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Design and Heat Transfer Analysis of AC Condenser For Different Materials

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Abstract

The main objective is to design, develop and utilize the high-efficient heat transfer of an AC condenser. In systems involving heat transfer, a condenser is a device or unit used to condense a substance from its gaseous to its liquid state, typically by cooling it. The latent heat is given up by the substance, and will transfer to the condenser coolant. An optimization technique that can be useful in assessing the best configuration of a finned-tube condenser is presented and the Heat transfer by convection in air cooled condensers is studied and improved in this work. The assessment is carried out on an air-cooled finned-tube condenser of a vapour compression cycle for air conditioning system. Heat transfer analysis is done on the condenser to evaluate the material and refrigerant. The materials considered for tubes are Copper and Aluminum alloy 1100 and for fins are 1050 and 1100. The refrigerants varied are R12, R 22 and R 134. 3D modeling is done in Pro/Engineer and analysis is done in Ansys.

Index terms:
Heat transfer, condenser, copper, Aluminum alloy, refrigerant, heat flux.

I.INTRODUCTION:

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.
A diagram of the refrigeration cycle:
1) Condensing coil,
2) Expansion valve,
3) Evaporator coil,
4) Compressor,

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 way phase changes 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.

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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). Cylinder un loaders are a method of load control used mainly in commercial air conditioning systems. On a semi-hermetic (or open) compressor, the heads can be fitted with unloaders which remove a portion of the load from the compressor so that it can run better when full cooling is not needed. Unloaders can be electrical or mechanical.

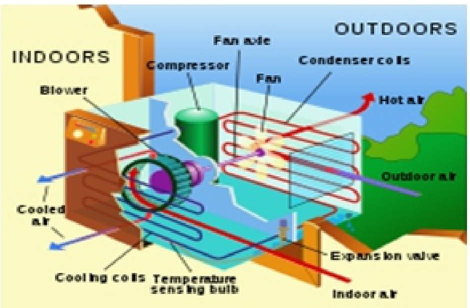

Fig1 : Image of A typical home air conditioning unit

II. RELATED WORK:

The idea behind the proposed system is to design optimization technique that can be useful in assessing the best configuration of a finned-tube condenser. Heat transfer by convection in air cooled condensers. Modeling is done in Pro/Engineer. Heat transfer analysis is done on the condenser to evaluate the material and refrigerant. The materials considered for tubes are Copper and Aluminum alloy 1100 and for fins are 1050 and 1100. The refrigerants varied are R12, R 22 and R 134. 3D modeling is done in Pro/Engineer and analysis is done in Ansys.

Air cooled condensers are used in small units like household refrigerators, deep freezers, water coolers, window air-conditioners, split air-conditioners, small packaged air-conditioners etc. These are used in plants where the cooling load is small and the total quantity of the refrigerant in the refrigeration cycle is small. Air cooled condensers are also called coil condensers as they are usually made of copper or aluminum coil. Air cooled condensers occupy a comparatively larger space than water cooled condensers.In the present work, the performance analysis of air cooled condensing unit has been carried out by varying the fin material and fin thickness. At present aluminum alloy 204 is being used for fins.

Two fin materials namely, Aluminum alloys 1100 and 6063were considered to study the effect of fin's thermal conductivity on the performance of the condenser. Pro Engineer is used to model the system. For thermal analysis purpose COSMOS Works software is used. Considering different factors for a condenser, such as heat transfer, density etc., Aluminum alloy 1100is found to be the best fin material.

3D MODEL OF CONDENSOR:

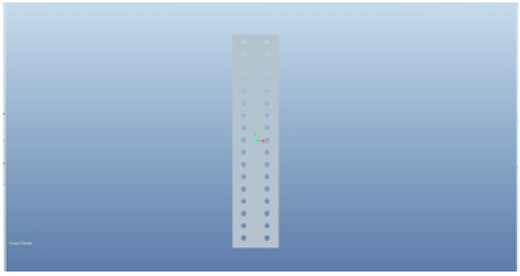

Fig2 : Image of A Fin

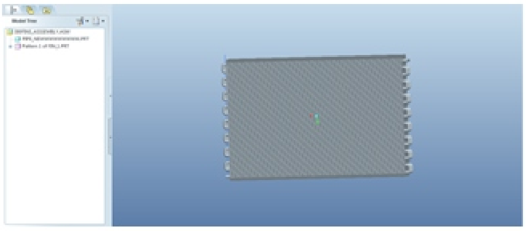

Fig3 : Image of Tubes

A condenser or evaporator is a heat exchanger, allowing condensation, by means of giving off, or taking in heat respectively.Construction principle:Refrigerant and air will be physically separated, at air conditioner condenser, and evaporator. Therefore, heat transfer occurs by means of conduction. 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.

Conductivity in air conditioner condenser and evaporator:

The factors that effect conduction of a material where the refrigerant is within the tube of an air conditioner condenser.

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The tube will have a circular wall. Fourier ‘slaw has stated that the rate of conduction heat transfer is proportional to, the thermal conductivity of the wall k W/m2, the mean surface area, A m2 the inverse of the wall’s thickness L in meters and the temperature difference between the inside wall, and the outside wall Selection of the tube for the condenser and evaporator has to meet few other criteria as well. It has to be durable, difficult to oxidize, easy to join with other lengths of similar tube, good strength and cheap. Copper and aluminum has proven time and time again, to meet all the criteria mentioned, with excellent thermal conductivity. It will imply that the rate of heat transfer will increase if the total surface area of the condenser’s or the evaporator’s is increased. Because most of the work done by the compressor will be converted into giving off, and taking in heat, we can have an insulator, if the temperature difference between the walls is high. In other words, we want the tube to be as “non-existent” as possible.

Specifications Of Condenser:

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.

III. DESIGNING OF PROPOSED MODEL:

In this paper we have presented a design and analysis of heat transfer of an AC condenser for using different materials. Initially need to prepare the analysis and designs related to heat transfer using PRO/ENGINEER, Finite Element Analysis (FEA), ANSYS. Air cooled condensers are used in small units like household refrigerators, deep freezers, water coolers, window air-conditioners, split air-conditioners, small packaged air-conditioners etc. These are used in plants where the cooling load is small and the total quantity of the refrigerant in the refrigeration cycle is small.

Air cooled condensers are also called coil condensers as they are usually made of copper or aluminum coil. Air cooled condensers occupy a comparatively larger space than water cooled condensers. Unlike evaporative condensers, air-cooled condensers have a capacity which is related to the dry-bulb temperature of the ambient air, rather than to its wet-bulb temperature. If working condenser pressures are not to become excessively high, making the plant expensive to run, large condenser surface areas must be used. This has set a limit on the practical upper size of air-cooled condensers. Their use in air conditioning has been commonly confined to plants having a capacity of less than 70 kW of refrigeration, although they have been used for duties as high as 2000 kW, in temperate climates. The hot gas discharged from the compressor is de superheated over approximately the first 5 per cent of the heat transfer surface, followed by condensation over the succeeding85 per cent, with a small drop in the condensing temperature, related to the frictional pressure loss.

A certain amount of sub-cooling of the liquid can then occur. Additional heat transfer surface may be provided to assist the sub-cooling, achieving an increase of about 0.9 per cent in the cooling capacity for each degree of liquid temperature drop, according to ASHRAE (1996). Propeller fans, direct-coupled to split-capacitor driving motors, are most commonly used to promote airflow, although axial flow or centrifugal fans are also sometimes adopted. Fan powers are about 20 to 40 W for each kW of refrigeration capacity. Noise is often a problem and this is made worse if there are obstructions in the inlet or outlet airflow paths. Although vertical fan arrangements are possible, with horizontal cooling airflow paths, these are susceptible to wind pressures and it is recommended that the condenser coils should be horizontal with vertical cooling airflow paths. Propeller fans will not deliver airflow against any significant external resistance. It follows that ducting connections are then not possible if these fans are used. A 20-degree difference between the entering dry-bulb temperature and the condensing temperature is often consistent with the avoidance of excessively large condenser surface areas. Air-cooled condensers are increasing in popularity because of the absence of water piping, the consequent simplicity of operation and the freedom from any health risk associated with the use of spray water. One objection to their use is that the capacity of the refrigeration plant does not gradually reduce as the ambient dry-bulb rises but ceases suddenly when the high pressure cut-out operates.

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A partial solution is to arrange for some of the compressor to be unloaded when the condensing pressure rises, before it reaches the cut-out point. Continued operation at a reduced capacity is then possible beyond the design ambient dry-bulb. It is a good plan to select air-cooled condensers to operate in an ambient temperature two or three degree higher than the design value chosen for the rest of the air conditioning system.

THERMAL ANALYSIS OF CONDENSOR TUBES AND FINS ALUMINUM ALLOY 1100 R-12 REFRIGERANT

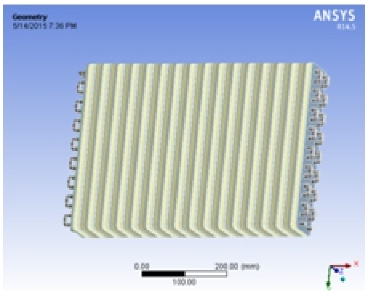

Fig4 : Figure of Pro-E design model in .iges format

Select mesh on left side part tree → right click → generate mesh →

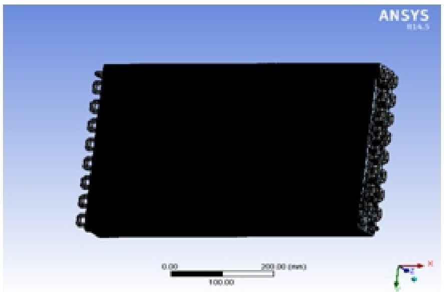

Fig5 : Figure of Pro-E design model in .iges format with film coefficient value

Select convection → select required area → click on apply → enter film coefficient value 29996.774W/m2C→ enter bulk temperature value 37 C→

Temperature

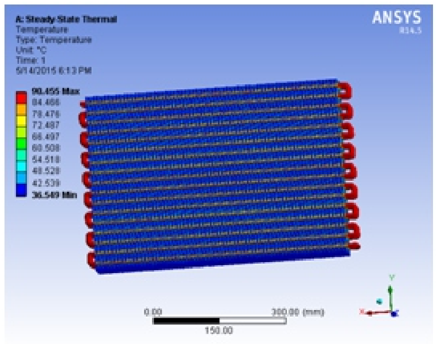

Fig6 : Figure of Pro-E design model in .iges format with temperature

Total Heat Flux

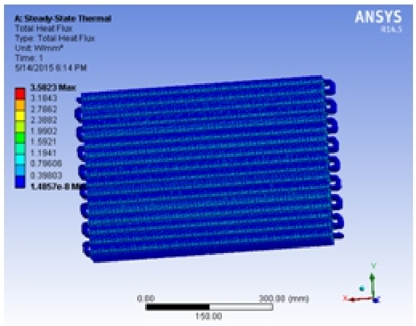

Fig7 : Figure of Pro-E design model in .iges format with total heat flux

Directional Heat Flux

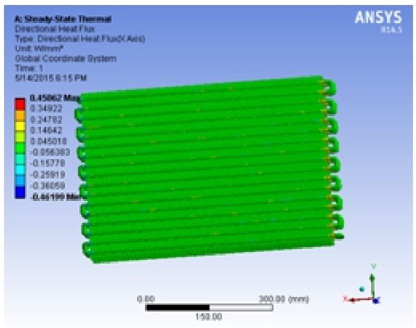

Fig8 : Figure of Pro-E design model in .iges format with directional heat flux

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GRAPHICAL REPRESENTATIONS OF TUBES COPPER AND FINS ALUMINUM ALLOY

a. Temperature o C

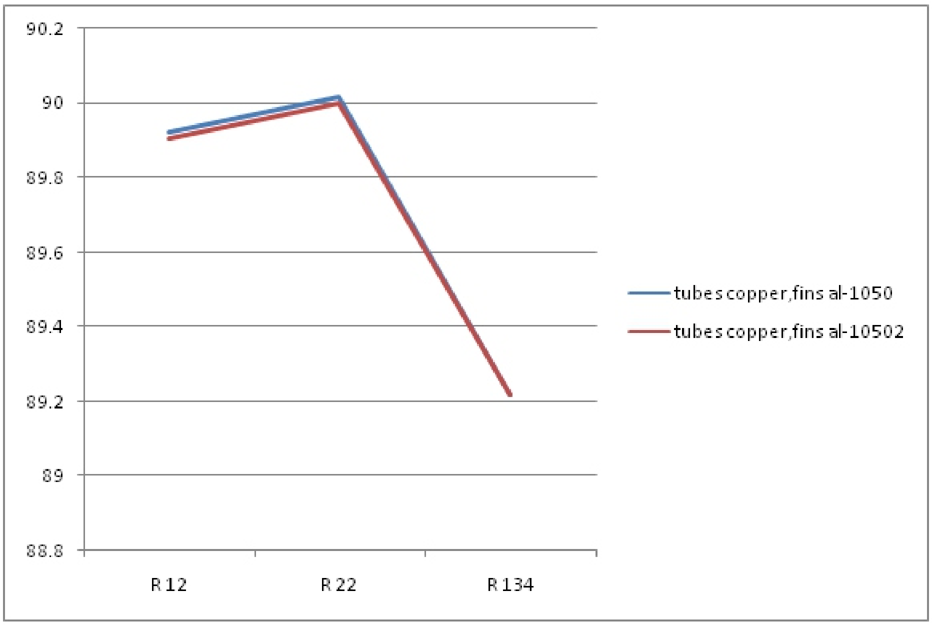

Fig9 : Figure of graphical representation of TUBES COPPER AND FINS ALUMINUM ALLOY with temperature

b. Total Heat Flux W/mm2

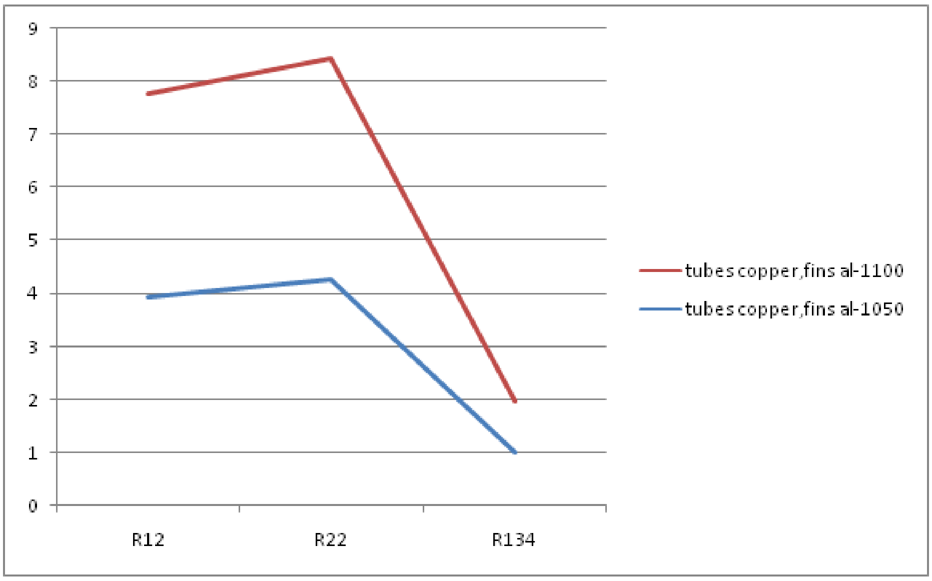

Fig10 : Figure of graphical representation of TUBES COPPER AND FINS ALUMINUM ALLOY with total heat flux

c. Directional Heat Flux W/mm2

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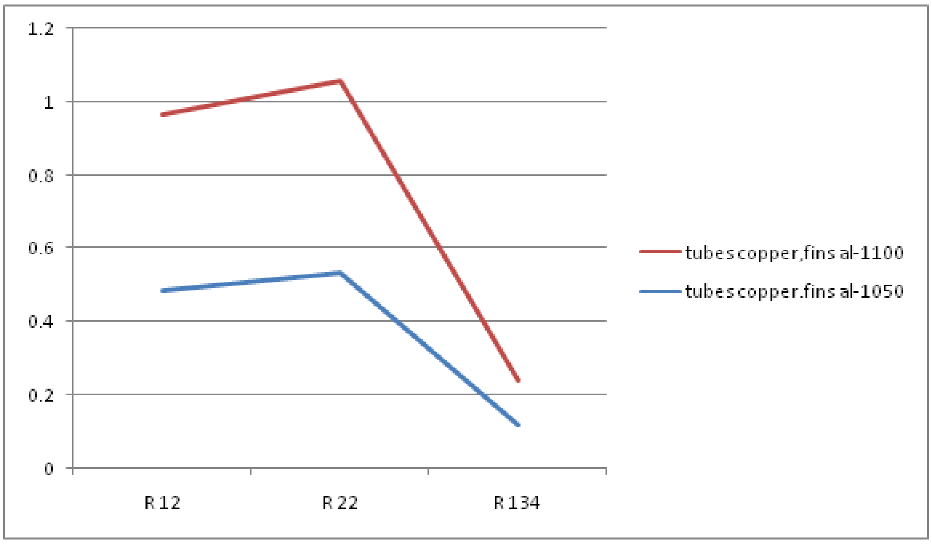

Fig11 : Figure of graphical representation of TUBES COPPER AND FINS ALUMINUM ALLOY with Directical heat flux

RESULTS TABLE

1. TUBES AND FINS ALUMINUM ALLOY 1100

	Temperature °C	Total Heat Flux W/mm²	Directional Heat Flux W/mm²
R-12	90.455	3.5823	0.45062
R-22	90.593	3.8558	0.51633
R-134	89.372	0.96862	0.11589

2. TUBES ALUMINUM ALLOY 1100 AND FINS ALUMINUM ALLOY 1050

	Temperature °C	Total Heat Flux W/mm²	Directional Heat Flux W/mm²
R-12	90.482	3.6677	0.46742
R-22	90.622	3.9495	0.53465
R-134	89.375	0.97875	0.11684

IV.CONCLUSION:

From the analysis results, the heat transfer rate is more when refrigerant R22 is used since heat flux is more. When compared the results for tube material between Copper and Aluminum, using Copper is better. But the disadvantage of using Copper is its weight, so aluminum alloy 1100 can be an alternative.

When compared the results for fin material between Aluminum alloy 1100 and 1050, using Aluminum alloy 1050 is better. Heat transfer analysis is done on the condenser to evaluate the material and refrigerant. The materials considered for tubes are Copper and Aluminum alloy 1100 and for fins are 1050 and 1100.

The refrigerants varied are R12, R 22 and R 134. 3D modeling is done in Pro/Engineer and analysis is done in Ansys. From the analysis results, the heat transfer rate is more when refrigerant R22 is used since heat flux is more. When compared the results for tube material between Copper and Aluminum, using Copper is better.

But the disadvantage of using Copper is its weight, so aluminum alloy 1100 can be an alternative. When compared the results for fin material between Aluminum alloy 1100 and 1050, using Aluminum alloy 1050 is better.

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