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DESIGNING OF CONDENSERS USING DIFFERENT MATERIALS AND THEIR COMPARISION

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ABSTRACT

This paper represents the designing of condenser using different materials viz SS304 and Copper. An experimental study has been carried out to see the effect of condensers material on the effectiveness. A graph has been plotted between the effectiveness and Logarithmic Mean Temperature Difference (LMTD). It has been shown from the graphs that effectiveness has a significant impact in condenser with copper as the material. Although it is two times costlier than SS304 condenser but it enhances the effectiveness by more than three times than the latter one.

Keywords: Condenser, Copper, SS304, LMTD, Effectiveness

INTRODUCTION

A shell and tube condenser is a versatile class of heat exchanger. It is the most common type of condenser used in all types of power plants and other large chemical processes, and it is very much suitable for the applications where the heat exchange is required at very high pressure. As its name indicates, this type of condenser or heat exchanger consists of a shell (a large pressure vessel) with a bundle of hollow tubes fitted inside the shell. The basic principle of operation is very simple as flows of two fluids with different temperature brought into close contact for heat exchange, but prevented from mixing by some sort of physical or metal barrier. Here the two fluids are the hot steam, expanded in the steam turbine and come in the condenser through the pipeline and the cold and fresh water which has to extract the heat. Then the temperature between two fluids tends to equalize by transfer of heat through the tube wall. Here in the condenser, the steam can be in the shell or supplied into the tube bundles. In order to transfer heat efficiently, a large heat transfer area is used, that means the number of the tubes in the tube bundle. In this way, the heat is extracted from the heated steam and the steam changes into the hot water by the phase transformation. This hot water can be used in many applications.

This project mainly focuses on designing of condenser, which is shell and tube steam condenser. The software used for designing is PRO-E. This software is technically simpler than CATIA where it has to refer to a complex designing steps and parameters that needed. The calculations consist of formulas of calculating the parameters in condenser such as heat transfer coefficient, heat transfer rate or heat capacity rate. To design this condenser, many considerations were taken. The shell size must be adaptable to the water flow rate. To determine how many tubes are used depends on the size of the shell. The condenser materials consisting of the shell, tube, baffle and the partition plates, are decided by the consulting the different industries who used to manufacture the condensers and the heat exchangers. Here in this project, two condensers were made of SS304 and Copper.

The Water flow rate can be determined by using the pumps of different capacities. To read the temperature, a laboratory thermometer is attached at inlet and outlet for both hot and cold fluids. Readings were taken and take into calculation were done. After the calculation, the graphs have been prepared between various different parameters. The manual calculation is done to check the analysis in the software whether it is compatible.

Rajiv Mukherjee [1] explains the basics of exchanger thermal design, covering such important topics such as:STC components; classification of STHCs according to construction and according to the services; data needed for thermal design; tube side design; shell side design, included with the tube layout, baffling, and shell side pressure drops; and mean temperature difference. The basic equations for tube side and shell side heat transfer and pressure drop have been also considered in this paper. Correlations for optimal condition of the working are also focused and explained with some tabulated formed data. This paper gives an overall idea to optimal design shell and tube heat exchangers and condensers. The optimized thermal design can be done by highly effective and efficient computer software.

Yusuf Ali Kara et al [2] have prepared a computer based design model for primary design of shell and tube heat exchangers with single pass fluid flow from both on shell and tube sides. The computer program has determined the total dimensions of the shell, the tube bundle, and optimum heat transfer surface area required to meet the specified heat transfer conditions by the calculations with minimum or allowable shell side pressure drop. They concluded that the circulating cold fluid in the shell-side has some advantages over the hot fluid as shell stream since the previous conditions cause lower shell-side pressure drop and requires a smaller heat transfer area than the second and next set-up and thus it is better to flow the stream with lower mass flow rate onto the shell side because of the baffled spacing.

R. Hosseini et al. [3] have experimentally obtained the heat transfer coefficient and pressure drop on the shell side of a shell-and-tube heat exchanger with three different types of copper tubes (i.e. smooth tubes, corrugated tubes and with micro-finned tubes). Also, the experimental data have been compared with theoretical data to the TEMA standards. Experimental work shows that the higher Nusselt number and pressure drops with respect to theoretical correlation that is based upon the Bell's method. The optimum condition for the flow rate (optimal condition is for the lowest increase of pressure drop) in replacing the existing smoother tubes with similar micro-finned tubed bundle was obtained for the oil cooler of the distinct transformer under investigation.Zahid H. Ayub [4] shows a charting method is developed to calculate the single-phase shell side heat transfer coefficient in a typical TEMA standard single segment shell and tube heat exchanger. Here, a case study of rating water-to-water exchanger is shown to produce the results from this method with the more established and easy procedures and software available in the market.

The results show from this new method is very much reliable and comparable to very much versatile HTRI software.

Resat Selbas et al[5] have applied genetic algorithms (GA) for the optimal design of shell-and-tube heat exchanger by varying these design variables such as: outer tube diameter, tube layout, number of tube passes, outer shell diameter, baffle spacing and baffle cut and other such parameters. From this research, it was concluded that the combinatorial algorithms such as GA can provide the significant improvements in the optimal designs compared to the traditional designs. GA application for determining the minimum heat exchanger cost is significantly faster than the previous one and has an advantage over other traditional methods in obtaining multiple solutions of same capacity of the heat exchanger.

Chintan D Patel et al. [6] used predetermined parameters (tube diameter, mass flow rate and pitch length) are used as input variable and the output parameter is taken maximum temperature difference of shell and tube heat exchanger. In this experiment, nine different models are made in Solid Works 2012 software and CFX analysis is carried out in ANSYS 12.0. The Minitab 16 software is used for Taguchi analysis of the heat exchanger. Result obtained from the Taguchi analysis decides that which combination of design parameter gives the minimum outlet temperature of water i.e. maximum heat rejection from the hot fluid. According to this paper, the most affected parameter on temperature of water from tube diameter, pitch length and mass flow rate is found out from Taguchi analysis. KEVIN M. LUNSFORD [7] provides some of the methods for increasing shell-and-tube exchanger performance. The methods consider the factors that whether the exchanger is performing correctly to begin with, excess pressure drop capacity in existing exchangers, the re-evaluate the fouling factors and the effects of the fouling factors on the exchanger calculations, and the use of augmented surfaces and the enhanced heat transfer. Here in this research paper, some examples are provided to show how commercial process simulation programs and shell-and-tube exchanger rating programs may be used to evaluate these exchanger performance issues and resolve such important issues. One of these examples shows that how novel heat transfer enhancement can be evaluated using basic shell-and-tube exchanger rating calculations along.

Material Details:

The details of the materials used in the condenser is given below-

Shell Material- SS304 and Copper

Tube Material- SS304 and Copper

Baffle Material- Mild Steel

Partition Plate Material- SS304 and Copper

Stand Material- Mild Steel

Inlet/Outlet Pipes Material- SS202

Dimensions:-

S. No.	Component Names	SS304 Condenser Component Dimensions (in mm)	Copper Condenser Component Dimensions (in mm)
1.	**Sheet Thickness**	0.81mm(20 Gauge)	0.81mm(20 Gauge)
2.	**Shell**		
	(a)Shell Sheet Dimension	500mm*302mm	500mm*302mm
	(b)Shell Diameter	96mm	96mm
3.	**Cap**		
	(a)Cap Dimension	105mm*314mm	105mm*314mm
	(b)Cap Diameter	100mm	100mm
4.	**Cap Holding Plate**		
	(a)Plate Dimension	120mm*120mm	120mm*120mm
	(b)Plate Thickness	0.81mm	0.81mm
5.	**Tube**		
	(a)Tube Length	510mm	510mm
	(b)Tube Diameter:-		
	(i)Inner Diameter	10mm	10mm
	(ii)Outer Diameter	12.5mm	12.5mm
6.	**Inlet-Outlet Pipes**		
	(a)Pipe Length	100mm	100mm
	(b)Pipe Diameter	24mm	24mm
	(c)Pipe Thickness	0.25mm	0.25mm
7.			

	Tube Sheet		
	(a)Dimensions	95mm diameter	95mm diameter
	(b)Thickness	1.5mm	1.5mm
	(c)No. of Holes	14	14
	(d)Diameter of hole	13mm	13mm
	(e)Distance Between Two holes	24mm	24mm
	(f)Pitch Type	Mixed(Rectangular And triangular)	Mixed(Rectangular And Triangular)
	Baffle		
	(a)Dimensions	95mm diameter	95mm diameter
	(b)Thickness	1.5mm	1.5mm
	(c)No. of Holes	14	14
	(d)Diameter of hole	13mm	13mm
	(e)Distance Between Two holes		
	(i)Vertically(Along The Shell Length)	16mm	16mm
	(ii)Horizontally(Along The Shell Length)	24mm	24mm
	(f)Distance Between The Top Edge and Bottom Edge through the Centre	63mm	63mm
	(g) Pitch Type	Mixed(Rectangular And Triangular)	Mixed(Rectangular And Triangular)
8.	**Partition Plate**		
	(a)Dimensions	100mm*96mm	100mm*96mm
	(b)Thickness	0.81mm	0.81mm

Condenser and its components:

Here are some 2-D view of the condensers dimensions with their baffles. Also, some pictorial view is also presented over here.

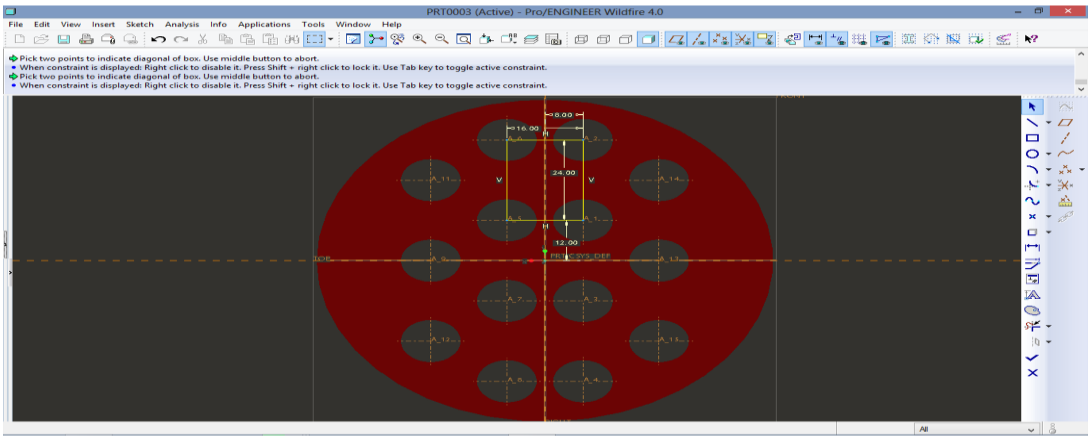

Fig 1: Dimensioning of Baffles

Fig 2: A view of condenser

Results and Discussions: Graphs has been plotted between LMTD and effectiveness for both of the materials SS304 and copper. It has been shown from the graph that effectiveness is more in case of condenser having copper as the material.

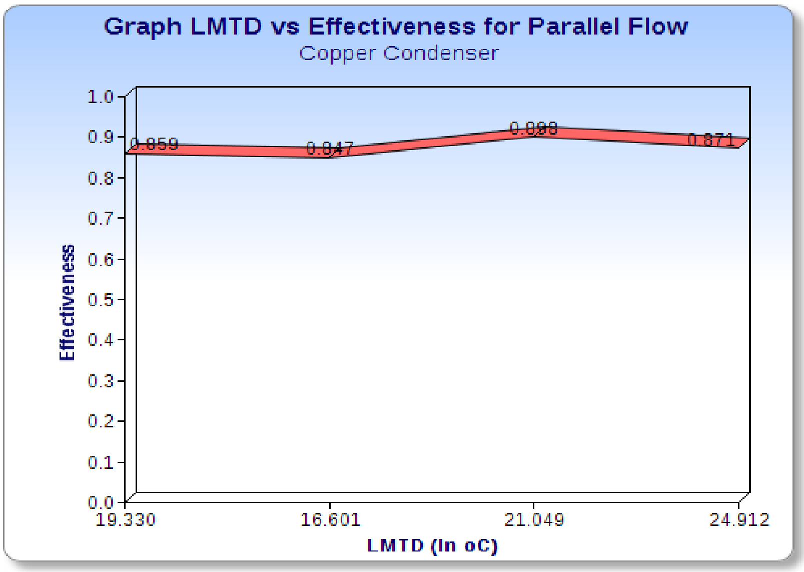

Fig3: Graph showing the variation of effectiveness with LMTD for copper condenser (parallel flow)

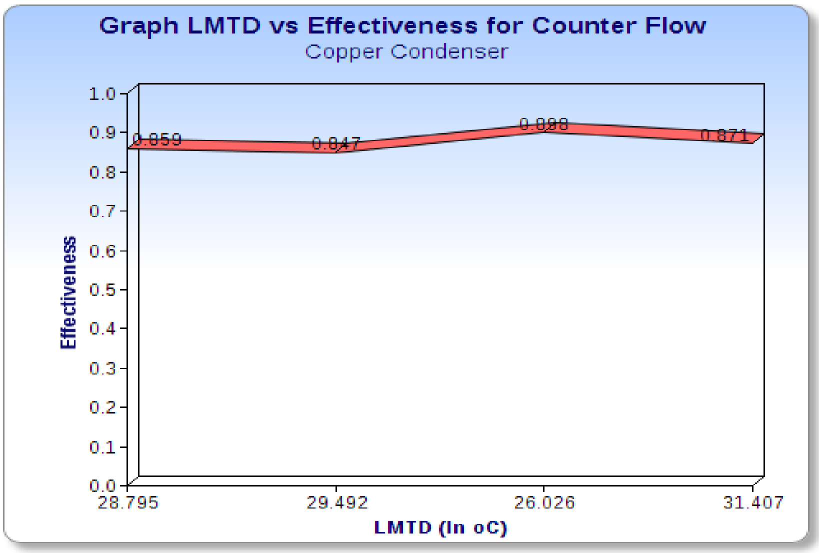

Fig4: Graph showing the variation of effectiveness with LMTD for copper condenser (counter flow)

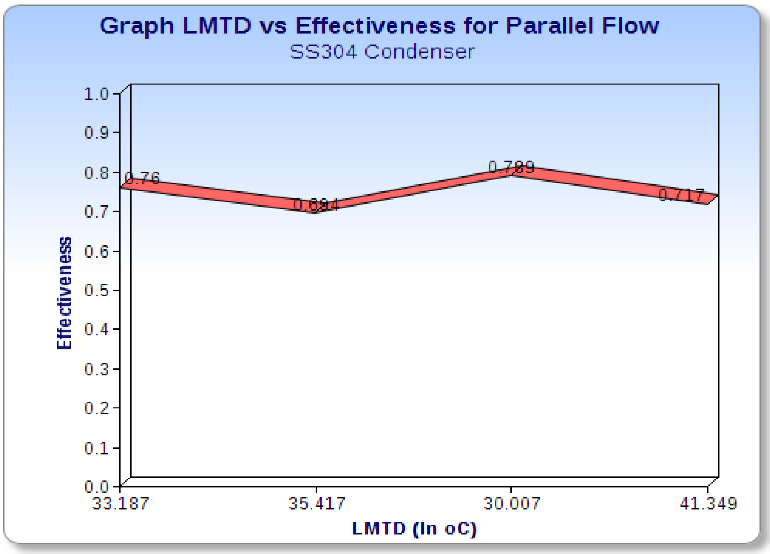

Fig5: Graph showing the variation of effectiveness with LMTD for SS304 condenser (parallel flow)

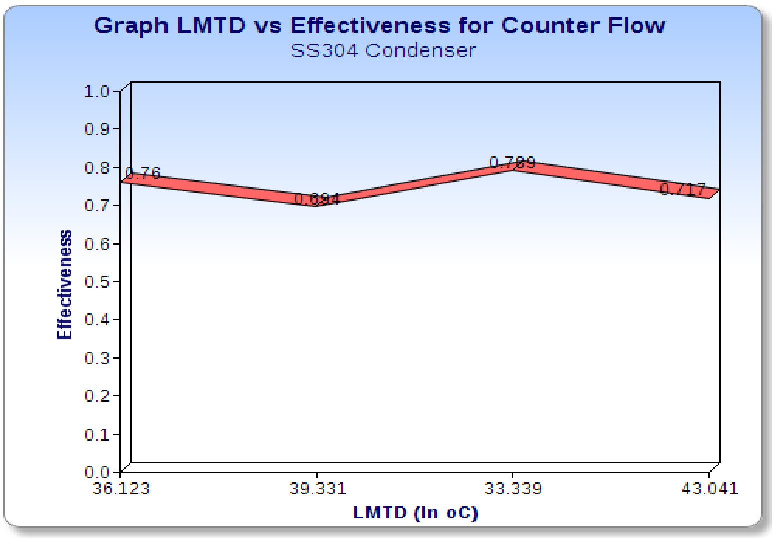

Fig6: Graph showing the variation of effectiveness with LMTD for SS304 condenser (counter flow)

Presumed Data

Specific Heat of cold fluid at constant pressure (In KJ/Kg-K) = Cpc = 4.187KJ/Kg-K
Specific Heat of hot fluid at constant pressure (In KJ/Kg-K) = Cph = 1.996KJ/Kg-K
Steam pressure- 1.5bar
Water mass flow rate = m_h= 4800lit/hr = 1.329kg/sec (1Lit. of water at NTP = 0.997kg)
Steam Mass Flow rate = m_c = 1kg/sec

Calculations showing the LMTD calculations for one temperature

LMTD for Parallel Flow (Copper)

$\theta_1 = t_{h1} - t_{c1}$ =(100-29) = 71°C
$\theta_2 = t_{h2} - t_{c2}$ = (39-37) = 2°C
LMTD= $(\theta 1 - \theta 2)/\ln(\frac{\theta 1}{\theta 2})$ = (71-2)/ln(71/2) = 19.330°C

LMTD for Counter Flow (Copper)

$\theta_1 = t_{h1} - t_{c2}$ =(100-37) = 63°C
$\theta_2 = t_{h2} - t_{c1}$ = (39-29) = 10°C
LMTD= $(\theta 1 - \theta 2)/\ln(\frac{\theta 1}{\theta 2})$ = (63-10)/ln(63/10) = 28.795°C

LMTD for Parallel Flow (SS304)

$\theta_1 = t_{h1} - t_{c1}$ =(100-29) = 71°C
$\theta_2 = t_{h2} - t_{c2}$ = (46-34) = 12°C
LMTD= $(\theta 1 - \theta 2)/\ln(\frac{\theta 1}{\theta 2})$ = (71-12)/ln(71/12) = 33.187°C

LMTD for Counter Flow

$\theta_1 = t_{h1} - t_{c2}$ =(100-34) = 66°C
$\theta_2 = t_{h2} - t_{c1}$ = (46-29) = 17°C
LMTD= $(\theta 1 - \theta 2)/\ln(\frac{\theta 1}{\theta 2})$ = (66-17)/ln(66/17) = 36.123°C

CONCLUSION

According to the outcomes of the whole work done, this is clear that the performance of Shell and Tube Condenser made up of copper material is far better than the condenser made by the SS304 material which is used in the power plant industries.

The effectiveness of the copper condenser is more than the condenser of SS304 because of the overall heat transfer coefficient of copper is more (1160 W/m^2-K) in comparison to the SS304 which is having 680 W/m^2-K). This affects the heat transfer from the hot fluid i.e. steam to the cold fluid i.e. the cooling water.

In the conclusion, the calculations and the graph-plotting shows the use of the copper made condensers are much more economical than that of the condensers made up of SS304 for the long term usages and for the saline water application as the cooling fluid in the power plants or in other industries as the heat exchanger.

The comparative analysis of the Copper and SS304 condensers is given below.

Sl. No.	Parameters	Condenser made of copper	Condenser made of SS304
1.	Effectiveness	Greater	Lesser
2.	Cost	More Costly (1.4 times costlier than SS304)	Less Costly
3.	Life cycle	If used in saline water, life is >= 5 years	If used in saline water, life is <=2 years

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