Performance Analysis And Design of Plate-Fin-And-Tube Condenser For Air-Conditioner

K. V. J. P. Narayana[1], M. Sai Santosh Kumar[2]

[1]*PG Scholar, Dept of Mechanical Engineering, V.K.R, V.N.B & A.G.K College of Engineering, AP, India*

[2] *Assistant Professor, Dept of Mechanical Engineering, V.K.R, V.N.B & A.G.K College Of Engineering, AP, India*

Abstract - Air conditioning systems have condenser that removes unwanted heat from the refrigerant and transfers that heat outdoors. The primary component of a condenser is typically the condenser coil, through which the refrigerant flows. Since, the AC condenser coil contains refrigerant that absorbs heat from the surrounding air, the refrigerant temperature must be higher than the air. In our project we have designed an air-cooled CONDENSOR for a home 1.5ton air conditioner. Presently the material used for coils is copper and the material used for fins is copper or aluminum G Al Cu 4IMG 204 whose thermal conductivity is 110-150W/m k. A 3D model of the condenser is done in parametric software Pro/Engineer. To validate the temperatures and other thermal quantities like flux and gradient, thermal analysis is done on the condenser coil by applying properties copper and present fin material G Al Cu 4IMG 204. We are analyzing by applying other material for fin Al 199 & 1100 whose thermal conductivity is 220W/m k which is more than that of present used material. And also we are varying inside cooling fluid Hydrocarbon (HC) and Hydrochloroflourocarbon (HCFC).The best material and best fluid for the condenser of our design can be checked by comparing the results. Thermal analysis is done in ANSYS.

I. INTRODUCTION

1.1AIR CONDITIONER

An air conditioner (often referred to as AC) is a home appliance, system or mechanism designed to dehumidify and extract heat from an area. The cooling is done using a simple refrigeration cycle. In construction, a complete system of heating, ventilation and air conditioning is referred to as "HVAC". Its purpose, in a building or an automobile, is to provide comfort during either hot or cold weather.

1.2 AIR CONDITIONING SYSTEM BASICS AND THEORIES

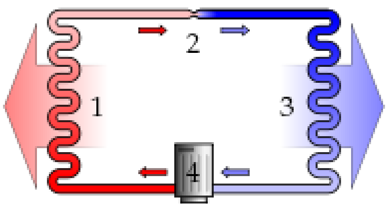

Fig1 Simple stylized diagram of the refrigeration cycle:

Fig1: Simple stylized diagram of the refrigeration cycle: In the refrigeration cycle, a heat pump transfers heat from a lower-temperature heat source into a higher-temperature heat sink. Heat would naturally flow in the opposite direction. This is the most common type of air conditioning. A refrigerator works in much the same way, as it pumps the heat out of the interior and into the room in which it stands.

This cycle takes advantage of the phase change work, where latent heat is released at a constant temperature during a liquid/gas phase change, and where varying the pressure of a pure substance also varies its condensation/boiling point. The most common refrigeration cycle uses an electric motor to drive a compressor. In an automobile, the compressor is driven by a belt over a pulley, the belt being driven by the engine's crankshaft (similar to the driving of the pulleys for the alternator, power steering, etc.). Whether in a car or building, both use electric fan motors for air circulation. Since evaporation occurs when heat is absorbed, and condensation occurs when heat is released, air conditioners use a compressor to cause pressure changes between two compartments, and actively condense and pump a refrigerant around. A refrigerant is pumped into the evaporator coil, located in the compartment to be cooled, where the low pressure causes the refrigerant to evaporate into a vapor, taking heat with it. At the opposite side of the cycle is the condenser, which is located outside of the cooled compartment, where the refrigerant vapor is compressed and forced through another heat exchange coil, condensing the refrigerant into a liquid, thus rejecting the heat previously absorbed from the cooled space. By placing the condenser (where the heat is rejected) inside a compartment, and the evaporator (which absorbs heat) in the ambient environment (such as outside), or merely running a normal air conditioners refrigerant in the opposite direction, the overall effect is the opposite, and the compartment is heated. This is usually called a heat pump, and is capable of heating a home to comfortable temperatures (25 °C; 70 °F), even when the outside air is below the freezing point of water (0 °C; 32 °F).

1.3. REFREGERENTS

"Freon" is a trade name for a family of haloalkane refrigerants manufactured by DuPont and other companies. These refrigerants were commonly used due to their superior stability and safety properties. However, these chlorine-bearing refrigerants reach the upper atmosphere when they escape. Once the refrigerant reaches the stratosphere, UV radiation from the Sun cleaves the chlorine-carbon bond, yielding chlorine radical. These chlorine atoms catalyze the breakdown of ozone into diatomic oxygen, depleting the ozone layer that shields the Earth's surface from strong UV radiation. Each chlorine radical remains active as a catalyst unless it binds with another chlorine radical, forming a stable molecule and breaking the chain reaction. The use of CFC as a refrigerant was once common, being used in the refrigerants R-11 and R-12. In most countries the manufacture and use of CFCs has been banned or severely restricted due to concerns about ozone depletion. In light of these environmental concerns, beginning on November 14, 1994, the Environmental Protection Agency has restricted the sale, possession and use of refrigerant to only licensed technicians, per Rules 608 and 609 of the EPA rules and regulations; failure to comply may result in criminal and civil sanctions. Newer and more environmentally-safe refrigerants such as HCFCs (R-22, used in most homes today) and HFCs (R-134a, used in most cars) have replaced most CFC use. HCFCs in turn are being phased out under the Montreal Protocol and replaced by hydro fluorocarbons (HFCs) such as R-410A, which lack chlorine. Carbon dioxide (R-744) is being rapidly adopted as a refrigerant in Europe and Japan. R-744 is an effective refrigerant with a global warming potential It must use higher compression to produce an equivalent cooling effect.

1.4 THE CONSTRUCTION PRNCIPLE

Refrigerant and air will be physically separated, at air conditioner condenser, and evaporator. Therefore, heat transfer occurs by means of conduction. We would like the heat exchanger that enables these processes, to have, High conductivity– this property will ensure that the low temperature difference between the outside wall, and inside wall High contact factor– this property ensures the passing air mass, will come in contact with the tubes, as much as possible.

1.5 SPECIFICATIONS OF CONDENSOR

The length and size of air conditioner condensers and evaporators have to be sized such that,

- The refrigerant is completely condensed before the condenser’s exit, and
- The refrigerant is completely boiled before the evaporator’s exit

Those two, depends mainly on the size of the compressor and refrigerant used.

Air conditioner manufacturers has to understand how conduction, as well as convection works, to design an effective, yet compact air conditioner condenser and evaporator, per unit heat transferred.

Normally, the condenser and evaporator will be designed to 110% of the intended heat transfer requirement, to cater for any performance drop during the service life.

It’s good that we know the basics now.

1.6 CONTACT FACTOR

It is the amount of media that needs to be heated up or cooled down, that comes directly in contact with the tube walls.

Contact factor will be very low, if the air inside a duct is passed through a straight tube with refrigerant. This happens as the amount of air that contacts the tube will be very low.

Therefore, we will increase the contact factor, by constructing the condenser and evaporator to have many passes within a given duct area. Thus, the passing air will “see” a lot of tubes on its passage. Hence the contact factor will be improved

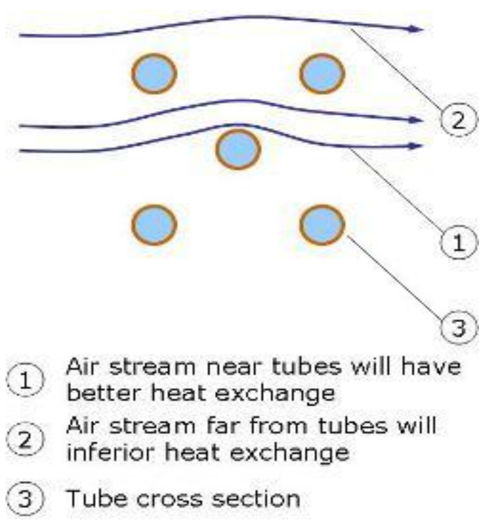

Fig 2 Contact Factor

The maximum theoretical contact factor is 100%. We will have contact factors around 80% for commercially produced air conditioner evaporators and air conditioner condensers. The real figures really depend on each manufacturer. The reciprocal of the contact factor, is the bypass factor, where it is equal to *1 – contact factor*.

2. COOLING LOAD CALCULATIONS

Cooling load calculations for air conditioning system design are mainly used to determine the volume flow rate of the air system as well as the coil and refrigeration load of the equipment to size the HVAC&R equipment and to provide the inputs to the system for energy use calculations in order to select optimal design alternatives. Cooling load usually can be classified into two categories: external and internal

2.1 EXTERNAL COOLING LOADS

These loads are formed because of heat gains in the conditioned space from external sources through the building envelope or building shell and the partition walls. Sources of external loads include the following cooling loads: 1. Heat gain entering from the exterior walls and roofs 2. Solar heat gain transmitted through the fenestrations 3. Conductive heat gain coming through the fenestrations 4. Heat gain entering from the partition walls and interior doors 5. Infiltration of outdoor air into the conditioned space

2.2 INTERNAL COOLING LOADS

These loads are formed by the release of sensible and latent heat from the heat sources inside the conditioned space. These sources contribute internal cooling loads: 1. People 2. Electric lights 3. Equipment and appliances If moisture transfers from the building structures and the furnishings are excluded, only infiltrated air, occupants, equipment, and appliances have both sensible and latent cooling loads. The remaining components have only sensible cooling loads. All sensible heat gains entering the conditioned space represent radioactive heat and convective heat except the infiltrated air, radioactive heat causes heat storage in the building structures, converts part of the heat gain into cooling load, and makes the cooling load calculation more complicated. Latent heat gains are heat gains from moisture transfer from the occupants, equipment, appliances, or infiltrated air. If the storage effect of the moisture is ignored, all release heat to the space air instantaneously and, therefore, they are instantaneous cooling loads.

2.3 COOLING LOAD CALCULATIONS

Width = 2.94m
Length = 9.06m
Height = 2.47m
Window = 1.36 X 1.18
Wall thickness = 0.25m
Door sizes = 0.8× 1.98
East wall = $9.06 \times 2.47 = 22.3782$
West wall = $9.06\times 2.47 = 22.3782$
South wall = $2.94\times 2.47 = 7.2618$
North wall = $2.94\times 2.47 = 7.2618$
West door = $0.8\times 1.9 = 1.52$
North window = $1.36\times 1.18 = 1.6048$
Bulbs = $6\times 40w = 240watts$
Floor volume = length x width x height = 9.06× 2.94 × 2.47 =65.791m^3
Door area = w× $h = 0.8 \times 1.98 = 1.584m^2$
Wall thickness = 0.254m
No of systems = 20
Window area = $1.36\times 1.18 = 1.6048m^2$
No of windows = 1 = 1.6048m^2
No of lights = 6 = $640 = 240watts$
Florescent coefficient = 1.25
Total lighting load = $240\times 1.25 = 300watts$
Solar heat gain factor(SHGF)
South wall = 140 w/m^2
North wall =120 w/m^2
West wall = 340 w/m^2
East wall = 60 w/m^2
Overall coefficient of heat transfer (U) w/m^{2}K
U_{wall} $= 1.56\ \mathrm{w/m^2K}$

U_{roof} = 5.675 w/m^{2}K
U_{floor} = 159 w/m^{2}K
U_{door} = 142 w/m^{2}K
U_{window} = 4.70 w/m^{2}K
Equivalent temperature differences (t_e)
t_e $of\ north\ wall$ = 90^0
t_e $of\ south\ wall$ = 11^0
t_e $of\ west\ wall$ = 11^0
t_e $of\ east\ wall$ = 6^0
t_e $of\ roof$ = 19^0
t_e $of\ floor$ = 2.4^0
No of persons = 40
Sensible heat load per person = 117W
Latent heat load per person = 50w
Ventilation required per person = 0.28m^3/min
Outdoor conditions:
Dry bulb temperatures = 38^{0}C RH 60%
W_2 = 0.011 kg/kg of dry air ratio
Assumptions:
Using a factor of 1.25 for fluorescent of light
Room latent heat load with 4% factor of safety
Estimation of sensible heat gain
South wall area = 7.2618 m^2
North wall area = 7.2618m^2
East and west wall area = 22.3782m^2
Equivalent temperature differences (t_e)
South wall sensible heat gain = UAH
= $1.56\times 7.2618 \times 11 = 124.612W$
North wall sensible heat gain = UAH
=$1.56\times 7.2618 \times 9 = 101.955W$
$= 101.955 - window\ area$
$= 100.350W$
East wall sensible heat gain = UAH
= $1.56\times 22.3782 \times 6 = 209.459W$
West wall sensible heat gain = UAH
= $1.56\times 22.3782 \times 11 = 384.009W$
$= 384.009 - door\ area = 382.425W$
Floor area sensible heat gain =$159\times 26.63 \times 2.4$
$= 10162.008W$
Roof area sensible heat gain = $5.675\times 26.63 \times 19 = 2871.379W$
Door area sensible heat gain =$142\times 1.584 \times 9 = 2024.352W$
South wall = $1.6048\times 4.70 \times 11 \times 2$
$= 82.968 \times 2 = 165.936$
North wall = $1.6048\times 4.70 \times 9 \times 1 = 67.88$
Solar heat gain through south glass:
Area of window$\times$ $SHGE\ for\ south$ = $1.6048 \times 2 \times 140 = 449.344m^2$
Total sensible heat gain per person$\times$ $no\ of\ persons = 117 \times 40 = 4680W$
Q$\times$ $total\ no\ of\ persons\ per\ person \times no\ of\ persons = 50 \times 40 = 2000W$
Amount of in filter air (vi) =length$\times$ $width \times height \times no\ of\ air\ changes/60$

$$65.791\times \frac{1}{60} = 1096.5\,\frac{m^3}{min} = 1.0965$$

Sensible heat gain due to infiltration air = .02044$\times$ $v_1 \times (tdb_1 - tdb_2)$
= $0.02044\times 1.096 \times (38 - 27) = 0.2465KW$
tdb_1 = out side temperature

$tdb_2 = in\ side\ temparature$

Latent heat gain due to infiltration air =50× $v_1 \times (W_1 - w_2)$

$= 50\times 1.096 \times (0.015 - 0.011) = 0.2192KW$

Sensible heat gain for computer = wattage per system× $no\ of\ system = 450 \times 20 = 9000W$

Total room sensible heat (RHS):

= 1.0495(heat gain from walls + windows + heat gain from person + due to infiltration + due to ventilation + due to lighting + due to computers)

=1.0495(816.846 + 449.344 + 0.2465 + 9000 + 200 + 63 +) = 11050.643W

Total room latent heat (RHL) =1.05(from persons + in filter air + ventilation)

= 1.05(4680+1.096+1.6048)

Latent +sensible heat = 4916.835W

Total heat = 25412.978 watts = 15967.478/3530 = 4.523 tons

1 ton=3530W We have to go for three 1.5 ton split air conditioning.

2.4 THERMAL FLUX CALCULATIONS

Inside temperature = 50^0C+273 = 323K

Atmospheric temperature =40^0C+273 = 313K

Total area = 39807.7× $2 = 79615.4mm^2 \quad = 0.079m^2$

Contact area = 47.12× $44 = 2073.28mm^2 \quad = 0.002073m^2$

Discharge of heat flow = x = 21mm

Tube thickness = 0.5

1. Copper : Thermal conductivity :K =385W/mk
2. Aluminum(99): K = 220 W/mk
3. Aluminum(204): K = 150 W/mk

$h_b = film\ coefficient\ for\ cu = 17\ w/m^2k$

$from\ air\ to\ fin$Aluminum(99): $15\ w/m^2k$

$from\ air\ to\ fin$Aluminum(204): $16\ w/m^2k$

$h_a = refregent\ used\ for\ hydro\ carbon = 900\ w/m^2k$

For Hydro fluoro carbon = 243 w/m^2k

2.5 HEAT FLUX FOR COPPER MATERIAL WITH HYDRO CARBON AS REFRIGERANT

Heat flow is given by = q = U× $A \times \Delta T_m$

Where U = overall heat transfer coefficient

$\Delta T_m = 16.6$

A = contact area = 0.002073m^2

Is given by U = $\frac{1}{\frac{1}{h_a}+\left(\frac{\Delta_r}{k_1}+\frac{x}{k_2}\right)+\frac{1}{h_b}}$

Where = $h_a = refregerent$

$h_b = air\ to\ fin$

$k_1 = tube\ material$

$k_2 = fin\ material$

by U = $\frac{1}{\frac{1}{900}+\left(\frac{0.5}{385}+\frac{21}{385}\right)+\frac{1}{17}} = 8.703\ w/m^2k$

Heat flow = q = U× $A \times \Delta T_m = 8.703 \times 0.002073 \times 16.6 = 0.299$

Heat flux = $\frac{q}{a} = \frac{0.299}{0.079} = 3.791\ w/m^2$

2.6 HEAT FLUX FOR ALUMINUM (1100) WITH HYDRO CARBON AS REFRIGERANT

Heat flow is given by = q = U× $A \times \Delta T_m$

U = $\frac{1}{\frac{1}{h_a}+\left(\frac{\Delta_r}{k_1}+\frac{x}{k_2}\right)+\frac{1}{h_b}} = \frac{1}{\frac{1}{900}+\left(\frac{0.5}{385}+\frac{21}{220}\right)+\frac{1}{15}} = 6.108\ w/m^2k$

Heat flow = q = U× $A \times \Delta T_m = 6.108 \times 0.002073 \times 16.6 = 0.210$

Heat flux = $\frac{q}{a} = \frac{0.210}{0.079} = 2.660\ w/m^2$

2.7 HEAT FLUX FOR ALUMINUM (204) WITH HYDRO CARBON AS REFRIGERANT

Heat flow is given by = q = U$\times A \times \Delta T_m$

U = $\frac{1}{\frac{1}{h_a}+\left(\frac{\Delta r}{k_1}+\frac{x}{k_2}\right)+\frac{1}{h_b}} = \frac{1}{\frac{1}{900}+\left(\frac{0.5}{385}+\frac{21}{150}\right)+\frac{1}{16}} = 4.8873\ w/m^2k$

Heat flow = q = U$\times A \times \Delta T_m = 4.887 \times 0.002073 \times 16.6 = 0.168$

Heat flux = $\frac{q}{a} = \frac{0.168}{0.079} = 2.128\ w/m^2$

2.8 HEAT FLUX FOR COPPER MATERIAL WITH HYDRO FLUORO CARBON

Heat flow is given by = q = U$\times A \times \Delta T_m$

U = $\frac{1}{\frac{1}{h_a}+\left(\frac{\Delta r}{k_1}+\frac{x}{k_2}\right)+\frac{1}{h_b}} = \frac{1}{\frac{1}{243}+\left(\frac{1.5}{385}+\frac{21}{220}\right)+\frac{1}{17}} = 8.4801 w/m^2k$

Heat flow = q = U$\times A \times \Delta T_m = 8.4801 \times 0.002073 \times 16.6 = 0.2918$

Heat flux = $\frac{q}{a} = \frac{0.2918}{0.079} = 3.693\ w/m^2$

2.9 HEAT FLUX FOR ALUMINUM (199) MATERIAL WITH HYDRO FLUORO CARBON AS REFRIGERANT

Heat flow is given by = q = U$\times A \times \Delta T_m$

U = $\frac{1}{\frac{1}{h_a}+\left(\frac{\Delta r}{k_1}+\frac{x}{k_2}\right)+\frac{1}{h_b}} = \frac{1}{\frac{1}{243}+\left(\frac{0.5}{385}+\frac{21}{220}\right)+\frac{1}{15}} = 6.0199 w/m^2k$

Heat flow = q = U$\times A \times \Delta T_m = 6.0199 \times 0.002073 \times 16.6 = 0.2017$

Heat flux = $\frac{q}{a} = \frac{0.2017}{0.079} = 2.6222\ w/m^2$

2.10 HEAT FLUX FOR ALUMINUM (204) MATERIAL WITH HYDRO FLUORO CARBON AS REFRIGERANT

Heat flow is given by = q = U$\times A \times \Delta T_m$

U = $\frac{1}{\frac{1}{h_a}+\left(\frac{\Delta r}{k_1}+\frac{x}{k_2}\right)+\frac{1}{h_b}} = \frac{1}{\frac{1}{243}+\left(\frac{0.5}{385}+\frac{21}{150}\right)+\frac{1}{16}} = 4.839 w/m^2k$

Heat flow = q = U$\times A \times \Delta T_m = 4.839 \times 0.002073 \times 16.6 = 0.166$

Heat flux = $\frac{q}{a} = \frac{0.166}{0.079} = 2.108 w/m^2$

3. MODEL OF CONDENSER

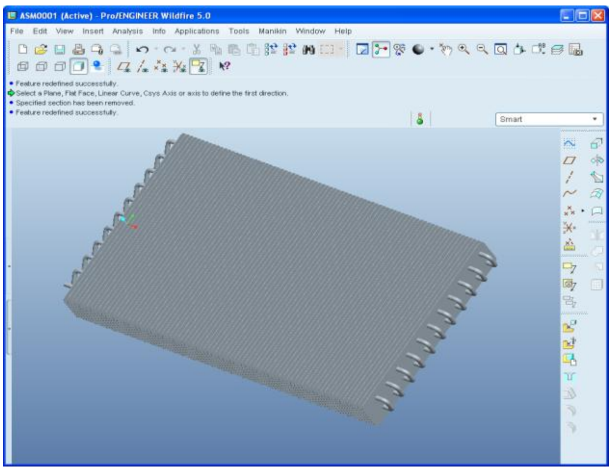

Fig: 3 Model of Condenser

4 ABOUT ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping. With virtual prototyping techniques, users can iterate various scenarios to optimize the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behavior of the product, be it electromagnetic, thermal, mechanical etc.

5 THERMAL ANALYSIS OF CONDENSER

5.1 COPPER FOR TUBE AND PLATE – HYDROCARBON FLUID

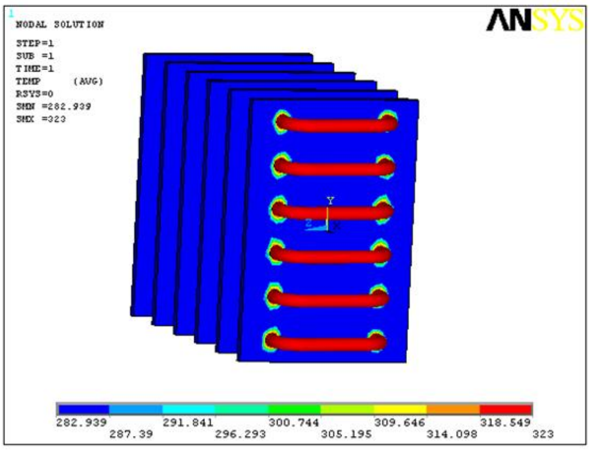

Fig 4 Temperature

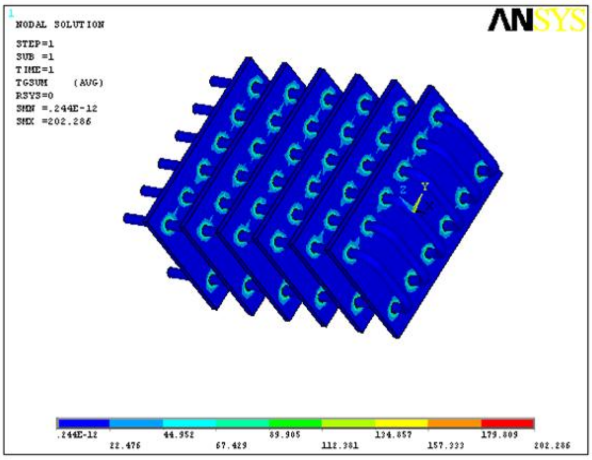

Fig 5 Thermal Gradient

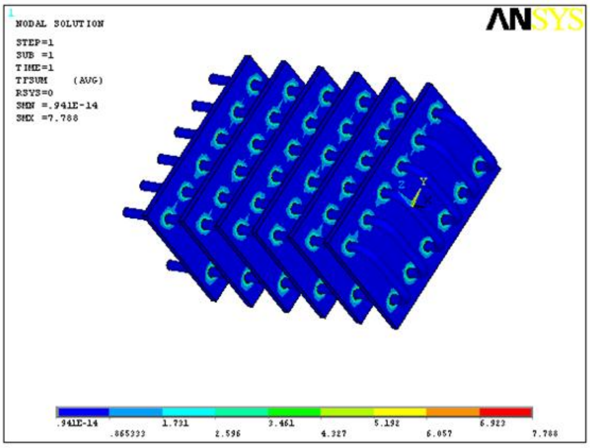

Fig 6 Thermal flux

5.2 COPPER FOR TUBE AND ALUMINUM ALLOY 204 FOR PLATE –HYDROCARBON FLUID

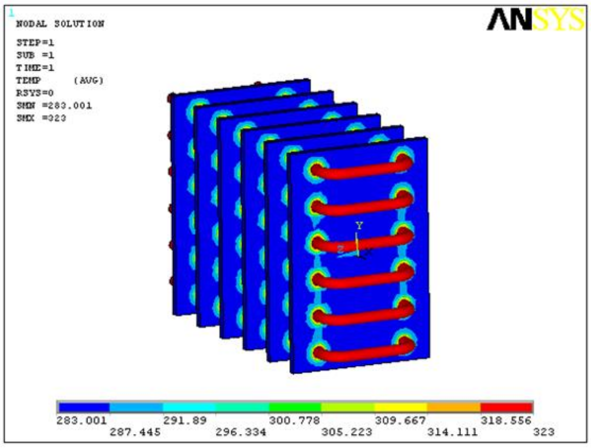

Fig 7 Nodal Temperature

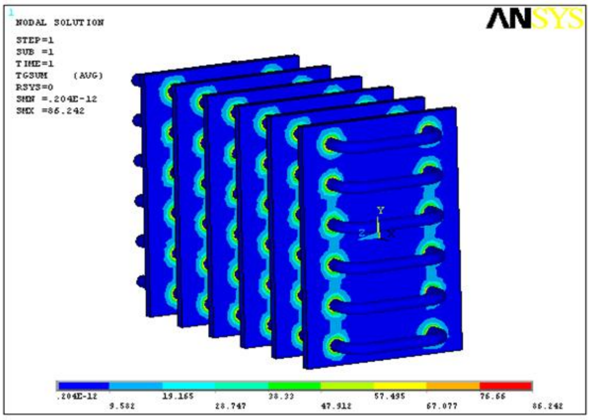

Fig 8 Thermal Gradient

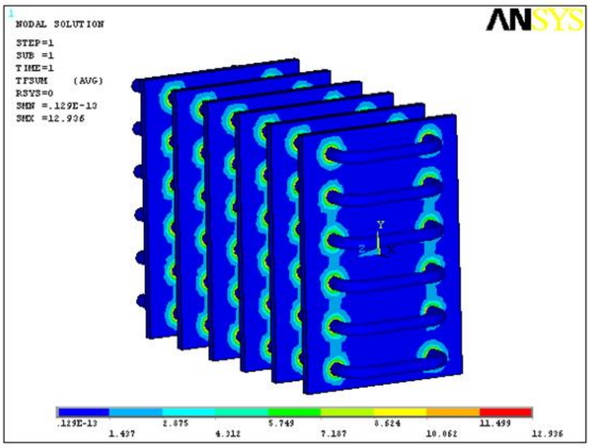

Fig 9 Thermal flux

5.3 COPPER FOR TUBE AND ALUMINUM ALLOY 1100 FOR PLATE HYDROCARBON FLUID

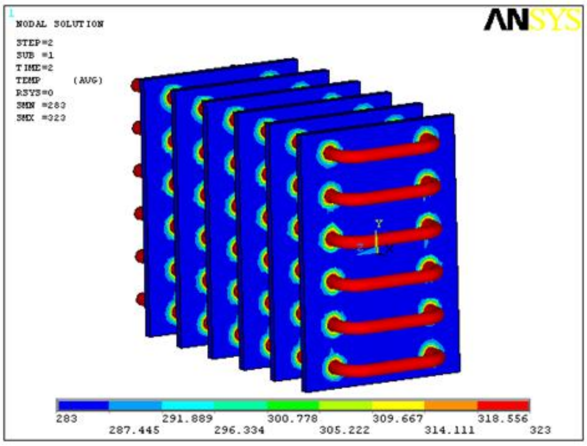

Fig 10 Temperature

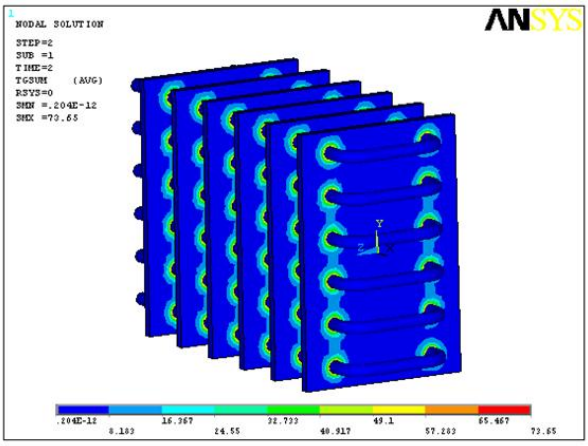

Fig 11 Thermal Gradient

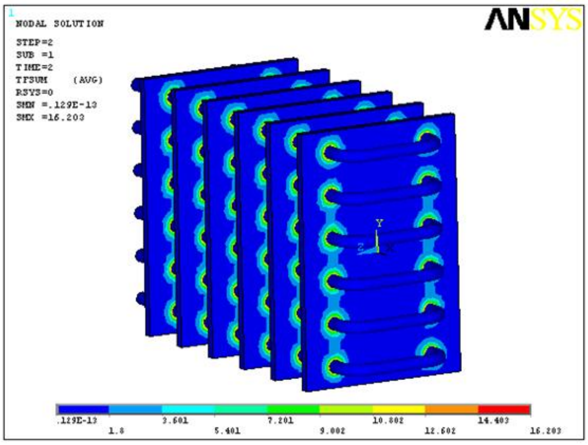

Fig 12 Thermal flux

Table 1 Thermal analysis for fluid Hydrocarbon

	Nodal Temperature (C)	Thermal Gradient (K/mm)	Thermal Flux (W/mm^2)
Copper Tube Copper Plate	323	202.286	7.788
Copper Tube Al 204 Plate	323	86.242	12.936
Copper Tube Al 1100 Plate	323	73.65	16.203

5.4 COPPER FOR TUBE AND PLATE – HYDRO FLUORO CARBON FLUID

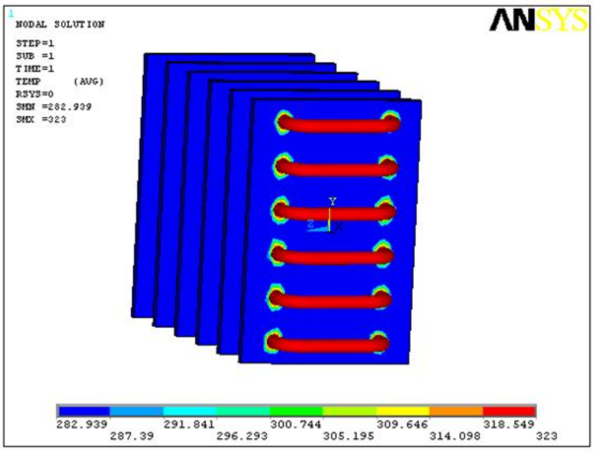

Fig 13 Nodal Temperature

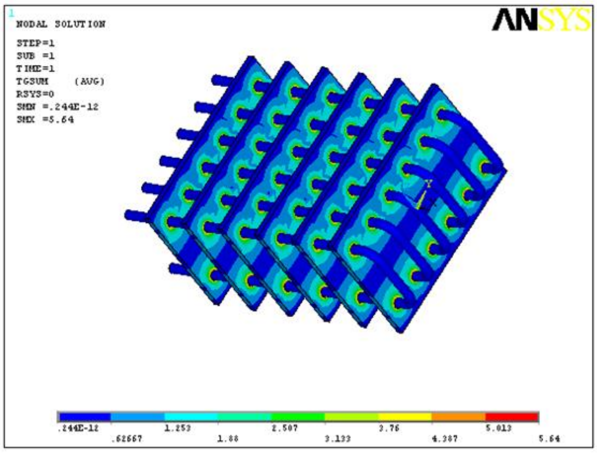

Fig 14 Thermal Gradient

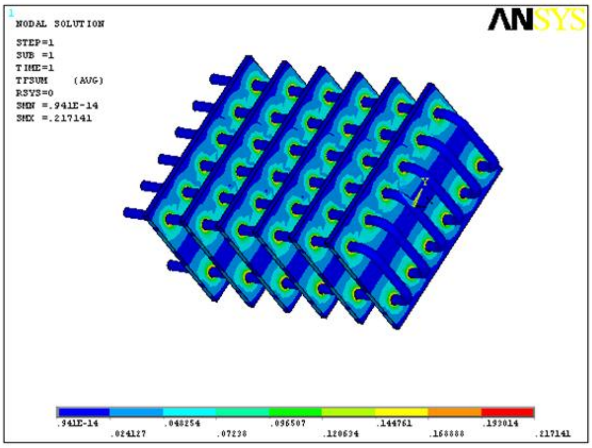

Fig 15 Thermal flux

5.5 COPPER FOR TUBE AND ALUMINUM ALLOY 204 FOR PLATE – HYDRO FLUORO CARBON FLUID

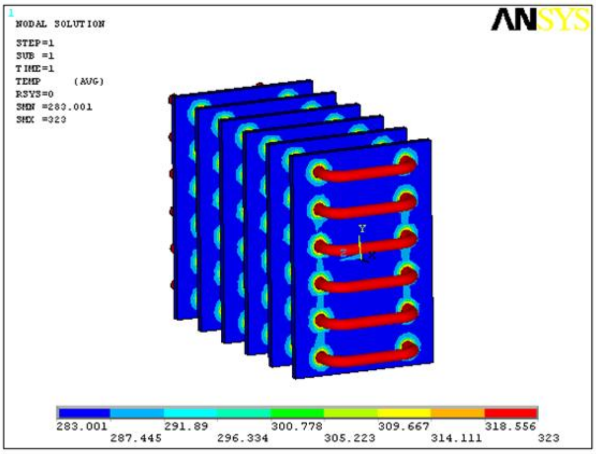

Fig 16 Nodal Temperature

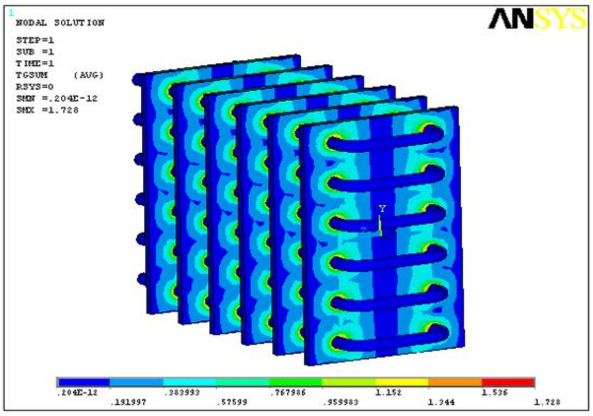

Fig 17 Thermal Gradient

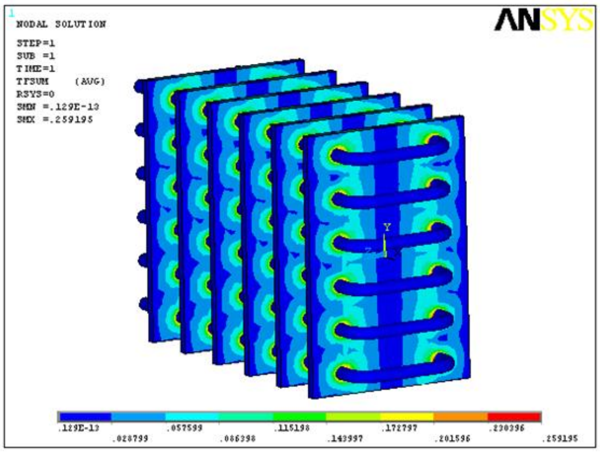

Fig 18 Thermal flux

5.6 COPPER FOR TUBE AND ALUMINUM ALLOY 1100 FOR PLATE – HYDRO FLUORO CARBON FLUID

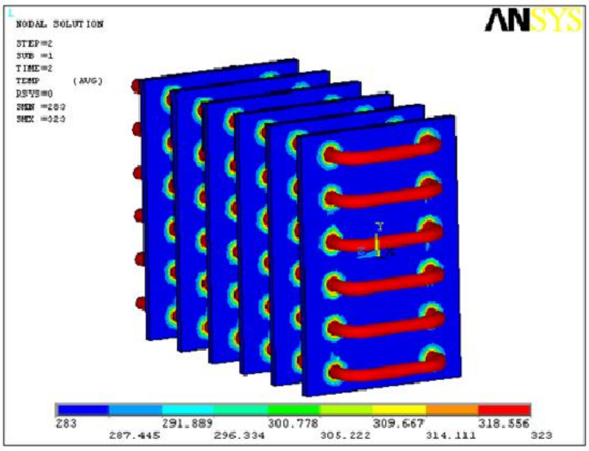

Fig 19 Nodal Temperature

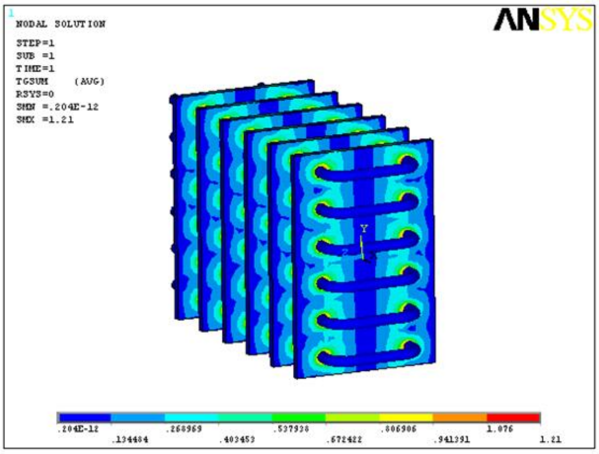

Fig 20 Thermal Gradient

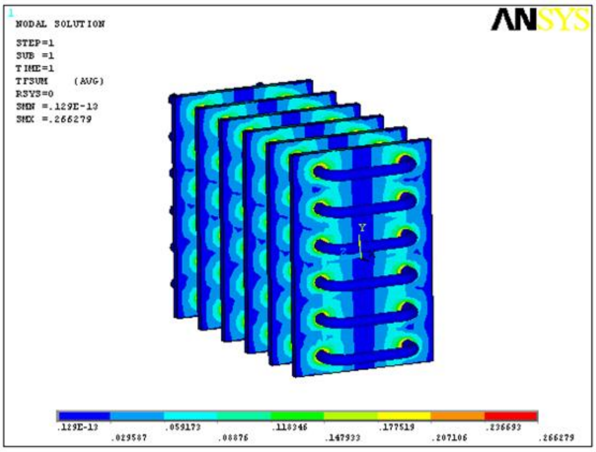

Fig 21 Thermal flux

Table 2 Thermal analysis for fluid Hydro fluro carbon

	Nodal Temperature (C)	Thermal Gradient (K/mm)	Thermal Flux (W/mm^2)
Copper Tube Copper Plate	323	5.64	10.498
Copper Tube Al 204 Plate	323	1.728	0.259195
Copper Tube Al 1100 Plate	323	1.21	0.266279

6. CONCLUSION

In our project we have done the modeling for an air-cooled condenser for 1.5ton air conditioner. 3D Modeling is done using Pro/Engineer.

We have performed Thermal analysis on the condenser by taking tube material as copper and varying the plate materials, Copper, Aluminum alloy 1100, Aluminum alloy 204. We also have done analysis by varying refrigerant Hydrocarbon and Hydro fluorocarbon.

In thermal analysis, we analyze the thermal properties like nodal temperature, thermal gradient and thermal flux. By observing the results, by using plate material Aluminum alloy 1100 has more thermal conductivity and its thermal flux is more. So using Aluminum alloy 1100 as fin is advantageous for condenser.

When comparing Hydrocarbon and Hydro fluorocarbon, using Hydrocarbon is more advantageous since its thermal flux is more.

7. REFERENCES

[1] Wang, C. C., Lee, C. J., Chang, C. T., and Chang Y. J., 1999. “Some Aspects of Plate Fin-and-Tube Heat Exchangers with and without Louvers,” J. Enhanced Heat Transfer, vol. 6, no. 5, pp. 357-368.

[2] Wang, C. C., Chi, Y. P. Chang, K. Y. C., and Chang, Y. J., 1998. “An Experimental Study of Heat Transfer and Friction Characteristics of Typical Louver Fin and Tube Heat Exchangers,” Int. J. of Heat and Mass Transfer, vol. 41, no. 4-5, pp.817-822.

[3] Chi, K., Wang, C. C., Chang, Y. J., and Chang, Y. P., 1998. “A Comparison Study of Compact Plate Fin-and-Tube Heat Exchangers,” ASHRAE Transactions, vol. 104, no. 2, pp. 548-555.

[4] Kays, W. M. and London, A. L., 1984. Compact Heat Exchangers, 3rd Edition, McGraw- Hill, New York.

[5] Shepherd, D. G., 1956. “Performance of One-Row Tube Coils with Thin Plate Fins,” Heating, Piping, & Air Conditioning, vol. 28, no. 4, pp. 137-144

[6] Rich, D. G., 1973. “The Effect of Fin Spacing on the Heat Transfer and Friction Performance of Multi-Row, Smooth Plate Fin-and-Tube Heat Exchangers,” ASHRAE Transactions, vol. 79, pt. 2, pp. 137-145.

[7] 2001 ASHRAE Handbook of Fundamentals

[8] 1997 ASHRAE Handbook of Fundamentals

[9] ASHRAE Cooling and Heating Load Calculation Manual [10] ASHRAE Standard 62, Indoor Air Quality

[10] Bivens, D. B., Shiflett, M. B., Wells, W. D., Shealy, G. S., Yokozeki, A., Patron, D. M. Kolliopoulos, K. A., Allgood, C. C., and Chisolm, T. E. C., 1995. “HFC-22 Alternatives for Air Conditioners and Heat Pumps, ”ASHRAE Transactions, vol. 101, pt. 2, pp. 1065-1071. [12]Baxter, V., Fischer, S., and Sand, J., 1998. “Global Warming Implications of Replacing Ozone-Depleting Refrigerants,” ASHRAE Journal, vol. 40, no. 9, pp. 23-30.

[11] International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 1, January- 2013 ISSN: 2278-0181

[12] Air Conditioning Engineering by R.S.KURMI