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Design and Heat Transfer Analysis of Surface Condenser for Different Materials of Tubes

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ABSTRACT: In this paper we have first designed a shell and tube type surface condenser which converts steam into condensate liquid. The design of surface condenser has been done using solid works in order to obtain various dimensions such as shell, tubes, baffles etc. Then thermal analysis of surface condenser has been performed in ANSYS. The heat transfer capabilities of several thermal materials have been compared by assigning different materials of tubes like Cu alloy, Al alloy, Structural Steel.

KEYWORDS: Shell and tube type surface condenser, tube materials, Thermal analysis, ANSYS

I.INTRODUCTION

The earliest laboratory condenser, a counter-flow condenser was invented in 1771 by the Swedish-German chemist Christian Weigel. In systems involving heat transfer, a condenser is a heat exchanger used to condense a gaseous substance into a liquid State through cooling. Condensers are used in air conditioning, industrial chemical processes such as distillation, steam power plants and other heat-exchange systems. Use of cooling water or surrounding air as the coolant is common in many condensers.

In thermal power plants, the purpose of a surface condenser is to condense the exhaust steam from a steam turbine to obtain maximum efficiency, and also to convert the turbine exhaust steam into pure water (steam condensate) so that it may be reused in the steam generator or boiler as boiler feed water



Fig. 1.2 Diagram of a typical water cooled surface condenser



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The adjacent diagram depicts a typical water-cooled surface condenser as used in power stations to condense the exhaust steam from a steam turbine driving an electrical generator as well in other applications.

II.MATERIAL OF TUBES

Copper Alloy

Copper and copper alloys are some of the most versatile engineering materials available. Copper is a tough, ductile and malleable material. These properties make copper extremely suitable for tube forming, wire drawing, spinning and deep drawing. The other key properties exhibited by copper and its alloys include:

Excellent heat conductivity

Excellent electrical conductivity

Good corrosion resistance

Good bio fouling resistance

Good machine ability

Retention of mechanical and electrical properties at cryogenic temperatures

Non-magnetic

Aluminum Alloy

Aluminum is the engineering material of choice for many applications. Properties that make aluminum popular and/or suitable include:

Light Strong High strength-to-weight ratio

Resilient Ductile at low temperatures

Corrosion resistant Non-toxic, Heat conducting, Reflective electrically conducting, Non-magnetic Non-sparking Non-combustible

Structural steel

These properties are useful for determining the quality of steel. High quality steel is used so that dependable and long lasting construction is possible. The most important components include the following High density High elastic modulus Low poissio ratio High tensile strength High yield strength Higher value of specific heat High Hardness

III.LITERATURE REVIEW

WILFRIED ROETZEL, CHAKKRIT NA RANONG., [1] calculated the axial temperature profiles in a shell and tube heat exchanger by numerically for given mal distributions on the tube side. For comparison the same mal distributions are handled with the parabolic and hyperbolic dispersion model with fitted values for the axial dispersion coefficient and third sound wave velocity. The analytical results clearly demonstrate that the hyperbolic model is better suited to describe the steady state axial temperature profiles.



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WILFRIED ROETZEL, AND CHAKKRIT NA RANONG.,[3] tested and compared the newer hyperbolic dispersion model and parabolic model considering the processes with pure mal distribution (without back mixing) on the tube side of a shell and tube heat exchanger and plug flow on shell side . The boundary conditions of the model equations are discussed in detail for the steady state and equations of the axial temperature profiles are provided in the programmable form. For the hyperbolic model simple relationships between the model parameters are derived. Considering the transient adiabatic processes in the tube bundle a concept for the experimental determination of the model parameter M, the third sound Mach number, is developed. Authors concluded that for an overall consideration of a heat exchanger with maldistribution the parabolic model is satisfactory. The parameter Pepar depends on both NTUs of the heat exchanger which makes the model difficult to handle. The advantage of the parabolic model is that only the only one parameter is needed. The hyperbolic model is superior to the parabolic model because it predicts the axial temperature profiles correctly, especially temperature jumps and (positive) slopes.

The Fourie's law of conduction is one such example of a study that was carried out by the French scientist Joseph Fourier. His study stated that the rate of flow of heat through a single homogenous solid is directly proportional to the area(A) of the section at right angles to the direction of heat flow, and to the change of the temperature with respect to the length of the path of the heat flow.

Subin Michael1 studies the changes in temperature profiles in each of the cases are taken into consideration for calculating effectiveness of heat exchanger. Better insights on optimal material selection for vital parts of a heat exchanger is obtained from comparative CFD analysis by adopting distinct industrial materials.

Ammar Ali Abd illustratedfully the thermal and mechanical design for this heat exchanger. Here, the redesign takes place to improve the design by reselect different parameters which can enhance the heat transfer through the exchanger. The new design suggested that four tubes passes need to be used with 1.38m tube length. In addition, the tube arrangement chosen to be square type with 0.9 m shell diameter. Finally its stated as With these parameters, the exchanger achieves high enough heat transfer coefficient and the pressure drop within specification.

IV.METHODOLOGY

(a)Using the standard dimensions of shell, tubes and baffles we have made a CAD model using Solidworks.



CAD model of surface condenser



Symmetry View of Surface condenser



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(b)The mesh has been generated to perform FEA. The meshing of surface condenser has been shown in the following fig.



Meshing of surface condenser

Condition	Temp.	of	Temp.	of
	water (C)		Vapour (C)	
Initial (step1)	22		260	
Final (step2)	122		200	

(c)This is the final and the most important stepof our analysis. Here we applied the thermal loads on the various faces and edges and simulated to get the value of thermal heat flux, temperature, deformation of tubes and equivalent stress of the overall assembly. The thermal loads applied are shown in the following figures.



Thermal loads on various faces and edges at initial condition



Thermal loads on various faces and edges at final condition

V.RESULT & DISCUSSION

Here we have employed three types of materials of tubes and put them under the above shown thermal loads. The description of material combinations and the heat flux, directional heat flux, temperature of tubes, total deformation and equivalent stress obtained from them is as described below:

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(A) Analysis of Cu alloy (tube material), Structural Steel (Shell and baffles)



Total Heat Flux for step 1



Total Heat Flux for step 2



Directional heat flux for step 1



Directional heat flux for step 2



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Max. Temp. Of tube for step 1



Max. temp. of tube for step 2



Total Deformation of tubes for Cu Alloy tube material



Max. Equivalent Stress for Cu Alloy tube material



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(B) Analysis of Al alloy (tube material), Structural Steel (Shell and baffles)



Total heat flux for step 1



Total heat flux for step 2



Directional heat flux for step 1



Directional heat flux of step 2



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Max. Temp of tubesfor step 1



Max. Temp. of tubes for step 2



Total deformation of tubes



Max.Equivalent stress value for Al alloy tube material



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(C) Analysis of Structural Steel (Tubes, Shell and baffles)



Total Heat flux for step 1



Total heat flux for step 2



Max. Directional heat flux for step 1



Max. Directional heat flux for step 2



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Max. Temperature for step 2



Max. Total deformation of tubes







Heat Flux for step 1 and step 2 for different materials of tubes



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Max. Temp. of tubes for step 1 and step 2 for different materials of tubes



Total Deformation of tubes for different materials of tubes



Max. Eqivalent Stress for different materials of tubes



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VI.CONCLUSION

Shell and	Tube		Max.	Max.	Max.Temp.(Total	Max.Stress(M
Baffles	mate		Heat	Directiona	. C)	Deformation (Pa)
material	rial		Flux	l Heat		mm)	
			(W/mm	Flux(W\m			
			2)	m2)			
Srtctural	Cu	Step	34.709	2.8874	458	3.7607	978.71
Steel	alloy	1(Initial)					
		Step	11.375	0.9462	265.09		
		2(Final)					
Structural	Al	Step	15.023	2.8767	410.94	4.8868	982.49
Steel	alloy	1(Initial)					
		Step2(Fina	4.9511	0.94247	249.59		
		1)					
Structural	Struc	Step	5.4255	2.7697	325.31	4.1063	972.85
Steel	tural	1(Initial)					
	Steel	Step	1.7781	0.90771	221.9		
		2(Initial)					

From this study it is clear that if we assign Cu alloy material to the tubes and structural steel material to the shell and baffles then we get the maximum heat flux 34.709 W/mm2 and 11.375 W/mm2 for step 1 and step 2 respectively while using Al alloy matter for tube we get maximum heat flux 15.023 and 4.9511 for step 1 and step 2 respectively and we assign structural steel for the whole assembly then we get maximum heat flux 5.4255 and 1.3778 for step 1 and step 2 respectively. So, we get the maximum heat flux by assigning Cu alloy material to tube and structural steel to shell and baffles. The total deformation of tube value is low for Cu alloy tube material among Al alloy and structural steel material of tubes. The max. equivalent stress value is 978.71 MPa for Cu alloy material , 982.49 MPa for Al alloy material and 972.85 MPa for Structural Steel. Hence, Cu alloy material is good for tubes because we get maximum heat flux, less deformation and low value of equivalent stress.

Here we analysis that the Cu alloy tubes better for high directional heat flux, low deformation and low sress while analysis of structural steel tubes for surface condenser we obtain the maximum temperature of tube is 325.31 C and 221.4 C for step 1 and step2 respectively which is low compare to Cu alloy and Al alloy tube materials. Structural steel have low cost, low weight and corrosion resistance properties. Hence, Structural steel material of tube is good for temperature conditions.

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