



Design and Thermal Analysis of Condenser in Air Conditioning System Using FEA

K. Gowthami, N. N. M. D. Lakshmi Narayana, S. Bhargav Kumar, D. Ajay Ratan, D. Luther Praful

Department of Mechanical Engineering, Godavari Institute of Engineering and Technology(A), JNTUK, Kakinada.

To Cite this Article

K. Gowthami, N. N. M. D. Lakshmi Narayana, S. Bhargav Kumar, D. Ajay Ratan and D. Luther Praful. Design and Thermal Analysis of Condenser in Air Conditioning System Using FEA. International Journal for Modern Trends in Science and Technology 2022, 8(S06), pp. 59-68. <https://doi.org/10.46501/IJMTST08S0710>

Article Info

Received: 26 April 2022; Accepted: 24 May 2022; Published: 30 May 2022.

ABSTRACT

Condensers are used in air conditioning systems to extract undesired heat from the refrigerant and send it to the outdoors. The condenser coil is the principal component of a condenser, through which the refrigerant flows, and fins are the extended surface of the hose pipe that aids in heat transmission to the atmosphere. Heat rejection from the condenser is dependent on a number of factors, including the surface area of the fins and tube, the material used in its manufacture, the length of the hose pipe, the refrigerant used in it, and so on. It is therefore critical to choose the right material for the condenser and modify the fins to improve the air conditioner's performance. The project's goal is to optimise design parameters.

KEYWORDS: Condenser, SOLIDWORKS, ANSYS, c17500, Al2014, MgAZ31B

1. INTRODUCTION

An air conditioner is a household equipment that dehumidifies and removes heat from a space. In a closed cycle known as the refrigeration cycle or heat pump cycle, all air conditioners use the same compression, condensation, expansion, and evaporation cycle. The heat is moved from a hotter to a cooler location using the same refrigerant. The first phase in the refrigeration cycle is compression, and a compressor is the piece of equipment that raises the working gas's pressure. Low-pressure, low-temperature refrigerant enters the compressor as a low-pressure, low-temperature gas and exits into condenser as a high-pressure, high-temperature gas. Among the two, one of the two types of heat exchangers used in a basic refrigeration loop is the condenser, or condenser coil. The condenser removes heat from the hot refrigerant gas vapour until it condenses into a saturated liquid condition, which is

referred to as condensation. The refrigerant condenses into a high-pressure, low-temperature liquid, which is then transported to the expansion device in the loop. The expansion device in a system does the same thing: it drops the pressure when the refrigerant leaves the condenser. Because of the pressure reduction, some of the refrigerant will boil quickly, resulting in a two-phase mixture. This rapid phase change is known as flashing, and it helps the evaporator, the next phase of process in the cycle, fulfil its role. The evaporator, like the condenser, is the second heat exchanger in a conventional refrigeration circuit and is named after its primary purpose. Given that it performs what we anticipate air conditioning to do - absorb heat - it acts as the end of a refrigeration cycle. When refrigerant enters the evaporator as a low-temperature liquid at low pressure and a fan drives air through the evaporator's fins, the air is cooled by the refrigerant absorbing heat from the place.

The refrigerant is then returned to the compressor, where the process continues.

In this paper, we optimise the design parameters by changing the thickness of the fin and creating slots to the fins with modified thickness to reduce the weight of the condenser. So, let's go through the condenser in more detail.

The condenser in air conditioning systems takes undesired heat from the refrigerant and sends it to the outside. A condenser is a device or unit used to cool a substance from its gaseous state to its liquid state in heat transfer systems. As a result, the latent heat is released. The substance will release latent heat and it will be transferred to the condenser coolant. Condensers can be constructed in a variety of ways, designs, and are available in variety of sizes ranging from small to large. For example, a condenser is used to cool a refrigerator, remove heat from the interior of the unit and transfers to the outside air. Condenser is employed as follows. Distillation and steam generation are examples of industrial processes. Other heat-exchange systems include power plants. The coolant is either cooling water or ambient air. The condenser coil, through which the refrigerant flows, is usually the most important part of the condenser. The refrigerant temperature must be higher than the air temperature because the AC condenser coil contains refrigerant that absorbs heat from the surrounding air. Heat transfer in condenser occurs by means of Convection.

1.1 Basic Types of Condenser

- Water – cooled Condenser
- Air – cooled Condenser
- Evaporative Condenser

Water – cooled Condensers are further divided into three types. They are: 1) Double – Pipe,

- 2) Shell and tube and
- 3) Shell and coil.

2. RELATED WORK

The proposed system is based on the idea of developing an optimization technique that can be used to determine the best configuration of a finned-tube condenser.

Convective heat transfer occurs in air-cooled condensers. Solidworks is used for modelling. The condenser is thermally analysed to evaluate the material and refrigerant. Copper is being considered for tubes, and c17500, Al2014, and MgAZ31B are being considered for fins. R12 is the variable refrigerant. Ansys is used for thermal analysis. Small units such as household refrigerators, deep freezers, water coolers, window air conditioners, split air conditioners, small packaged air conditioners, and so on use air cooled condensers. These are used in plants with a small cooling load and a small amount of refrigerant in the refrigeration system. Because they are typically made of copper or aluminium coil, air cooled condensers are also known as coil condensers. Air cooled condensers take up more space than water cooled condensers. The current study examined the performance of an air-cooled condensing unit by varying the fin material and thickness. It is critical to consider a metal with high thermal conductivity and low density for refrigeration applications when designing condenser fins. Aluminum is used to make the fins.

To study the effect of fin's thermal conductivity on condenser performance, three fin materials were considered: Aluminium alloy Al2014, Copper alloy c17500, and Magnesium alloy MgAZ31B. The system is modelled in Solidworks. For Thermal analysis, ANSYS Software is used. When various factors for a condenser are considered, such as heat transfer and temperature, Magnesium alloy MgAZ31B is found to be the best fin material. A condenser or evaporator is a heat exchanger that allows condensation by releasing or absorbing heat. The refrigerant and air will be physically separated at the air conditioner condenser and evaporator. As a result, heat transfer occurs via conduction. The heat exchanger that allows these processes to take place, High conductivity ensures that the temperature difference between the outside and inside walls is kept to a minimum.

The length and size of air conditioner condensers and evaporators must be sized in such a way that the refrigerant is completely condensed before the condenser's exit and completely boiled before the evaporator's exit. These two factors are primarily determined by the size of the compressor and refrigerant

used. To design an effective, yet compact air conditioner condenser and evaporator per unit heat transferred, air conditioner manufacturers must understand how conduction and convection work. To account for any performance drop during the service life, the condenser and evaporator are typically designed to 110 percent of the intended heat transfer requirement.

LITERATURE REVIEW

- 1) Design and Analysis of Condenser using 3D Modelling Software.

Author: A. Harsha Vardhan Reddy, G. Rajasekhar Reddy, G. Phanindra, K. Vijay Kumar.

Year of Publishing: 2018.

Observation: In this paper, we observed that both Copper and aluminium alloys are being considered as materials for tubes. R 12 refrigerants will be used. Temperature distribution and heat transfer rates are determined using CFD analysis. The heat transfer is higher in CFD analysis at condenser length 405mm. The heat flux is greater for copper material at condenser length 405mm in thermal analysis. As a result, we conclude that the best material for condenser tubes is Copper.

- 2) Design and Heat Transfer Analysis of AC Condenser by Optimising Material.

Author: Kishor Kumar Hirwani, Jwaharlal Dandu.

Year of Publishing: 2019.

Observation: In this paper, we observed that CFD analysis was performed on both Evaporator and condenser models with different fluids (R30 & R160) to determine the heat transfer coefficient, heat transfer rate, mass flow rate, and pressure drop. By increasing the mass flow inlets and observing the CFD analysis of the evaporator, the heat transfer rate and heat transfer coefficient values are increased. And R160 fluid refrigerant has the highest heat transfer coefficient value. As a result, it can be concluded that the refrigerant R160 fluid performs better.

- 3) Design and Analysis of AC Condenser for Improving Efficiency.

Author: N. Venkatesh, B B V Kishore.

Year of Publishing: 2017.

Observation: In this thesis, we studied about the performance of several louver fin arrangements at

various wind speeds and observed the comparison of them to each other and the basic flat fin model.

- 4) Design, Optimization and Performance Analysis of Condenser for HVAC Automobile System for R-290.

Author: Parikshit A. Ladke, C.S. Choudhari.

Year of Publishing: 2016.

Observation: The optimization results show that by keeping the frontal area of the condenser constant and varying geometrical parameters, the COP of the system decreases as the outer diameter increases. It is also concluded from varying the number of rows and fins per inch that 12 fins per inch gives better performance and 2 rows gives better performance. According to experimental analysis, air flow velocity also plays a role in improving system performance. We observed that increasing air velocity increases the Coefficient of Performance and Refrigerating Energy of the system.

- 5) Design and Analysis of Air Cooled Condenser by using Copper and Aluminium tubes.

Author: V. P. Karthik, N. Prithiviraj, R. Sateesh, J. Govindaraj.

Year of Publishing: 2018.

Observation: In this paper, we observed that copper tubes have a higher heat transfer rate than aluminium tubes for the same experimental setup. Copper tubes are preferred for applications requiring a high rate of heat transfer in diesel units (or) thermal power plants, while aluminium tubes are used for applications requiring a low rate of heat transfer.

- 6) Thermal Analysis of AC Condenser Coil.

Author: Chavan Karthik, Dr. M. Naveen Kumar

Year of Publishing: 2018.

Observation: CFD analysis is used in this thesis to determine temperature distribution and heat transfer rates by varying the refrigerants. Heat transfer analysis is performed on the condenser to determine the best material. According to the analysis results, the heat transfer rate is greater when the refrigerant R22 is used. When the results for fin material between Aluminum alloy 1100 and 1050 are compared, Aluminum alloy 1050 performs better.

- 7) Performance Analysis and Design of Plate-Fin and Tube Condenser for Air Conditioner.

Author: K. V. J. P. Narayana, M. Sai Santosh Kumar

Year of Publishing: 2016.

Observation: In this paper, we observed that using Aluminum alloy 1100 as a fin is advantageous for condensers. When comparing refrigerants, Hydrocarbon and Hydrofluorocarbon, using Hydrocarbon is more advantageous because it has a higher thermal flux.

8) CFD and Thermal Analysis on AC Condenser by using Different Fluids and Different Material.

Author: Manish Kumar Goswami, DR M. Babu.

Year of Publishing: 2019.

Observation: According to this paper, while observing CFD analysis R134A has a higher heat transfer coefficient and a higher heat transfer rate than other fluids in CFD analysis. By considering Thermal analysis results, Heat flux is greater when R22 and Copper are used and When the fluid R134A and the material Copper are used, the heat transfer rate increases.

3. PROPOSED WORK

In this paper, we optimise the design parameters by changing the thickness of the fin and creating slots to the fins with modified thickness to reduce the weight of the condenser. So, let's go through the fins in more detail.

3.1 Cooling Plate (Fin)

Condenser fins are thin metal slats that run along the outside of your air conditioner's frame. The condenser fins' purpose is to move warm air away from the air conditioner while it is running. The fins' purpose is to increase the surface area of the condenser, making it easier to transfer the heat of the refrigerant to the surrounding air. Heat moves from the inside to outside of the coil when the warm, gaseous refrigerant flows through the condenser. Condenser fins and evaporator fins are the two types of air conditioner fins. Each does a similar job of allowing air to flow smoothly through and out of an air conditioner, but in their own way. Condenser fins are located on the outdoor portion of an air conditioner near the compressor and resemble a grill with metal fins running the length of it. These air conditioner fins are a component of the condenser that aids heat movement away from the air conditioner, allowing heat to disperse more quickly. Evaporator fins are located on the evaporator and help with the thermal energy exchange process that occurs with the

surrounding air as it extracts heat from the air. Air is blown across the evaporator fins and cooled before being routed from the air conditioner through ducts and vents into various rooms.

The dimensions of the cooling plate are:

| Dimensions of the fin | Values |
|--------------------------|--------|
| Length of fin | 210 mm |
| Breadth of fin | 44 mm |
| Thickness of fin | 0.8 mm |
| Circle diameter | 10 mm |
| No. of circles | 16 |
| Distance between circles | 25 mm |
| Small circle diameter | 6.2 mm |
| No. of small circles | 2 |

Table: 1 Dimensions of the fin

3.2 Tubes

Condenser tubes are specifically designed to condense process fluid from the tube's exterior. This application is common in heat exchangers, ranging from being part of a

chiller's condenser and evaporator refrigeration cycle to condensing steam in surface condensers and everything in between. Copper-nickel alloys, brass, titanium, stainless steel, and ferritic stainless steel are the most common tube materials in a condenser.

3.3 MATERIAL SELECTION

The following materials are selected for the Fins:

- Al2014:** It is an aluminum alloy with alloying elements of copper, silicon and magnesium. It has high conductivity, good machinability, and excellent corrosion resistance.
- c17500:** It is a copper alloy with alloying elements of cobalt and beryllium. It has high conductivity, good resistance, and good machining performance.
- MgAZ31B:** It is a magnesium alloy with alloying elements of aluminium and zinc. It is lightweight, resistant, has a high conductivity, and has a low density.

| Materials selected | c17500 | Al2014 | MgAZ31B |
|--|----------------------|---------------------|---------------------|
| Density[Kg/m ³] | 8750 | 2800 | 1770 |
| Poisson's Ratio | 0.34 | 0.34 | 0.35 |
| Coefficient of Thermal Expansion[1/°C] | 1.76e ⁻⁰⁵ | 2.3e ⁻⁰⁵ | 2.6e ⁻⁰⁵ |
| Thermal | 200 | 192 | 96 |

| | | | |
|----------------------------|-----|-----|------|
| Conductivity [W/m °C] | | | |
| Specific heat [J/kg °C] | 890 | 875 | 1000 |

Table 2: Properties of Selected Materials

Specifications of Selected Condenser:

| Parameters | Values |
|-------------------------|-----------|
| Capacity of Condenser | 1.5 ton |
| No. of Condenser fins | 48 |
| Connecting rod length | 282.50 mm |
| Connecting rod diameter | 6 mm |
| Pipe outer diameter | 10 mm |
| Pipe inner diameter | 9.5 mm |
| Thickness of pipe | 0.5 mm |
| Length of pipe | 291 mm |

Table 3: Specifications of Condenser

3.4 DESIGN OF CONDENSER:

The design of condenser is done in solidworks with two modifications:

Modification-1: Design of Condenser by modifying the thickness of the fins.

Modification-2: Design of above modified Condenser by creating slots to the fins.

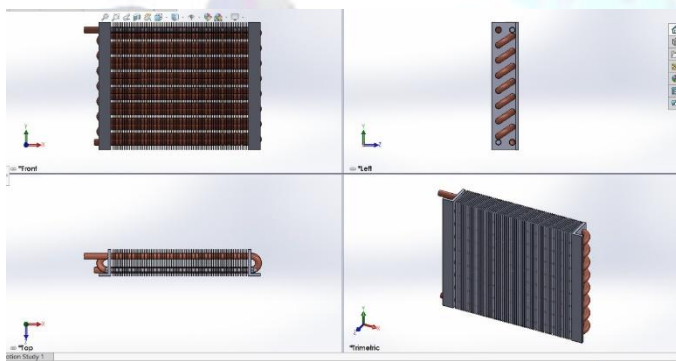


Figure 1 (a) Design of Standard condenser with a fin thickness of 0.8 mm.

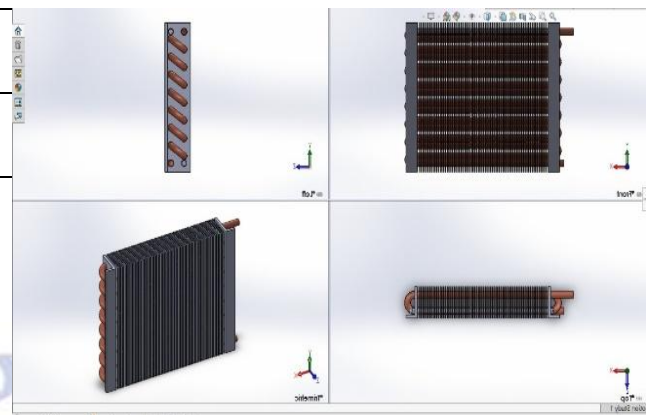


figure 1 (b) Design of Condenser with a modified fin Thickness of 0.5 mm.

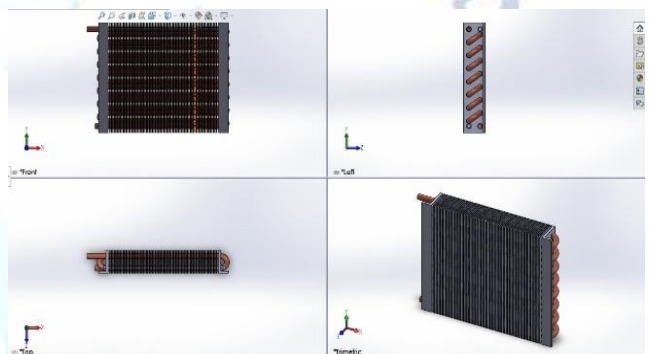


Figure1 (c) Design of condenser by creating slots to modified fin.

3.5 THERMAL ANALYSIS

The Steady State Thermal Analysis is carried out using the ANSYS Software.

The design of condenser is completed in Solidworks using FEA analysis and is transferred to the ANSYS for performing steady state thermal analysis using various materials.

Finite Element Analysis (FEA) is a numerical method for breaking down a complex system into very small pieces (of user-defined size) known as elements. The software creates a comprehensive explanation of how the system works as a whole by implementing equations that govern the behaviour of these elements and solving them all. This type of analysis is commonly used for the design and optimization of systems that are far too complex to

analyse manually. Because of their geometry, scale, or governing equations, systems that fit into this category are overly complex. Many colleges' Mechanical Engineering Departments use ANSYS as the standard FEA teaching tool. ANSYS is also used in the departments of Civil and Electrical Engineering, as well as Physics and Chemistry.

IMPORTED MODEL:

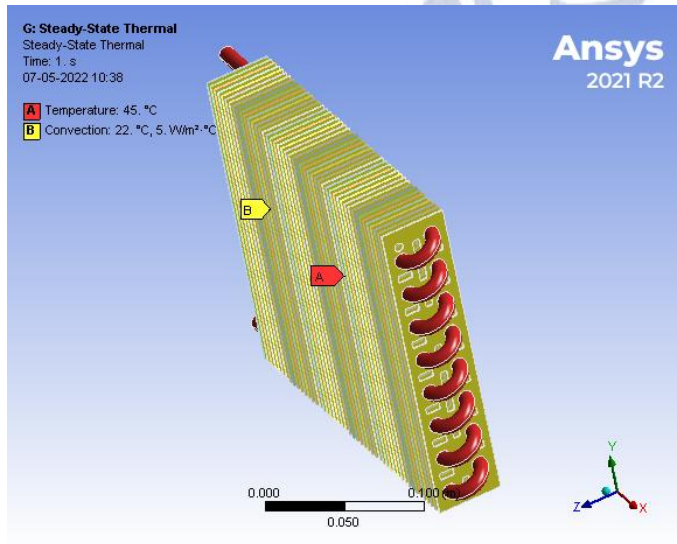


Figure 2 (a) Boundary conditions of imported condenser

MESHED MODEL:

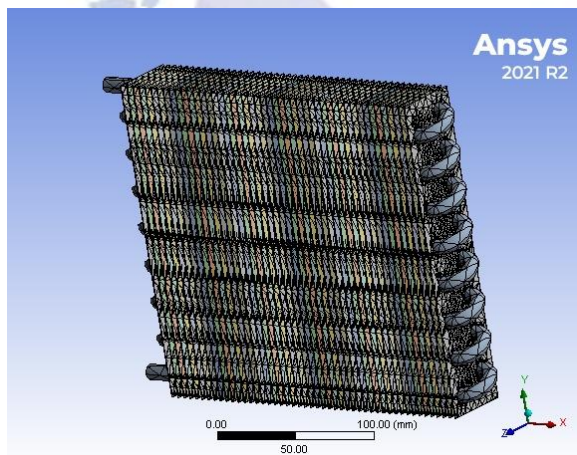


Figure2 (b) Meshed Model

Boundary Conditions of Imported Condenser:

Temperature: 45° C

Ambient Temperature: 22° C

Convection Coefficient: 5 W/m² °C

Thermal Analysis of standard Condenser with copper tube, c17500 fins:

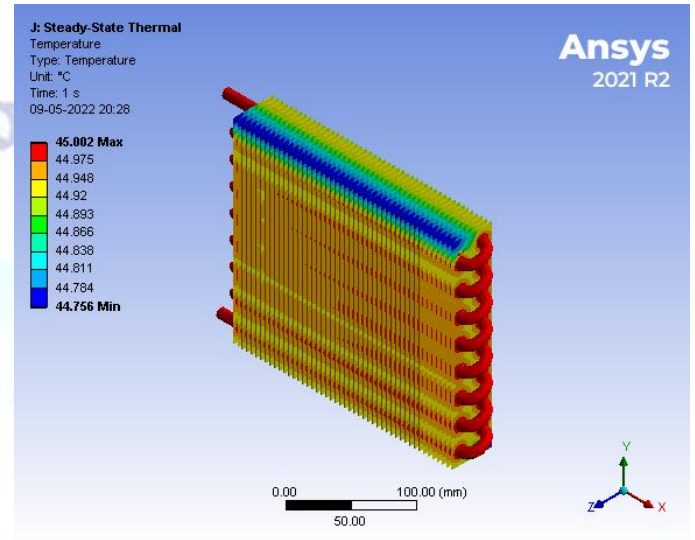


Figure 3 (a) Temperature

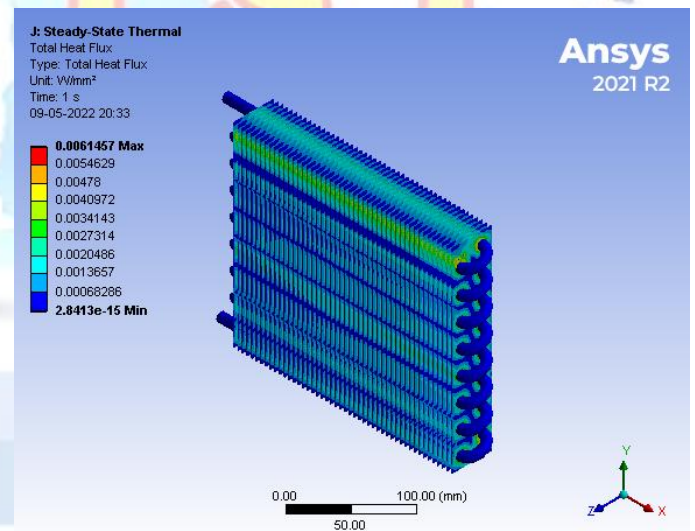


Figure 3 (b) Total Heat Flux
Thermal Analysis of standard Condenser with copper tube, Al2014 fins:

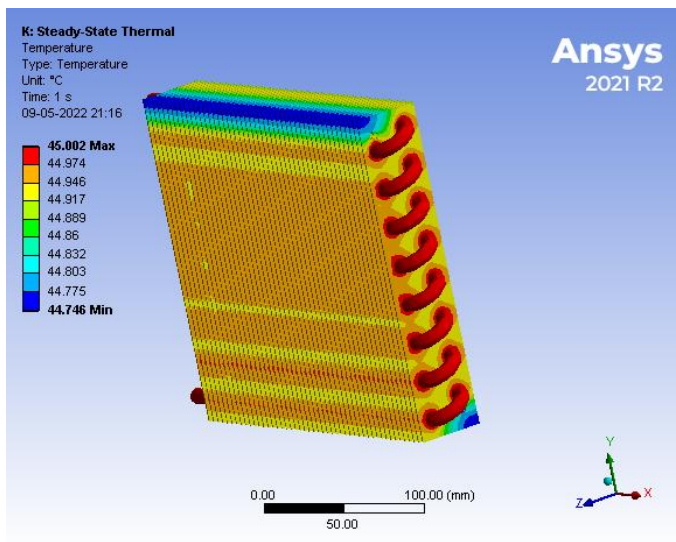


Figure 4(a) Temperature

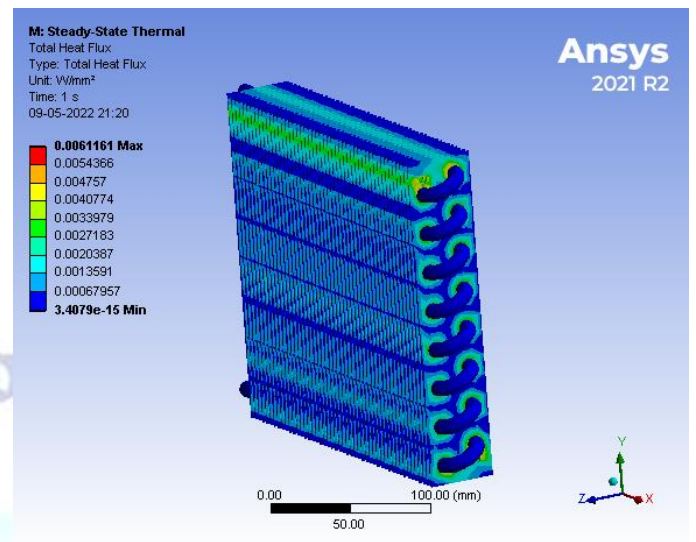


Figure 5 (b) Total Heat Flux

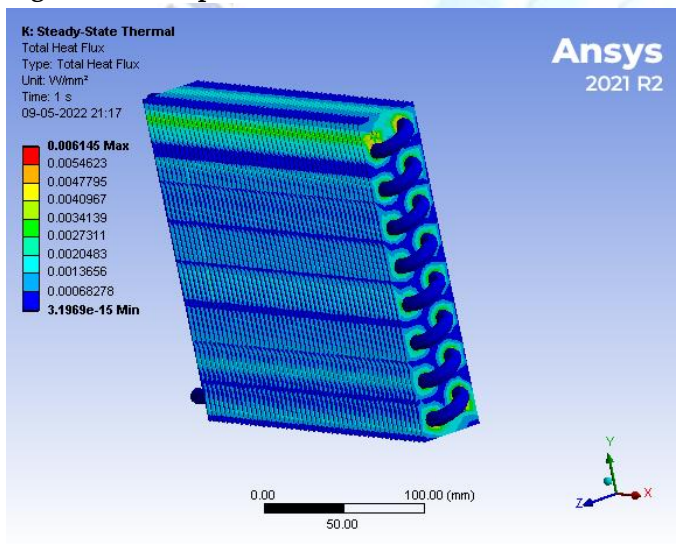


Figure 4 (b) Total Heat Flux

Thermal Analysis of standard Condenser with copper tube, MgAZ31B fins:

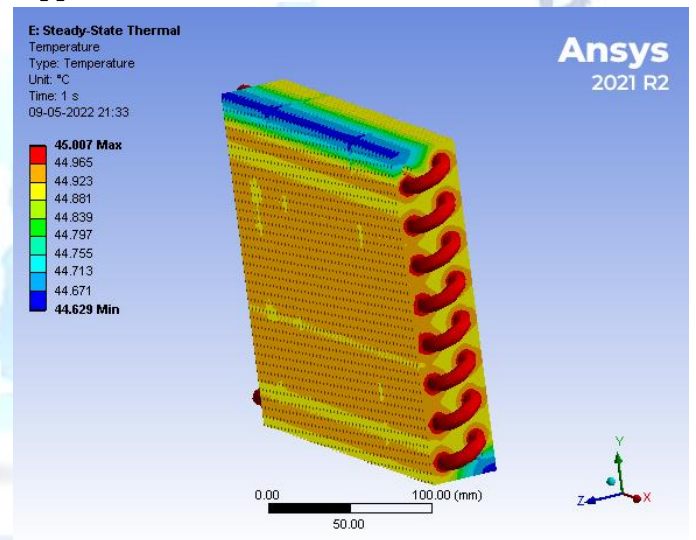


Figure6 (a) Temperature

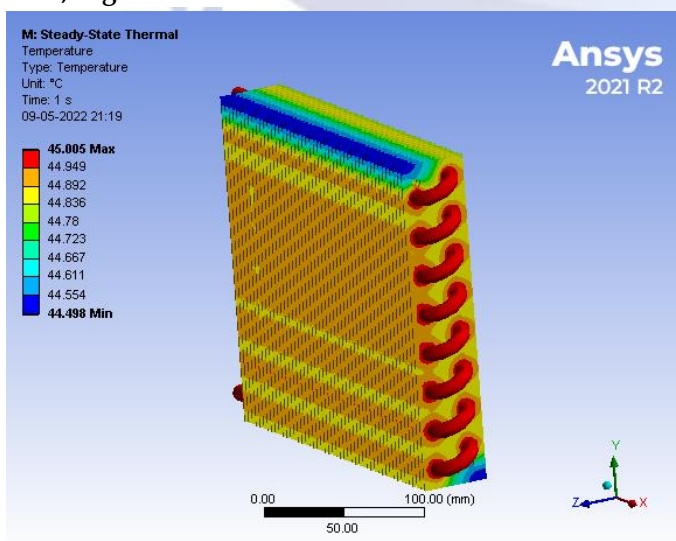


Figure 5 (a) Temperature

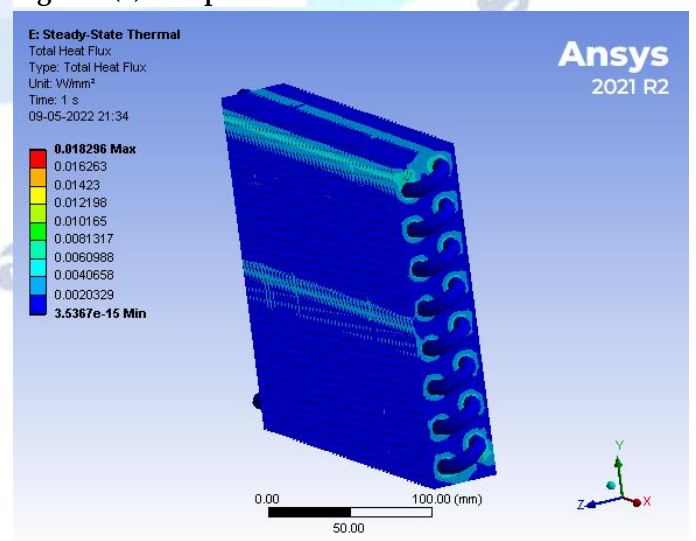


Figure 6 (b) Total Heat Flux

Thermal Analysis of modified (1) Condenser with copper tube, Al2014 fins:

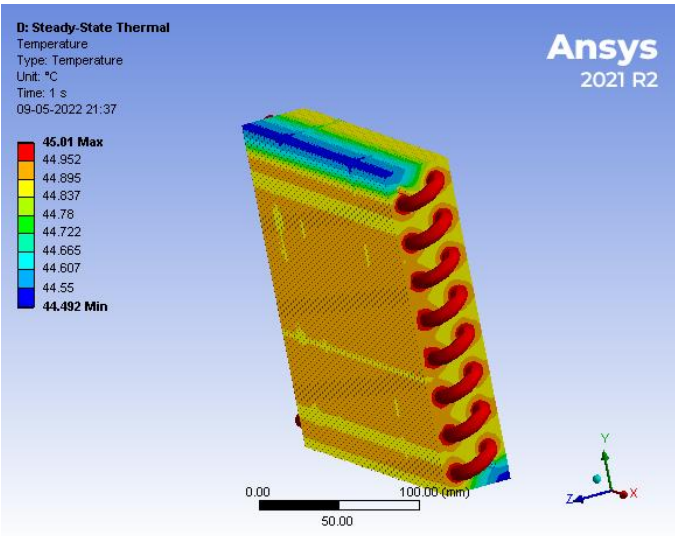


Figure 7 (a) Temperature

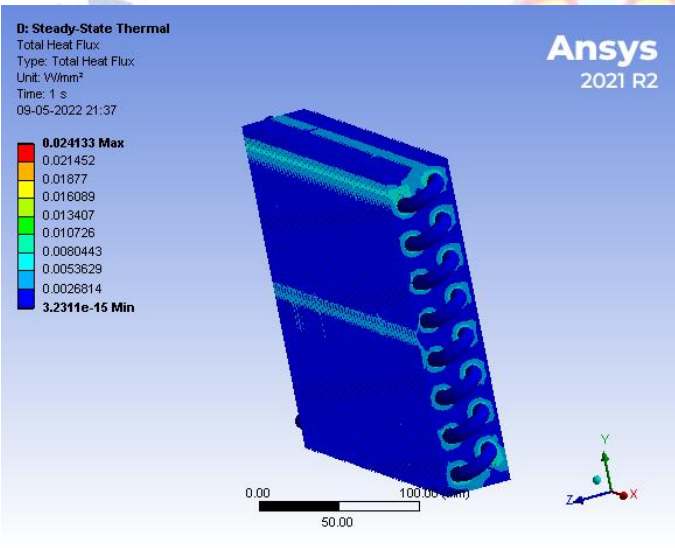


Figure 7 (b) Total Heat Flux

Thermal Analysis of modified (1) Condenser with copper tube, MgAZ31B fins:

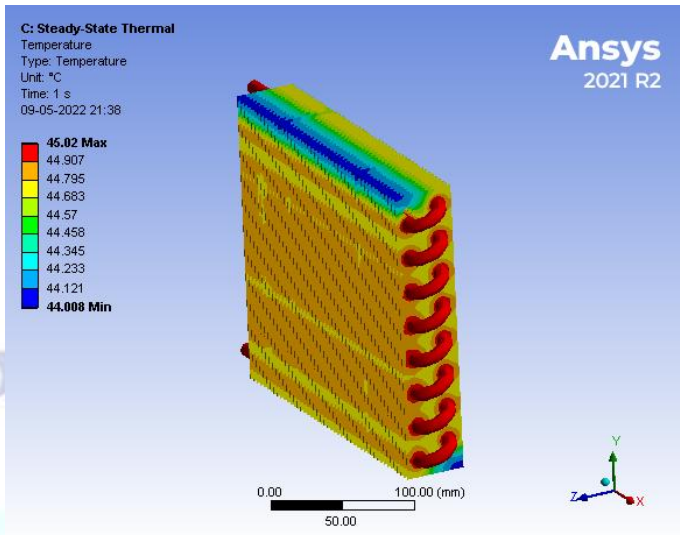


Figure 8 (a) Temperature

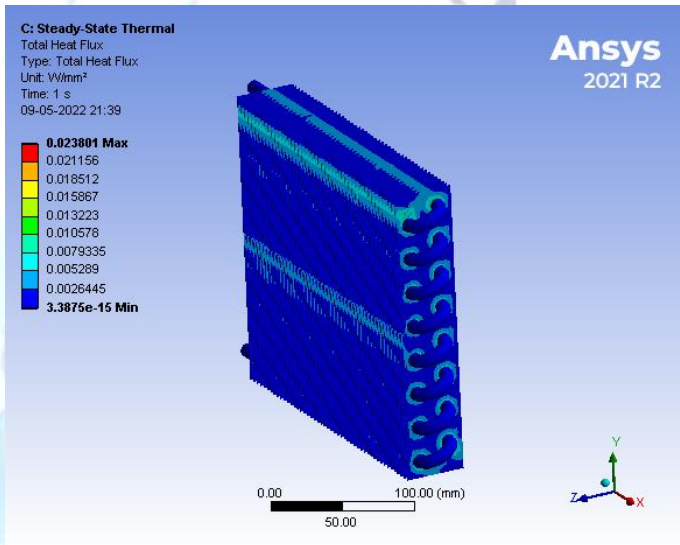


Figure 8 (b) Total Heat Flux

Thermal Analysis of modified (2) Condenser with copper tube, c17500 fins:

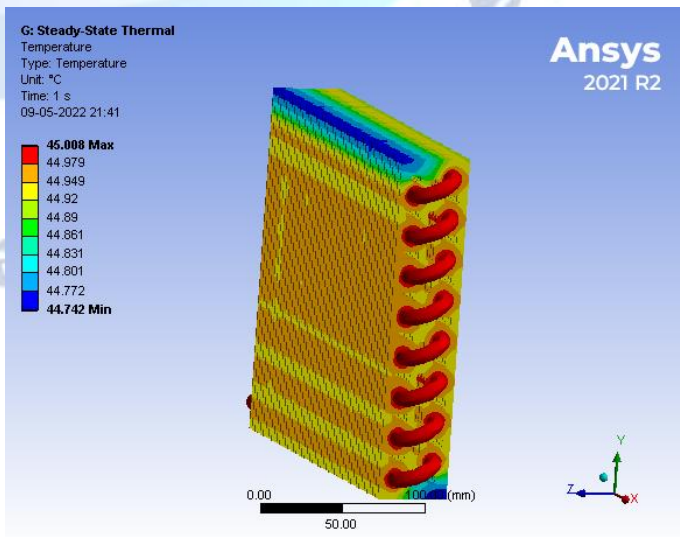


Figure 9 (a) Temperature

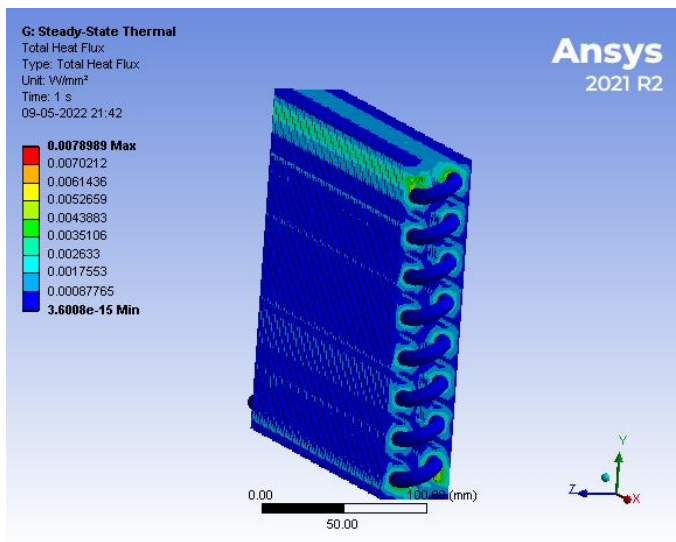


Figure 9 (b) Total Heat Flux

Thermal Analysis of modified (2) Condenser with copper tube, Al2014 fins:

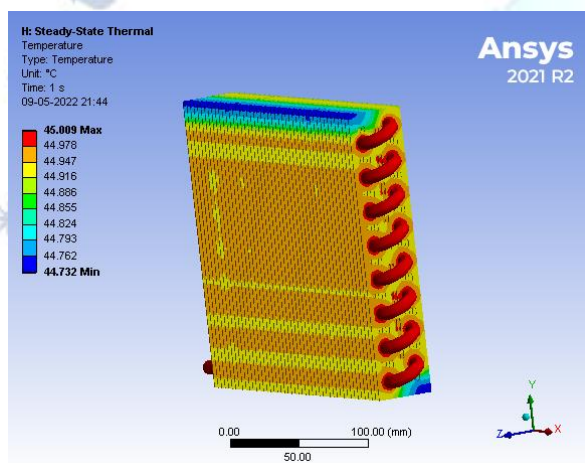


Figure 10 (a) Temperature

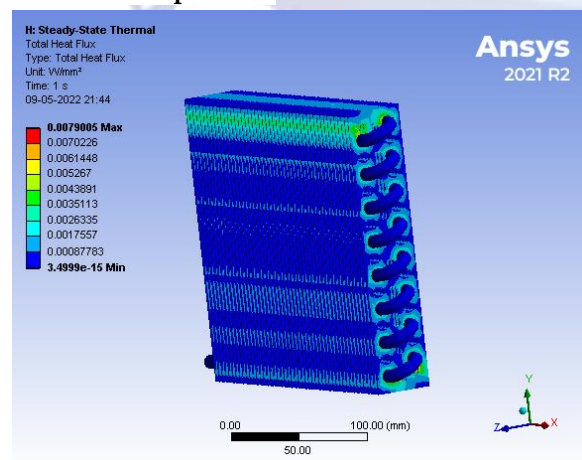


Figure 10 (b) Total Heat Flux

Thermal Analysis of modified (2) Condenser with copper tube, MgAZ31B fins:

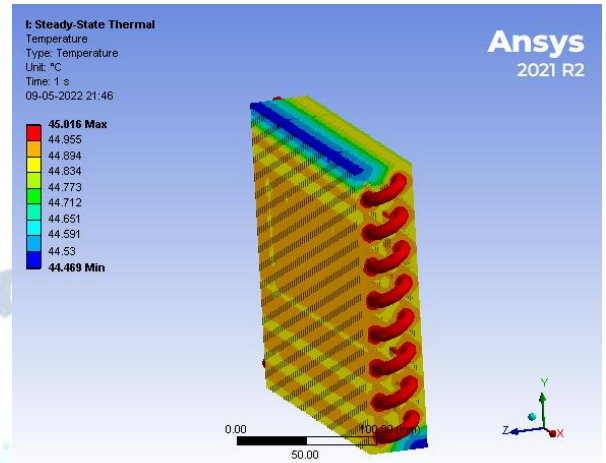


Figure 11 (a) Temperature

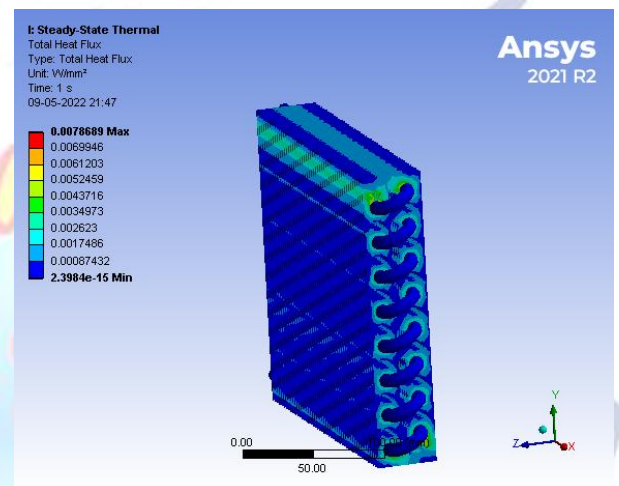


Figure 11 (b) Total Heat Flux

4. RESULT

The condenser tubes are made of copper in this optimization process, and the fin materials are varied in the order of c17500, Al2014 and MgAZ31B for the Standard design and the other modified designs of condensers.

| Fins Material | Temperature (°C) | | Total heat flux (W/m²) | |
|---------------|-------------------|--------|------------------------|-------------------------|
| | Max | Min | Max | Min |
| c17500 | 45.002 | 44.756 | 6.146×10^3 | 2.8413×10^{-9} |
| Al2014 | 45.002 | 44.746 | 6.145×10^3 | 3.1969×10^{-9} |
| MgAZ31B | 45.005 | 44.498 | 6.116×10^3 | 3.4079×10^{-9} |

Table 4: Standard Condenser with c17500 as tube material

| Fins Material | Temperature (°C) | | Total heat flux (W/m ²) | |
|---------------|-------------------|--------|-------------------------------------|-------------------------|
| | Max | Min | Max | Min |
| c17500 | 46.007 | 44.629 | 18.296×10 ³ | 3.5367×10 ⁻⁹ |
| Al2014 | 45.01 | 44.492 | 24.133×10 ³ | 3.2311×10 ⁻⁹ |
| MgAZ31B | 45.02 | 44.008 | 23.801×10 ³ | 3.3875×10 ⁻⁹ |

Table 5: Modified (1) Condenser with c17500 as tube material

| Fins Material | Temperature (°C) | | Total heat flux (W/m ²) | |
|---------------|-------------------|--------|-------------------------------------|-------------------------|
| | Max | Min | Max | Min |
| c17500 | 45.008 | 44.742 | 7.898×10 ³ | 3.6008×10 ⁻⁹ |
| Al2014 | 46.009 | 44.732 | 7.900×10 ³ | 3.4999×10 ⁻⁹ |
| MgAZ31B | 45.016 | 44.469 | 7.868×10 ³ | 2.398×10 ⁻⁹ |

Table 6: Modified (2) Condenser with c17500 as tube material

5. CONCLUSION

In our project, we designed an aircooled condenser for a 1.5ton air conditioner. Solidworks is used for design. We conducted thermal analysis on the condenser by using c17500 tube material and varying the fin materials, copper alloy c17500, aluminium alloy Al2014, and magnesium alloy MgAZ31B. We analyse the thermal properties temperature and heat flux in thermal analysis. Using the fin material Aluminum alloy Al2014 and the modification-1 design (by reducing the thickness of the fin), the heat flux is increased. Modification -2 (creating slots in the condenser's fin) design also gives more heat flux than the standard design but less than the modification-1 design. As a result, using Aluminum alloy Al2014 as a fin and reducing the thickness of the fin benefits the condenser. The modification-2 is not as effective as modification 1.

According to the findings, both the temperature and total heat flux are optimal for the modification-1 design when compared to the modification-2 design and the standard

design, and when compared to copper alloy and magnesium alloy, Aluminium alloy (Al2014) is more efficient.

FUTURE SCOPE

Consider the following points when expanding on your thesis work. The modified condenser in modification 1 can be made with slots, which will increase the heat flux and efficiency of the condenser. Computational Fluid Dynamic (CFD) analysis can also be performed by changing the refrigerants.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

- [1] Harsha Vardhan Reddy, G. Rajasekhar Reddy, G. Phanindra, K. Vijay Kumar. Design and Analysis of Condenser using 3D Modelling Software.2018.
- [2] Kishor Kumar Hirwani, Jwaharlal Dandu. Design and Heat Transfer Analysis of AC Condenser by Optimising Material. 2019.
- [3] N. Venkatesh, B B V Kishore. Design and Analysis of AC Condenser for Improving Efficiency. 2017.
- [4] Parikshit A. Ladke, C.S. Choudhari. Design, Optimization and Performance Analysis of Condenser for HVAC Automobile System for R-290. 2016.
- [5] V. P. Karthik, N. Prithiviraj, R. Sateesh, J. Govindaraj. Design and Analysis of Air Cooled Condenser by using Copper and Alumimium tubes. 2018.
- [6] Chavan Karthik, Dr. M. Naveen Kumar. Thermal Analysis of AC Condenser Coil. May 2018. Siddhartha Institute of technology and sciences. International Journal of research.
- [7] K. V. J. P. Narayana, M. Sai Santosh Kumar. Performance Analysis and Design of Plate-Fin and Tube Condenser for Air Conditioner. 2016.
- [8] Manish Kumar Goswami, DR M. Babu. CFD and Thermal Analysis on AC Condenser by using Different Fluids and Different Material. 2019.