

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shell which contains a bundle of tubes. In most applications the hot fluid flows over the outside of the tubes and the coolant flows through the tubes exchanging the heat between the thermally conductive materials used in the heat exchanger design. The flexibility of the design means that STHE s provide an ideal cooling solution for a variety of Marine, Hydraulic, Rail, Industrial and other applications [2].

Shell and tube type heat exchangers are the most versatile and suitable for almost all applications, irrespective of duty, pressure and temperature. This 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. This type of heat exchangers have been widely used in power plant, air conditioning, chemical plant, oil refineries, sewage treatment plant, petrochemical plant and other chemical processes. They are used extensively as process heat exchangers in the petroleum-refining and chemical industries; as steam generators, condensers, boiler feed water heaters and oil coolers in power plants; as condensers and evaporators in some air-conditioning and refrigeration applications; in waste heat recovery applications with heat recovery from liquids and condensing fluids; and in environmental control [3-4].

Most of the ordinary heat exchangers are classical shell and tube heat exchangers, which are designed in the 1930s. As its name implies, STHE consists of a bundle of parallel tubes inside a shell and it is the most common type of heat exchanger. The schematic diagram of a common designed STHE is given in Fig.1.

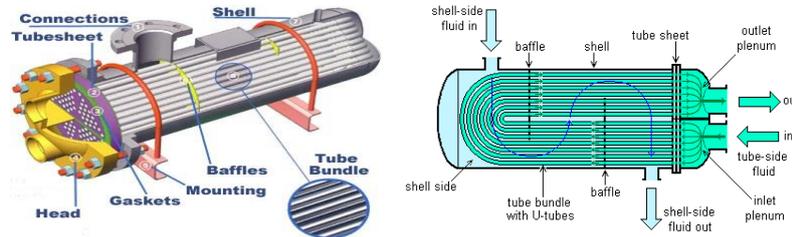


Fig.1. Major Components of Typical Shell and Tube Heat Exchanger

As shown in above figure, one fluid flows through a number of tubes, and the other fluid with different temperature flows over the shell but outside the tubes to transfer heat through the tube walls. The two fluids are separated by the tube walls so that they never mix. Due to this design, a large numbers of tubes are used to enlarge the heat transfer area and transfer heat efficiently. In a word, it is an efficient way to use waste heat in order to conserve energy [5]. In this paper we have used finite element method for discretization of complex elements [6].

II. LITERATURE REVIEW

The present study is taken up with the major objective of obtaining optimal thermal performance at shell and tube side and consequent achievement of hike in heat transfer by design and simulation of STHE.

Rajeev Mukherjee [7] provided overall idea to design optimal STHE. The optimized thermal design can be done by sophisticated computer software however a good understanding of the underlying principles of exchanger designs needed to use this software effectively.

K. C. Leong et.al [8] has proposed software for the thermal and hydraulic design of shell and tube heat exchangers with flow- induced vibration checks has been developed in a Windows-based Delphi programming environment. Its user-friendly input format and excellent colour graphics features make it an excellent tool for the teaching, learning and preliminary design of shell and tube heat exchangers. Design methodology is based on the open literature Delaware method while flow-induced vibration calculations adhere closely to the methodology prescribed by the latest TEMA

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standards for industry practice. It is hoped that the software will bridge the gap between the teaching of engineering fundamentals and the existing industry practice of shell and tube heat exchanger design.

A.Gopi Chand et.al [9] has proposed a simplified model for the study of thermal analysis of shell-and-tubes heat exchangers of water and oil type .This paper shows how to do the thermal analysis by using theoretical formulae and for this they have chosen a practical problem of counter flow STHE of water and oil type, by using the data that come from theoretical formulae, they designed a model of STHE using Pro-E and done the thermal analysis by using FLOEFD software and comparing the result that obtained from FLOEFD software and theoretical formulae. For simplification of theoretical calculations they have also done a MATLAB code which is useful for calculating the thermal analysis of a counter flow of water- oil type STHE. The result after comparing both was that they were getting an error of 0.023 in effectiveness.

Paresh Patel and Amitesh Paul [10] had performed thermal analysis of shell and tube type heat exchanger using ANSYS and CFD analysis has been carried out for different materials like steel, copper and aluminium and on the basis of results obtained they have described which material gives best heat transfer rates. Sometimes an image may contain text embedded on to it. Detecting and recognizing these characters can be very important, and removing these is important in the context of removing indirect advertisements, and for aesthetic reasons.

Hari Haran et.al [11] proposed a simplified model for the study of thermal analysis of shell and tube type heat exchangers of water and oil type is proposed. This paper shows how to do the thermal analysis by using theoretical formulae and for this they have chosen a practical problem of counter flow STHE of water and oil type, by using the data that come from theoretical formulae and they designed a model of STHE 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 they have also done a C code which is useful for calculating the thermal analysis of a counter flow of water-oil type STHE. The result after comparing both was that they were getting an error of 0.0274 in effectiveness.

III. PROBLEM FORMULATION

In this paper we are concerned with the study of heat transfer capabilities of various thermal materials that are generally used for shells, tubes or baffles of shell and tube type heat exchanger. The fact which is noticeable is that the purpose of heat exchange can be done through any moderate conductor of heat. However, the study of material properties becomes necessary when we have to exchange a large amount of heat within a minimum stipulated time in order to meet out process and production standards as well as to secure the time economy. Under these circumstances it is inevitable to ensure the good heat transfer capabilities of the materials. Here we are considering two materials viz. Admiralty Brass (composition is copper - 69 %, zinc - 30 %, tin - 1 %) and Red Brass. (Composition is copper - 85 %, zinc -5 %, tin - 5%, lead - 5 %). Finally we are going to compare analytical results with experimental results and select the most suitable one.

IV. METHODOLOGY

The physical model of STHE was developed by taking design data from previous authors [12-13] and static structural and thermal analysis was done by using Pro-E&ANSYS.

Table 1 : Design Data for Shell and Tube Heat Exchanger

S.No	Design Data(s)	Value(s)
1.	Quantity of water	50m ³ /hr
2.	Quantity of oil	14.75m ³ /hr
3.	Water inlet temperature	33c
4.	Oil outlet temperature	45c

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5.	Allowable pressure drop on water side	0.6 kg/cm ²
6.	Allowable pressure drop on oil side	0.6 kg/cm ²
7.	Fouling factor on water side	0.0004 hr-m ² -°C/kcal
8.	Fouling factor on oil side	0.0002 hr-m ² -°C/kcal
9.	Thermal conductivity of tube material	66 BTU/hr-ft ² °F (From TEMA)
10.	Number of tubes	90
11.	Number of tube passes	2
12.	Length of tube	3.300 m
13.	Outside diameter of the tube	0.01905m
14.	Thickness of tube	0.00165m
15.	Inside diameter of tube	0.01575m
16.	Tube pitch	0.0254m
17.	Number of baffles	33
18.	Baffle cut	22%
19.	Baffle thickness	0.006m
20.	Shell inside diameter	0.307m
21.	Shell outside diameter	0.3238m
22.	Shell thickness	0.0084m
23.	Baffle spacing	0.086m

V. MODELLING AND ANALYSIS OF SHELL AND TUBE HEAT EXCHANGERS

Modelling of Heat Exchanger Using Pro-E:

In the present paper, the components of heat exchanger are modelled using part drawing features and then using assembly modules, the assembly of the heat exchanger is generated as in the Fig.2. After generating the model we have put those parts under the below stated thermal & static structural loading conditions and solved out the same under steady state thermal simulation.

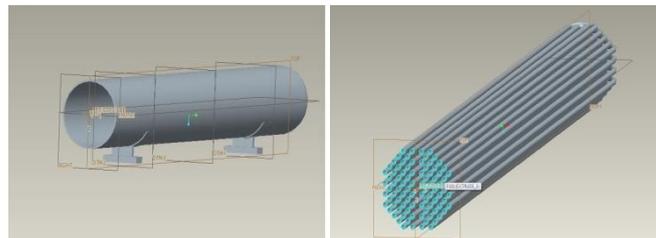


Fig 2. 3-D modeled Shell and Tubes of STHE

VI. EXPERIMENTAL RESULTS

Thermal and Structural analysis on Shell

Fig. 3 and 4 depicts the results of static structural and thermal analysis was done on shell and we have observed maximum Equivalent stress, Normal stress in X-axis, Normal stress in y-axis, Normal stress in z-axis, Shear stress in XY plane, Shear stress in YZ plane, Total Deformation and Temperature Distribution.

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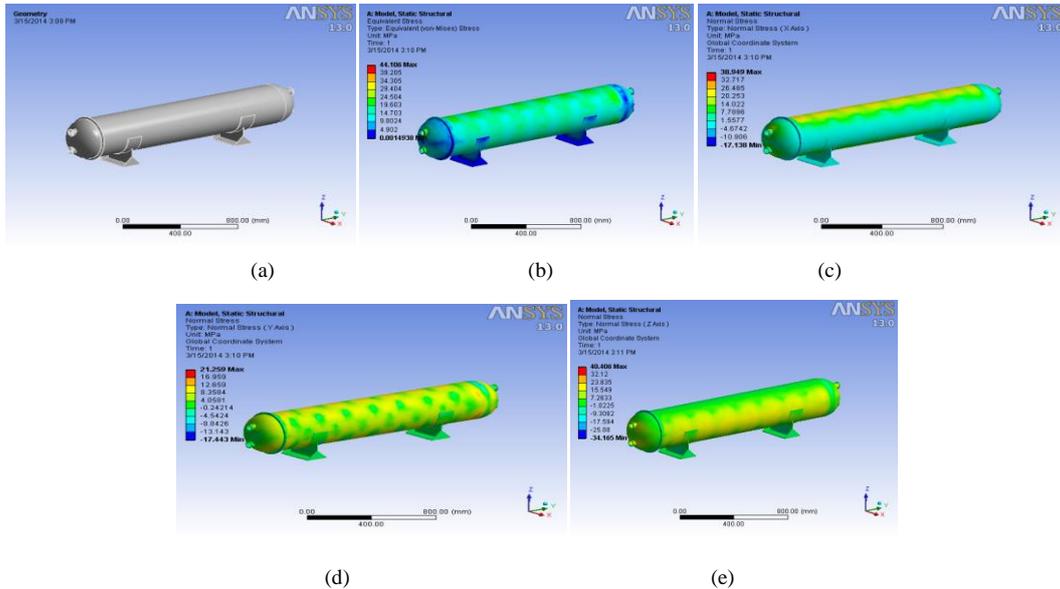


Fig. 3. Static Structural Analysis on Shell (a) Geometry (b) Equivalent stress (c) Normal stress in X-axis (d) Normal stress in y-axis (e) Normal stress in z-axis

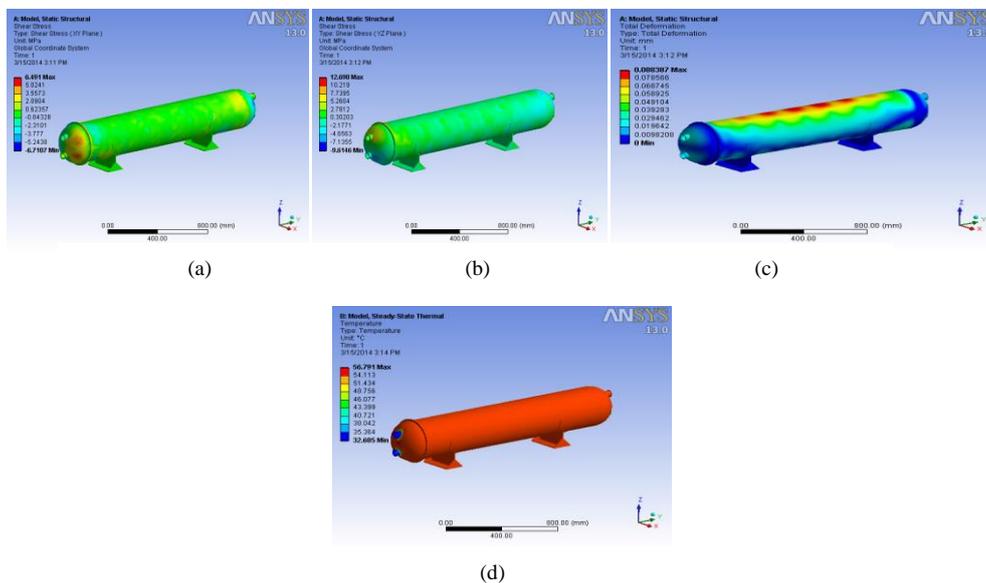


Fig. 4. Static Structural and Thermal Analysis on Shell (a) Shear stress in XY plane (b) Shear stress in YZ plane (c) Total deformation (d) Temperature distribution

From the Thermo-mechanical analysis on the shell was conducted and it was found that the developed stresses are with in the safe stress zone. Hence there is no need to change the shell. The efficiency of the Heat Exchanger depends upon the tubes and hence modifications are done for the tube efficiency can be increased either by changing tube dimensions or tube material. Here we will replace the original material that is Admiralty Brass with Red Brass.

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Thermal and Structural Analysis on Tube

The Thermal and Structural Analysis on Tube of heat exchanger are modelled using geometry and then applied mesh afterwards we go over the set up and given the boundary conditions and material of tubes i.e. Red Brass and Admiralty Brass and click on the solution and finally we got results that are better than original material i.e. Admiralty Brass. Fig.5 depicts the results of static structural and thermal analysis was done on tube and we have observed Temperature Distribution, Total Heat Flux, Total Deformation and Maximum Equivalent stress for Admiralty and Red Brass.

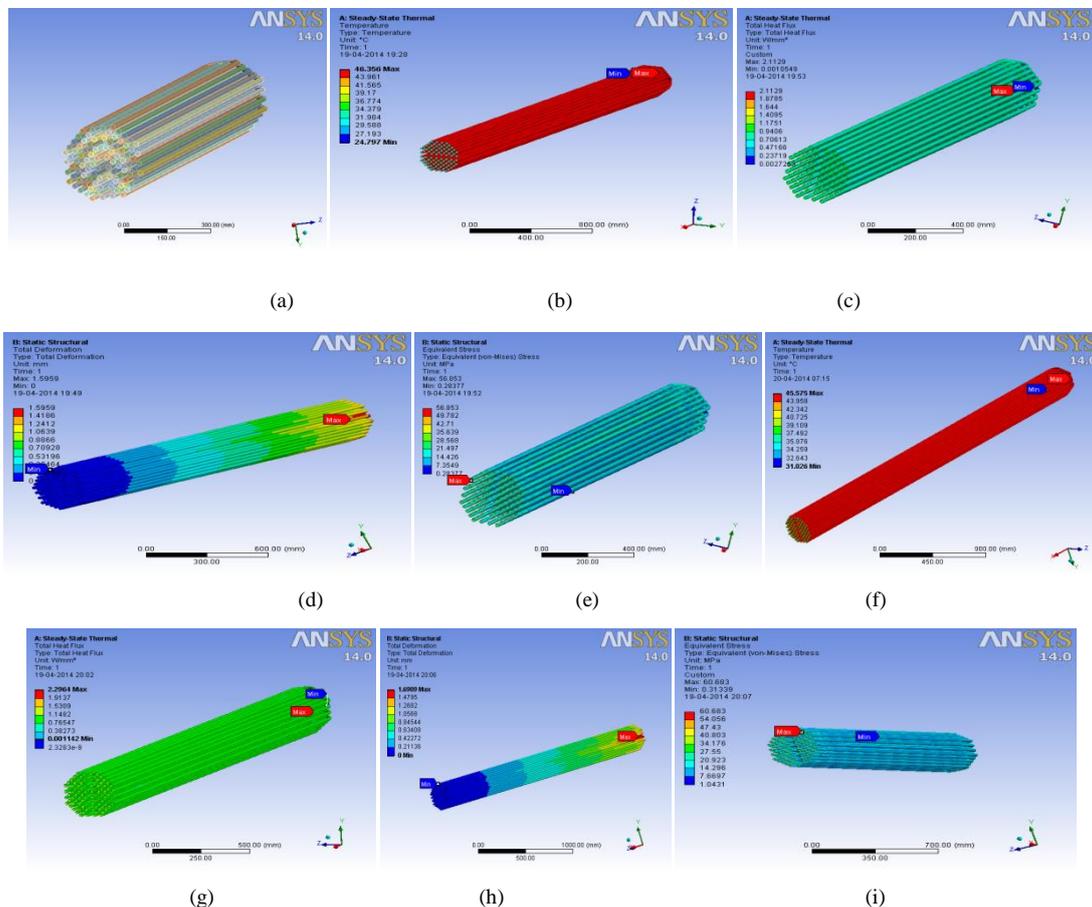


Fig. 5. Static Structural and Thermal Analysis on Tubes (a) Geometric model of tubes for analysis (b) Temperature distribution for Admiralty Brass (c) Total heat flux for Admiralty Brass (d) Total Deformation for Admiralty Brass (e) Equivalent stresses for Admiralty Brass (f) Temperature distribution for Red Brass (g) Total heat flux for Red Brass (h) Total deformation of Red Brass (i) Equivalent stress of Red Brass

From the Thermal and Structural Analysis was done on the tube, we observed that max temperature is less for red brass that means heat exchange is more, for better rate of heat transfer we obviously need better heat exchange. maximum heat flux is high for red brass that means amount of heat transfer is high per given surface area and total deformation and equivalent stresses are within the safe zone so finally we observed from this analysis red brass shows optimal performance than admiralty brass.

VII. COMPARISON OF RESULTS AND DISCUSSIONS

The critical components have been designed for sufficient mechanical strength. The distribution of Temperature, Total Heat Flux, Total Deformation and Equivalent Stresses are shown in the Table.2.as shown in Table and graph.

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Table 2: Evaluated Results of Thermal and Static among the Two Materials

Distribution		Admiralty Brass	Red Brass
Temperature (Centigrade)	max	46.356	45.575
	min	25.797	31.026
Total heat flux (W/mm ²)	max	2.1129	2.2964
	min	0.00101	0.00114
Total deformation (mm)	max	1.59	1.69
	min	0	0
Equivalent stresses (Mpa)	max	56.85	60.68
	Min	0.2837	0.3133

From this study it is clear that if we assign Red Brass to the whole assembly then we will get the best possible value of heat flux i.e. 2.2964 W/mm² (It is the rate of heat energy transfer through a given surface, per unit time and thermal conductivity is higher than Admiralty Brass) amongst the discussed materials.

Comparison Graphs:

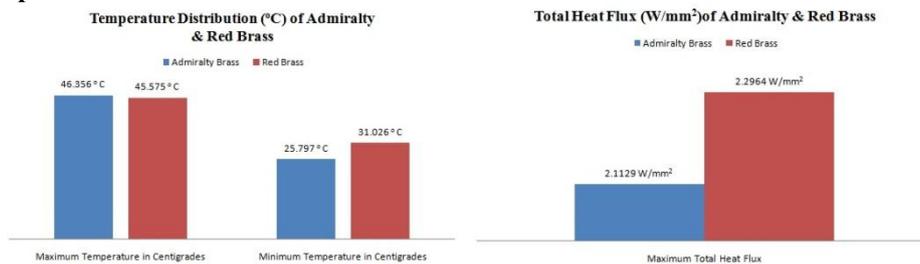


Fig 6. Comparison between Temperature Distributions of Admiralty Brass & Red Brass and comparison of Maximum Total Heat Flux of Admiralty Brass & Red Brass

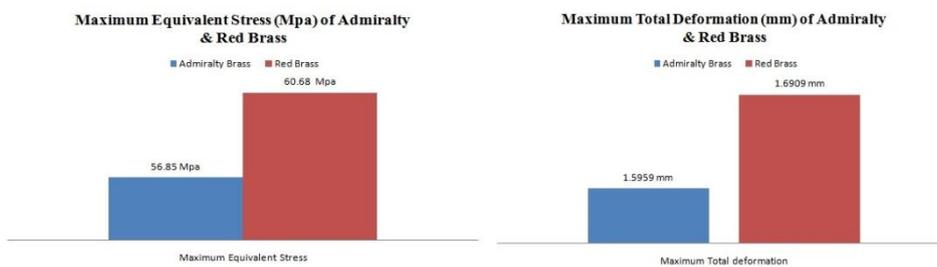


Fig7. Comparison of Maximum Equivalent Stress of Admiralty & Red Brass and Comparison of Maximum Total deformation of Admiralty & Red Brass

VIII. CONCLUSION

The design and analysis of STHE was done with two different materials viz. Admiralty Brass replaced with Red Brass. The observed results shows that all the two materials are thermally and structurally safe, but comparison on total heat flux, temperature distribution, deformation and equivalent stresses we found that Red Brass shows better results than the other one. Hence we consider that Red Brass is the best material that suits for STHE. Thus the design can further be improved by taking new materials and methodologies for the shell and tube side and correlate the results with experimental data that will automatically increase the heat transfer.

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