Modeling and Analysis of AC Condenser by Optimizing Material to Improving the Heat Transfer Rate

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Abstract - An air conditioning (AC) condenser is a crucial component in the refrigeration cycle, responsible for releasing heat absorbed from indoor air. It functions by converting high pressure, high-temperature refrigerant gas into a liquid state through heat dissipation. The performance of an air conditioning (AC) system is significantly influenced by the efficiency of its condenser. In one ton ac condensers have large diameter reduces refrigerant velocity and pressure drop increases compressor workload. In this project, an air-cooled condenser for a one-ton home air conditioner is designed, in which the coil material currently used is copper.

To reduce the cost of the condenser, the design is optimized by changing the tube diameter while keeping the same length, without compromising load conditions. 3D models are created using SolidWorks, a parametric modeling software. Thermal analysis is conducted in ANSYS to validate temperature distribution, heat flux, and other thermal properties. The condenser coil and fins are analyzed using different materials like aluminum alloy, copper alloy, and structural steel. These materials are tested alternately to determine their effectiveness compared to the currently used material and analysis is done in ANSYS software which is used for thermal simulation.

Key Words: Air Conditioning (AC) Condenser, Heat Dissipation, High Pressure Refrigerant, Compressor Workload, Refrigerant Velocity, Pressure Drop, 1 Ton AC System, Copper Coils, 3D Modelling, SolidWorks.

INTRODUCTION

An air conditioner (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. In systems involving heat transfer, a condenser is a device or unit used to condense a substance from its gaseous to its liquid state, by cooling it. In the latent heat is given up by the substance, and will transfer to the condenser coolant in systems involving heat transfer, a condenser is a device or unit used to condense a substance from its gaseous to its liquid state, by cooling it. In so doing, the latent heat is given up by the substance, and will transfer to the condenser coolant.

2. Problem Identification, Applications, Refrigerants and Types

Problem Identification:

The performance of an air conditioning (AC) system is significantly influenced by the efficiency of its condenser. In one ton ac condensers have large diameter reduces refrigerant velocity and pressure drop increases compressor workload.

Purpose:

To reduce the cost of the condenser, the design is optimized by changing the tube diameter while keeping the same length, without compromising load conditions. 3D models are created using SolidWorks, a parametric modeling software. The condenser coil and fins are analyzed using different materials like aluminum alloy, copper alloy, and structural steel. These materials are tested alternately to determine their effectiveness compared to the currently used material and analysis is done in ANSYS software which is used for thermal simulation.

Applications:

Air cooled – If the condenser is located on the outside of the unit, the air- cooled condenser can provide the easiest arrangement. These types of condensers eject heat to the outdoors and are simple to install. Most common uses for this condenser are domestic refrigerators, upright freezers and in residential packaged air conditioning units. A great feature of the air-cooled condenser is they are very easy to clean. Since dirt can cause serious issues with the condenser's performance, it is highly recommended that these be kept clear of dirt

Water cooled – Although a little pricier to install, these condensers are the more efficient type. Commonly used for swimming pools and condensers piped for city water flow, these condensers require regular service and maintenance They also require a cooling tower to conserve water. To prevent corrosion and the forming of algae, water cooled condensers require a constant supply of makeup water along with water treatment. 8 Depending on the application you can choose from tube in tube, shell and coil or shell and tube condensers. All are essentially made to produce the same outcome, but each in a different way.

Evaporative – While these remain the least popular choice, evaporative condensers can be used inside or outside of a building and under typical conditions, operate at a low condensing temperature. Typically, these are used in large commercial air conditioning units. Although effective, they are not necessarily the most efficient.

Refrigerants:

A refrigerant is a fluid used in HVAC systems to absorb heat from one area and release it in another. It undergoes phase changes (liquid ↔ gas) to transfer heat efficiently. 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 a 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.

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 (R134a, 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. R744 is an effective refrigerant with a global warming potential of 1.

Types of refrigerants:

- CFCs (Chlorofluorocarbons) – e.g., R-12
- HCFCs (Hydrochlorofluorocarbons) – e.g., R-22
- HFCs (Hydrofluorocarbons) – e.g., R-134a, R-410A
- HFOs (Hydrofluoroolefins) – e.g., R-1234yf
- Natural Refrigerants

Applications of Specific Refrigerants:

- R-410A: Used in modern split/window ACs (high pressure, high efficiency)
- R-32: An improved version of R-410A with lower GWP
- R-290: Used in green ACs and refrigerators (eco-friendly, very efficient)
- R-134a: Car ACs, chillers, refrigerators
- R-717 (Ammonia): Industrial refrigeration systems

3. EXPERIMENTAL PROCEDURE

Steps of Modelling of Ac Condenser:

➢ **Copper Pipe**

- Select Front Plane – Sketch the Circle of Ø10mm.
- Select Extrude tool – Specify the Distance
- The rod is displayed in an isometric view with a light red color, indicating Copper material

➢ **Shell 1**

- Select Shell tool – Select the faces to be shell
- Specify the thickness as 0.5mm – Ok
- Select Front Plane – Sketch the straight cylinder with a reddish-brown color.

➢ **Sweep:**

- Select Front Plane – Sketch the entities for Profile for Sweep.
- Select Front Plane – Sketch the entities for Path for Sweep.
- The semi-circle is centered on the vertical axis and connected to the rectangular base, forming a D-shape.
- Select Sweep tool – Specify sketch2 as Profile and sketch1 as Path - Ok

➢ **Shell 2 :**

- Select Shell tool – Select the faces to be shell
- Specify the thickness as 0.5mm – Ok.
- Select ends of a pipes are open and designed to connected with other pipes.

➢ **Supporting Pipe:**

- Select Front Plane - Sketch the Circle of Ø6mm
- Select Extrude tool – Specify the Distance as 282.5mm.
- Select front plane -- extruded to a length of 282.5mm.

➢ **Copper Pipe1:**

- Draw the path for the pipe as including the curved sections and straight lines.
- Exit the sketch.
- Create a new sketch.
- Draw a circle with a diameter of 10mm
- Select Sweep tool – Specify the Sketch2 as Profile

- Select Sweep tool – Specify the Sketch2 as Profile
- Generate the pipe follows the complex 3D path

➢ **Copper Pipe2:**

- Select sweep tool – Complete the pipe geometry

➢ **Cooling Plate:**

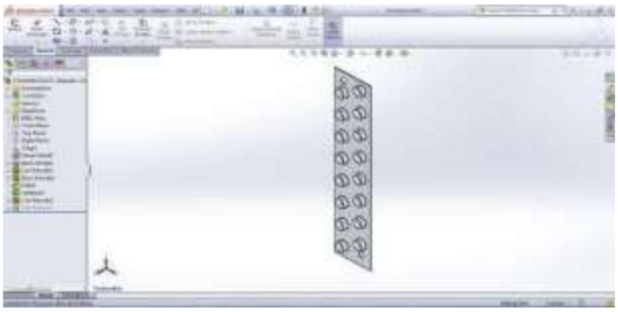

Fig 1: Cooling Plate

➢ **End plate 1:**

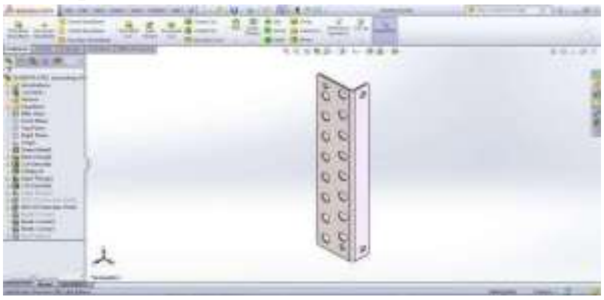

Fig 2: End Plate1

- Create base plate geometry for one end of the condenser include hole placements as per assembly design.

➢ **End Plate 2:**

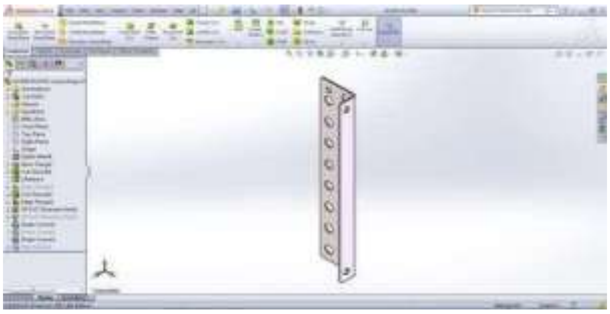

Fig 3: End Plate2

- Create matching or mirrored end plate as plate 2

➢ **Assembly:**

- Insert components – add all parts such as pipe, plate.

➢ **Assembled model :**

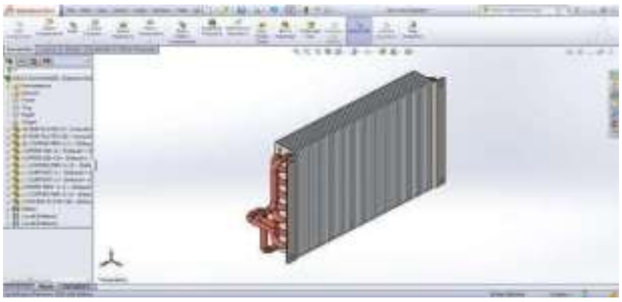

Fig 4: Final Condenser

The first step is to start a new project in the workbench window.

Start Ansys workbench.

1. Open ANSYS Workbench15.0, It opens a project Schematic window with tool box, graphical User Interface with some other important tools. Use import tool to import the geometry with STP file format.
2. After importing the model into project schematic window drag and drop the Transient thermal analysis tab on to the screen from the toolbox window and link the geometry to geometry both will be linked together. Double click on the model it opens the mechanical window with object.
3. From the outline tab – select the geometry – Part – from the bottom detailed window- material –Assignment – Select required material.
4. To generate the meshing, there are two methods one is automatic mesh generation and the other is with required size meshing. In this we used auto meshing with medium meshing.
5. Set the initial temperature as 30 ^{0} C, Set the final temperature as 100 ^{0}C. Analysis Settings: step end time 600 Sec.
6. Right click on Analysis settings – Insert – Temperature – enter 100^{0}c and select the portion. Right click on Analysis settings – Insert – heat flow – Enter the film coefficient as 100 W/mm^{2} bulk (final Temp) as 30 ^{0}C.

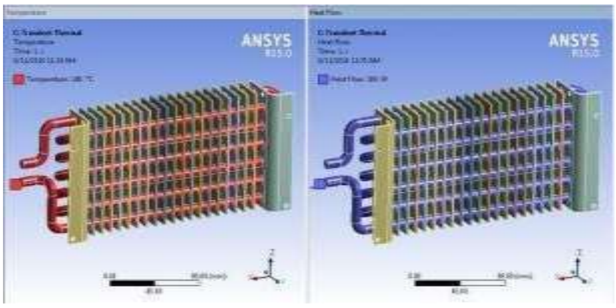

Fig 5: Heat flow in coils

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7. Right click on Analysis settings – Insert – Temperature – enter 26 ^{0}c and select the portion. Right click on Analysis settings – Insert – heat flow – Enter the film coefficient as 100 W/mm^2 bulk (final Temp) as 30 ^{0}C.

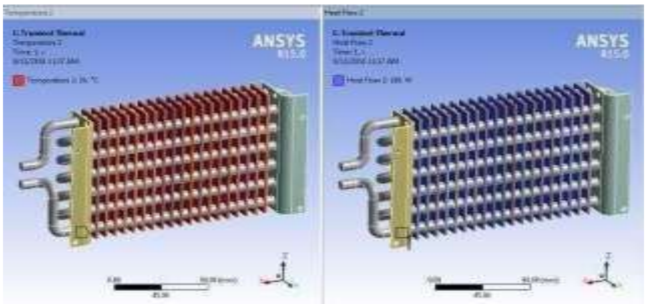

Fig 6: Heat flow in fins

8. Right Click on solution – Insert heat flux - Right Click on solution – Solve. The results window looks as below.

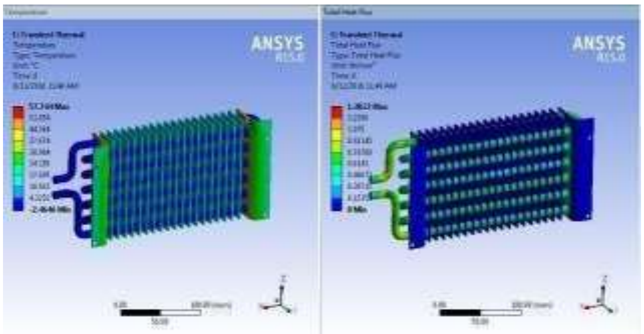

Fig 7: Global maximum and minimum temperature graph.

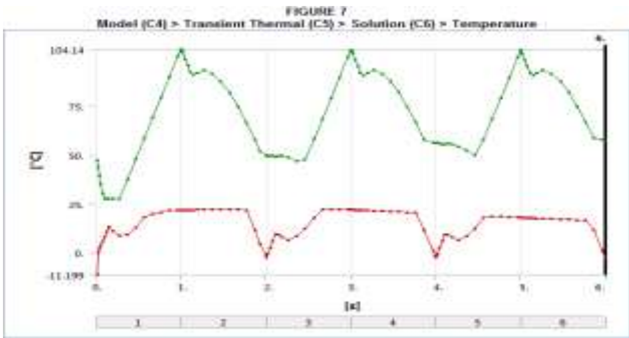

Table 1: Results for the structural steel material

Results	Minimum	Maximum	Units	Time (S)
Temperature	-1.8535	53.77	C	6
Total heat flux	0	4.477	w/mm	6

Table 2: Aluminum Alloy Material

Results	Minimum	Maximum	Units	Time(S)
Temperature	-2.4646	57.44	C	6.
Total	0	1.3822	w/mm	6

9. **Solution:** Right Click on solution – Insert Temperature and heat flow - Right Click on solution – Solve. The results window looks as below.

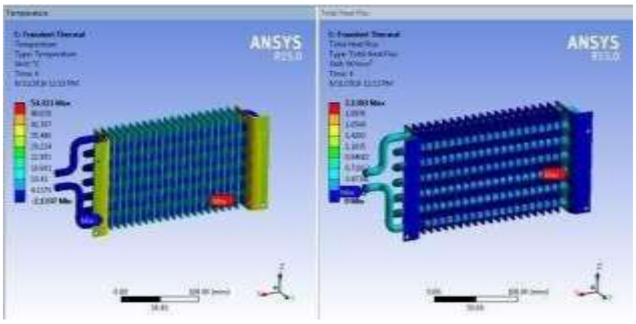

Fig 8: Global maximum and minimum temperature graph

Table 5.5 Results for the structural steel material

Results	Minimum	Maximum	Units	Time(s)
Temperature	-2.4646	57.44	C	6
Total heat flux	0.	1.3822	w/mm	6

10. For the specific material in individual body
Solution: Right Click on solution – Insert Temperature and heat flow - Right Click on solution – Solve. The results window looks as below.

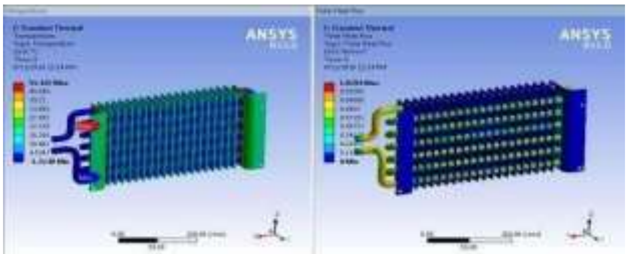

Fig 9: Insert temperature and heat flux

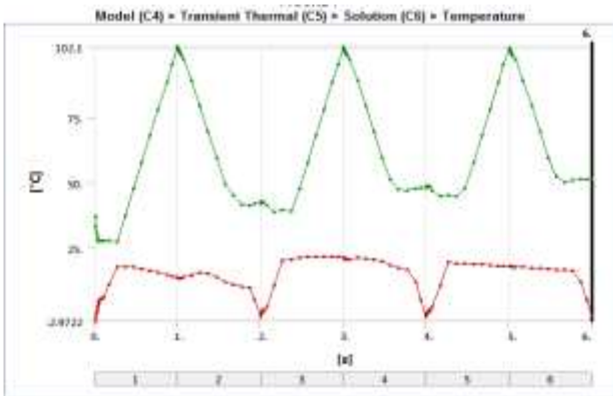

Fig 10: Global maximum and minimum temperature graph

Table 5.6 Results for the structural steel material

RESULTS	MINIMUM	MAXIMUM	UNITS	TIME
Temperature	-1.3248	51.447	° C	6
Total Heat Flux	0.	1.0294	W/mm²	6

4. RESULTS:

Based on the results obtained from the transient thermal analysis conducted using ANSYS 15.0 for the AC condenser, different materials were analyzed to study their thermal performance under an applied heat flow of 100 W/mm² and a temperature of 100°C. For "Structural Steel", with the coil and fins set at temperatures of 100°C and 26°C respectively, the total temperature recorded was 57.744°C, and the total heat flux was 1.3822 W/mm²°C. When "Copper Alloy" was used, with the same thermal conditions for coils and fins (100°C and 26°C), the total temperature was slightly lower at 53.777°C, while the total heat flux was significantly higher at 4.477 W/mm²°C. For "Aluminum Alloy", again under the same conditions, the total temperature was measured as 54.311°C, and the total heat flux recorded was 2.1303 W/mm²°C.These results suggest that copper alloy shows the highest heat transfer rate among the individual materials, while the composite configuration results in the lowest total temperature, indicating better overall thermal management.

5. CONCLUSION

The transient thermal analysis of the AC condenser using ANSYS 15.0 demonstrates that material selection has a significant impact on thermal performance. Among the individual materials tested, copper alloy exhibited the highest heat flux (4.477 W/mm²°C), indicating superior heat transfer capability. Aluminum alloy also showed better thermal performance than structural steel, but not as effective as copper. Notably, the composite configuration—utilizing structural steel for the clamp, copper for the coils, and aluminum for the fins—achieved the lowest overall temperature (51.447°C), reflecting improved thermal distribution and efficiency. These findings highlight that while copper offers excellent heat conduction, combining materials strategically can enhance overall condenser performance by optimizing both heat transfer and structural functionality.

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