As per UGC guidelines an electronic bar code is provided to seure your paper

International Journal for Modern Trends in Science and Technology, 7(09): 35-40, 2021

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0709007
Available online at: http://www.ijmtst.com/vol7issue09.html

Modeling and Performance Analysis of AC Plant Heat Exchanger

V. Harika[1] | Dr. K. Vasantha Kumar[2]

[1] M.Tech Student, Dept. of Mechanical Engineering, JNTUH College of Engineering, Kondagattu, Jagtial, Telangana India
[2] Assistant Professor and HOD, Department of Mechanical Engineering, Jawaharlal Nehru Technological University Hyderabad College of Engineering, Jagtial, Telangana state, India

To Cite this Article
V. Harika and Dr. K. Vasantha Kumar. Modeling and Performance Analysis of AC Plant Heat Exchanger. *International Journal for Modern Trends in Science and Technology* 2021, 7, pp. 35-40. https://doi.org/10.46501/IJMTST0709007

Article Info
Received: 15 August 2021; Accepted: 07 September 2021; Published: 10 September 2021

ABSTRACT

AC plant Chiller is considered as a shell-and-tube heat exchanger and generally applied in a water-cooled chiller. These days shell and tube heat exchanger (STHX) is the most common type of heat exchanger broadly used in marine ships, due to its high pressure application. The AC plants fitted on-board Marine ships consist of a Chiller i.e. parallel flow heat exchanger with baffles. It is important to improve the performance of a chiller so that the usage of electrical energy can be reduced while the quality of a product can be increased. The water is cooled by using refrigerant in this chiller. This project mainly deals with modeling the prototype of basic geometry of shell and tube heat exchanger using Solidworks and meshing using simulation run using CFD package ANSYS. In this paper, by varying the number of baffles and different fluids they are water, R134a and R410a their performance of the chiller is studied. In this work, effect of the baffle spacing on the performance of a heat exchanger has been examined. Thermal and fatigue analysis is done in ANSYS for two materials Aluminum and Copper for better fluid at from CFD analysis.

KEYWORDS: chiller, shell and tube, R134a, R410a baffles, CFD, Solid works.

1.INTRODUCTION

In order to remove excess heat generated by different types of process, a chiller is needed. The chiller can produce chilled water to a process by removing the heat energy in the water that coming from a process. The chiller can be classified into two major types which are an air-cooled chiller and water-cooled chiller. The method of a water-cooled chiller to produce chilled water is using a shell-and-tube heat exchanger, which generally called as chiller barrel, to absorb the heat energy of the water through heat transfer into the refrigerant gas. In this project, the performance of a chiller will be analyzed. By increasing the performance, which also known as the effectiveness of heat exchanger, in a chiller system process, the cost of the electrical energy will able to be reduced as well. Heat exchangers are one of the mostly used equipment in the process industries. Heat Exchangers are used to transfer heat between two process streams. One can realize their usage that any process which involve cooling, heating, condensation, boiling or evaporation will require a heat exchanger for these purpose. Process fluids, usually are heated or cooled before the process or undergo a phase change. Different heat exchangers are named according to their application. For example, heat exchangers being used to condense is known as condensers, similarly heat exchanger for boiling purposes are called boilers. Performance and efficiency of heat exchangers are measured through the amount of heat transfer using least area of heat transfer and pressure drop. A better presentation of its efficiency is done by calculating over all heat transfer coefficient. Pressure drop and area required for a certain amount of heat transfer, provides an insight about the capital cost and power requirements (Running cost) of a heat exchanger.

1.1. Factors Affecting the Performance of Shell and Tube Heat Exchanger

For a given shell geometry, the ideal configuration depends on the baffle cut, the baffle spacing, and baffle inclination angle. Even after fixing the right baffle cut and baffle space the performance can be still improved. So it is very important to have an optimum baffle spacing to give minimum pressure drop.

1.2. Heat Exchanger Failures

Heat exchangers usually provide a long service life with little or no maintenance because they do not contain any moving parts. However, there are four types of heat exchanger failures that can occur, and can usually be prevented: mechanical, chemically induced corrosion, combination of mechanical and chemically induced corrosion, and scale, mud and algae fouling. Mechanical-These failures can take seven different forms: metal erosion, steam or water hammer, vibration, thermal fatigue, freeze-up, thermal expansion and loss of cooling water.

2.LITERATURE REVIEW

Hassab et.al[1] present a simulation model of air cooled condenser of reciprocating water chillers using R134a as a refrigerant at steady state condition which present generalize thermal design at different cooling load which include mathematical equation for heat transfer and pressure drop.

Flohr et.al [2] investigated the influence of aluminum brazing process operating on R407C and POE lubricant. It shows that the presence of brazing flux residues has no negative influence on apparent running condition and the stability of refrigeration system on R407C and POE lubricant, even under worst condition such as the absence filter dryer and with artificially high moisture content.

Jannick et.al[3] theoretically investigated the simultaneous capacity measurement and comparison of mechanical produced and brazed heat exchanger with identical dimension and design. In average, capacity improvement of 1.5% were measured for the aluminium brazed heat exchanger.

Aute et al[4] studied how genetic algorithm is powerful tool to develop optimal tool design for air cooled condenser. This study uses two different ranking schemes, the multiple solutions thus obtained which is same quality; provide greater flexibility to designer, thereby leading to a better system.

Jiang et al [5] introduced the genetic simulation and optimization tool for design of air cooled condenser, it shows the ratio of condenser capacity for the best performer i.e. R32 and the worst performer i.e. R600a, was 1.18.

M.W Browne et.al [6] : This paper presents an overview of various simulation techniques that may be useful for predicting the in-situ (dynamic) performance of vapour-compression liquid chillers over a wide range of operating conditions. Four models were considered namely steady-state and transient physical models, and steady-state and transient neural network models. It was found that the steady-state models can give excellent results (to within ±5%) during quasi-static operation. However under more dynamic conditions discrepancies of up to ±20% can occur. They also have the obvious limitations during the shutdown process where they will either drastically overestimate the work input or under predict the cooling capacity depending on the choice of the convergence variable

PK.Bansal et al. [7]: presents a steady-state moel or predicting the performance of vapour-compression liquid chillers over a wide range of operating conditions.. In particular, it employs an elemental NTU-e methodology to model both the shell-and-tube condenser and evaporator. The approach allows the change in heat transfer coefficients throughout the heat exchangers to be accounted for, thereby improving both physical realism and the accuracy of the simulation model. The model predicts the electrical work input to the compressor, and the coefficient of performance (COP), and the condenser capacity to within ±10% for the majority of operating conditions for both chillers. The model is also able to predict the refrigerant temperatures in the condenser and the evaporator to within ±1% for the majority of operating conditions.

a) Problem Description

In the research by R. Shankar Subramanian, the shell and tube heat exchanger is taken in the water with various temperatures. In this thesis, along with water, refrigerants (R134a and R410a) of the shell and tube heat exchanger is analyzed for heat transfer properties, temperature, pressure, velocity and mass flow rates in CFD analysis. In thermal analysis, two materials Copper and Aluminum are considered for heat exchanger. Modeling is done in Solid works, Thermal, fatigue analysis and CFD analysis is done in ANSYS.

3.COMPUTATIONAL MODELLING AND ANALYSIS

A) MODELING

Solid Works (stylized as SOLIDWORKS) is a strong modeling computer-aided layout (CAD) and laptop-aided engineering (CAE) computer application that runs on Microsoft Windows. Solid Works is published with the aid of Dassault Systems.

Table: 1 Design Parameters

PARAMETERS	VALUES
Heat Exchanger length	495 mm
Inner diameter of shell	200 mm
Outer diameter of Tube	23 mm
Inner diameter of Tube	19 mm
No of tubes	5
Baffles to be varied	3, 6, 9

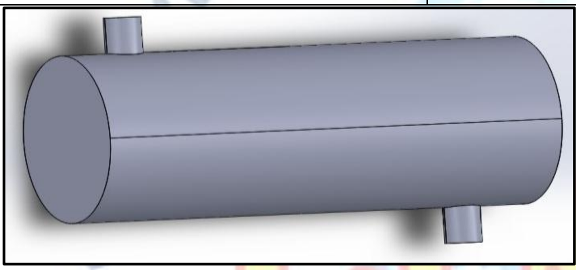


Fig: 1 3D model of shell and tube heat exchanger.

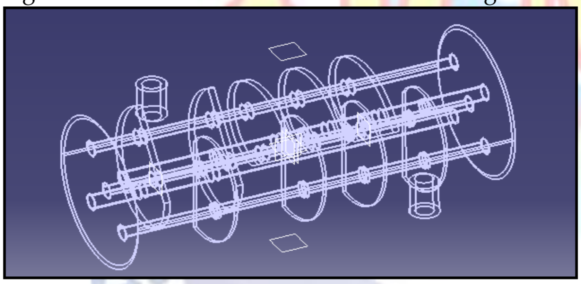


Fig: 2 3D model of shell and tube heat exchanger with 9 baffles

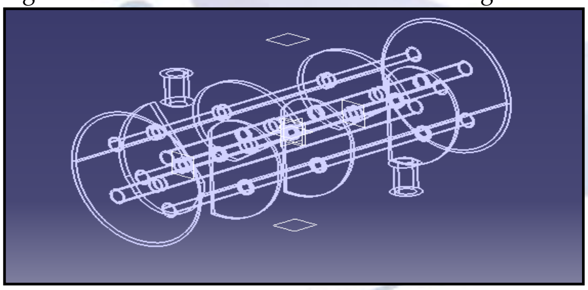


Fig: 3. 3D model of shell and tube heat exchanger with 6 baffles

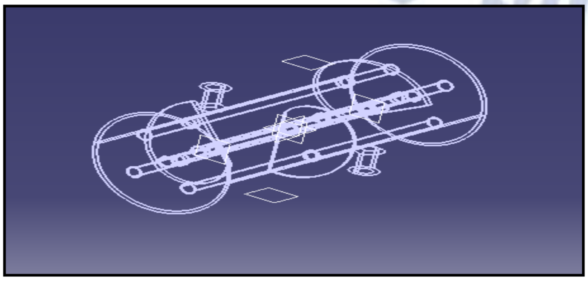


Fig: 4. 3D model of shell and tube heat exchanger with 3 baffles

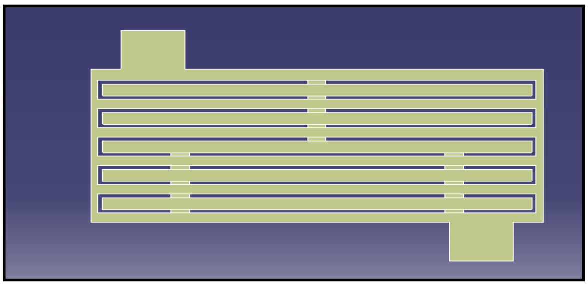


Fig: 5 surface design of shell and tube heat exchanger with 3 baffles

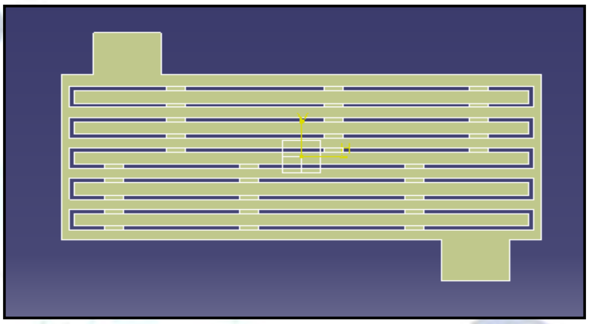


Fig: 6 surface design of shell and tube heat exchanger with 6 baffles

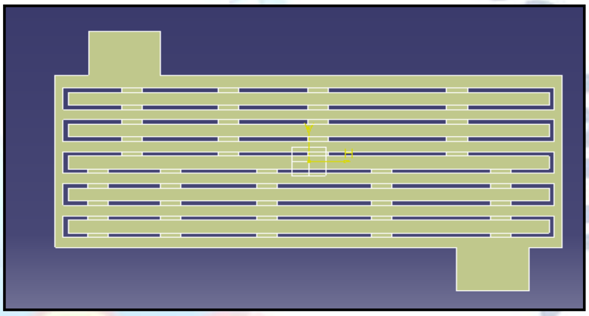


Fig: 7. surface design of shell and tube heat exchanger with 9 baffles

B) ANALYSIS

ANSYS is capable of both steady state and transient analysis of any solid with thermal boundary conditions. Steady-state thermal analyses calculate the effects of steady thermal loads on a system or component. Users often perform a steady-state analysis before doing a transient thermal analysis, to help establish initial conditions. A steady-state analysis also can be the last step of a transient thermal analysis; performed after all transient effects have diminished.

C) MATERIALS AND PROPERTIES

1. R-134a properties

R134a is also known as Tetrafluoroethane (CF3CH2F) from the family of HFC refrigerant. It is now being used as a replacement for R-12 CFC refrigerant in the area of centrifugal, rotary screw, scroll and reciprocating compressors.

- Density = 1326.6 kg/m3
- Specific heat = 1043.0 j/kg/k
- Thermal conductivity = 0.0042 w/m-k
- Viscosity = 0.000279 kg/m-s

2. R410A Refrigerant is widely used as a refrigerant in many air conditioning applications, usually packaged in rose color cylinders.

•Density = 1133 kg/m3
•Specific heat = 1570.0 j/kg/k
•Thermal conductivity = 0.055 w/m-k
•Viscosity = 0.006 kg/m-s

4.CFD ANALYSIS OF HEAT EXCHANGER

The model is designed with the help of SOLID WORKS and then import on ANSYS for Meshing and analysis. The analysis by CFD is used in order to calculating pressure profile and temperature distribution. For meshing, the fluid ring is divided into two connected volumes. Then all thickness edges are meshed with 360 intervals. A tetrahedral structure mesh is used. So the total number of nodes and elements is 8516 and 4414.

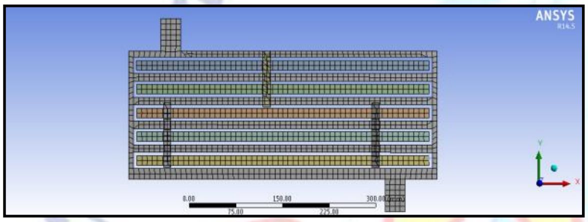


Fig 8: Meshed model of Heat exchanger.

CFD Boundary conditions

Mass Flow Rate → 1.2Kg/s , Inlet Cold Temperature – 283K and Inlet holt Temperature – 323K

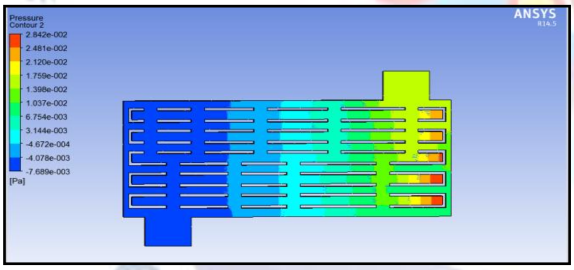


Fig 9: Static Pressure of Heat exchanger.

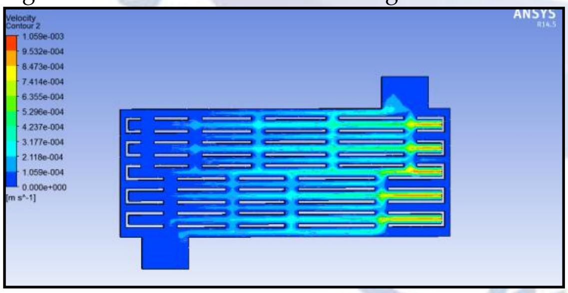


Fig 10: Velocity of Heat exchanger.

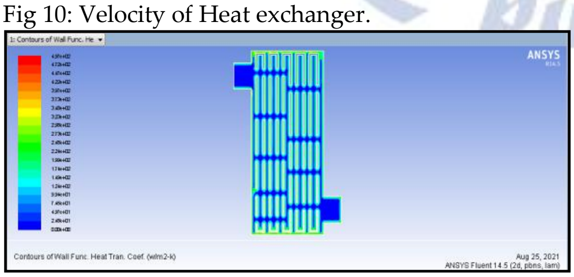


Fig 11: Heat transfer coefficient of Heat exchanger.

Mass Flow Rate	(kg/s)
c_i	0.090000011
c_o	0
h_i	0.0074999998
h_o	0
interior-split.5_	0.38800892
wall-split.5_	0
Net	0.097500011

Fig 12: Mass Flow Rate of Heat exchanger.

Total Heat Transfer Rate	(w)
c_i	-2988.4954
c_o	0
h_i	-142.88051
h_o	0
wall-split.5_	0
Net	-3131.3759

Fig 13: Heat transfer rate of heat exchanger

5.THERMAL ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER

ANSYS can be used to determine temperatures, thermal gradients, heat flow rates, and heat fluxes in an object that are caused by thermal loads that do not vary over time. Thermal analysis is conducted on heat exchanger taking into account heat transfer coefficients from CFD analysis by adjusting the aluminum and copper materials.

Boundary conditions

Temperature – 323K

Convection -1.20e+03

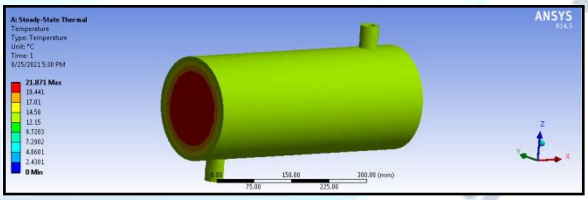


Fig 14: Temperature of heat exchanger

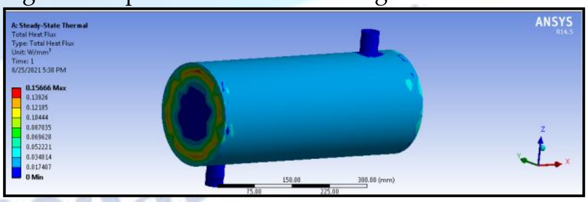


Fig 15: Heat flux of heat exchanger

6.FATIGUE ANALYSIS SHELL AND TUBE HEAT EXCHANGER

Fatigue analysis establishes whether your model is susceptible to fatigue damage when subjected to a varying load. You can use constant amplitude loading for situations in which the stress cycles are regular, such as a rotating shaft operating at a constant speed.

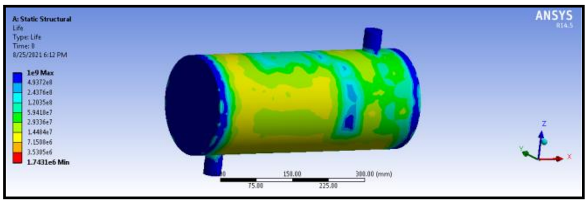


Fig 14: life of heat exchanger

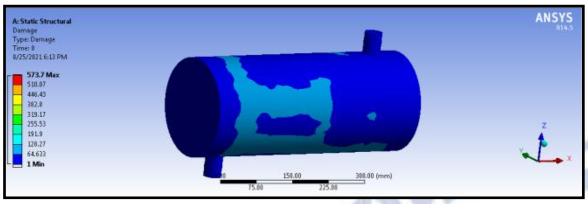


Fig 16: Damage of heat exchanger

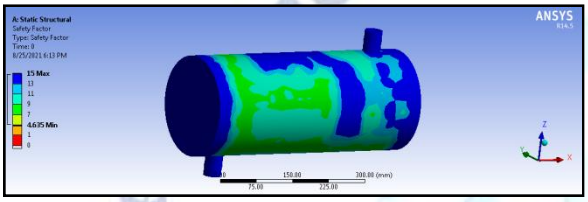


Fig 17: safety factor of heat exchanger

7.RESULTS AND DISCUSSIONS

1. CFD ANALYSIS

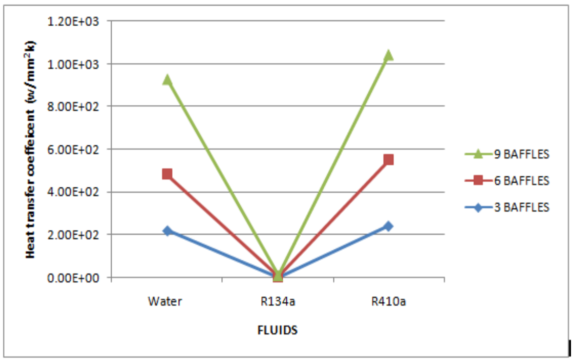
In this CFD analysis the heat transfer rate was found by using the different refrigerants.

Table: 1 CFD Analysis results of shell and tube heat exchanger

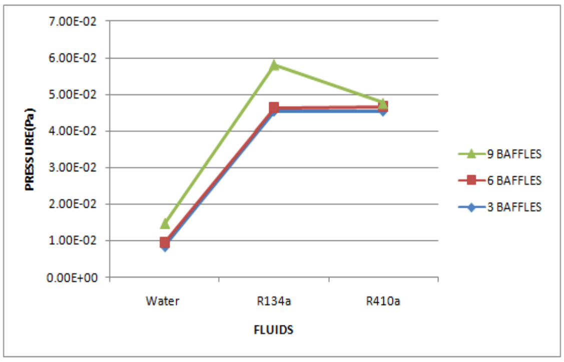
No .of baffles	Fluid	Pressure (Pa)	Heat transfer coefficient (W/m²-k)
3	Water	8.29e-03	2.19e+02
	R134a	4.544e-02	1.84e+00
	R410a	4.544e-02	2.41e+02
6	Water	1.20e-03	2.64e+02
	R134a	9.04e-04	1.86e+00
	R410a	1.059e-03	3.07e+02
9	Water	5.127e-03	4.47e+02
	R134a	1.17e-02	4.4e+00
	R410a	1.15e-03	4.97e+02

Fluid	Velocity (m/s)	Mass flow rate(Kg/sec)	Heat transfer rate (w)
Water	8.29e-03	0.09750011	8341.522
R134a	9.046e-04	0.0975004	2080.3938
R410a	1.059e-03	0.097504	3131.561

Graph: 1 plotted between heat transfer coefficient and different working fluids and number baffles



Graph: 2 Fluids and Number of baffles Vs Pressure



Taking into account the effects of the above CFD study, the coefficient of heat transfer is more for design with 9 baffles. By comparing the results between fluids the heat transfer coefficient is higher for refrigerant 410a.

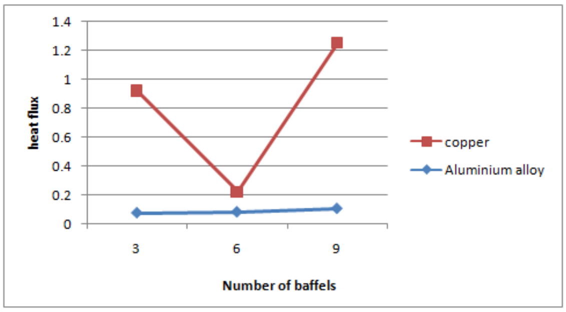
2. Thermal analysis

In this thermal analysis, the rate of heat transfer for different materials is shown below.

Table: 3 Thermal analysis results shell and tube heat exchanger

No of baffles	Materials	Heat flux (W/mm²)
3	Aluminum alloy	0.07288
	Copper	0.84818
6	Aluminum alloy	0.07941
	Copper	0.14247
9	Aluminum alloy	0.10339
	Copper	1.1557

Graph: 3 Materials and Number of baffles Vs Heat Flux



By analyzing results, it is found that the heat flux is more for heat exchanger with 9 baffles. By comparing the results between materials the heat transfer coefficient is higher for copper.

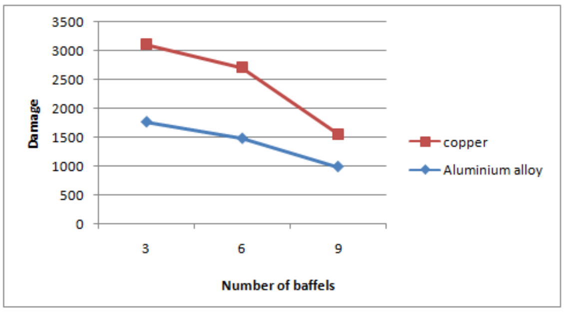
3. Fatigue analysis

Fatigue analysis used for estimate life, damage and safety factor of a component under static loading conditions.

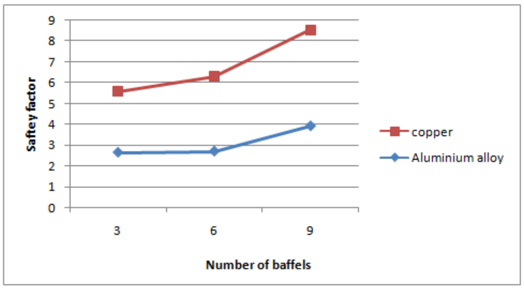
Table: 4 fatigue analysis results of shell and tube heat exchanger

No of baffles	Materials	Damage	Safety factor
3	Aluminum alloy	1767.9	2.6459
	Copper	1344.2	2.9399
6	Aluminum alloy	1479.5	2.7046
	Copper	1236.5	3.5878
9	Aluminum alloy	984.44	3.9165
	Copper	573.7	4.615

Graph: 4 Materials and Number of baffles Vs Damage



Graph: 5 Materials and Number of baffles Vs Safety factor



By observing the Fatigue analysis results the Safety factor value more at copper material with 9 baffles when compared to other material and 3 and 6 baffles.

8.CONCLUSION

In this project, by varying the Number of baffles and different fluids they are water, R134a and R410a their performance in the chiller barrel. 3D model of the shell and tube heat exchanger is done in SOLIDWORKS. CFD analysis is done on the shell and tube heat exchanger for all fluids .thermal and fatigue analysis is done in ANSYS for two materials Aluminum and Copper for better fluid at from CFD analysis.

By observing the CFD analysis results the heat transfer coefficient value more at R410a with 9 baffles when compared to other fluids and 3 and 6 baffles.

By observing the Thermal analysis results the heat flux value more at copper material with 9 baffles when compared to other material and 3 and 6 baffles.

By observing the Fatigue analysis results the Safety factor value more at copper material with 9 baffles when compared to other material and 3 and 6 baffles.

So it can be concluded the R410a fluid and copper material is the better for shell and tube heat exchanger with 9 baffles.

REFERENCES

[1] M.A. Hassab, S.M. Elsherbiny, and H.E. Fath, Thermal analysis of air cooled condenser of water chillers, Alexandria engineering journal, Vol.42.2003

[2] F Flohr, C. Meurer, H. W. Swidersky, H. J. Belt, Perspectives of aluminum as a constructive material for stationary refrigeration and air conditioning system, International Refrigeration and Air Conditioning Conference,2002.

[3] P. Jannick, C. Meurer, H. W. Swidersky , Potential of brazed tube fin heat exchanger in comparison to mechanical produced fin tube heat exchanger, International Refrigeration and Air Conditioning Conference" 2002.

[4] V. C. Aute, R. Radermacher and M.V.Naduvath, Constrained Multi-Objective Optimization of a Condenser Coil Using Evolutionary Algorithms, International Refrigeration and Air Conditioning Conference,USA, 2004.

[5] Jiang H., Aute V., Radermacher R., A User-Friendly Simulation And Optimization Tool for Design of Coils, International Refrigeration and Air Conditioning Conference at Purdue, Paper 546, 2002.

[6] M.W. Browne and P.K Bansal, Modelling of In-Situ Liquidchiller. International refrigeration and air conditioning. 2000

[7] M.W. Browne,2000 , An elemental NTU-s model for vapour-compression liquid chiller. International journal refrigeration. 24 ,2001 612-627

[8] K.T Chan, 2001 ,Energy performance of chillers with water mist assisted air cooled condensers. International building performance association 12th conference.

[9] K.A Manske ,2001, Evaporative cooling control in industrial refrigeration systems.International journal of refrigeration vol 4 ,no 7,pp 676-691-

[10] C.V Le P.k Bansal, J.D Tedford ,Three zone system simulation model of a multiple chiller plant. Applied thermal energy vol 24 2004, 1995-2015.