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Implementation of Air Cooled Condensers Using CAD Modeling in ANSYS System

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Abstract –A condenser is a mechanism or unit used in heat transfer systems to condense a substance from its gaseous to a liquid state, often by chilling it. In this way, the heat is transferred to the condenser coolant and is given up by the material. Typically, condensers are heat exchangers with diverse designs and range from small to very huge manufacturing units utilized in plant processes.In this work, the air-cooled Finns tube condensers for an air-conditioning system are studied on the convective heat transfer features of the vapor compression cycle. The condenser is used to find the optimal designs and coolants utilizing R134 or R11 coolants for heat transfer and CFD calculations.The effect of fins made from Aluminium on condenser design is also analyzed for both the refrigerants (R11 and R134). The CAD model is created with Creo software, and the CFD analysis is performed with ANSYS CFX software. For analysis, the standard k-epsilon turbulence model is utilized. The heat rejection rate is calculated theoretically using simulation findings, and a comparison analysis is performed.

Keywords:Condenser Heat Transfer,Air-cooled condensers Refrigeration.

I. INTRODUCTION

The condenser is designed for small size and large size. The small size is compatible and could be held by hand while large sizes are employed in industrial units for plant operations. In domestic refrigerators, the cabin heat is extracted fromthe outside environment by the use of a condenser.Condensers are utilized in air conditioning, industrial chemical operations. Including distilling, steaming power plants &other heat-exchange devices. Usage cooling water or surrounding air as the coolant is typical in several condensers. The principal purpose of a condenser is to collect exhausted steam from a steam engine or turbine &condense the steam. The advantage is that the energy which will be wasted on the environment is used.

Transfer of Heat from the condenser occurs via buoyancy-induced natural convection and radiation in the natural convection type. The total heat transfer coefficient in these condensers is low due to limited airflow and low radiation heat transfer. As a result, to reject a given quantity of heat, a comparatively large condensing surface is required. Household refrigerators and freezers are an example.The air circulation over the surface of the condenser is maintained in the force convectional type condensers by utilizing a blower or a fan.Evaporative cooling is accomplished by forming a thin water film around the condenser tubes. Evaporative cooling has a very high heat transfer coefficient.

In the early 1970s, air-cooled condensers (ACC) were first used in the US power sector, but only the past 10-15 years saw a substantial rise in installations due to increasing attention to environmental protection. Increasing home and industrial water consumption has also led to an increasing interest in the usage of Air Cooled condensers. The air-cooled condenser was launched in the U.S. energy sector at the beginning of the 1970s, but the number of installations only rose considerably in the previous 10-15 years because of the rising concern for environmental safety. In addition, the rising demand for household and industrial water has boosted the usage of Air Cooled condensers. This study evaluates the effectiveness of the air-cooled condenser in better environments of operation. It has been shown that air-cooled condenser efficiency is degraded under high ambient temperatures and windy situations. The rate of ACC heat rejection also relies on the surface texture of the fins and therefore on the exterior fouling of the finned tubes caused by weather &interior condensate fouling (Ammonia corrosion). An ACC is a pressure vessel that refreshes fluid circulation in finned tubes by pushing ambient air to the outside of the tubes.

The most obvious benefits of ACCs are:

- No difficulty caused by thermal &chemical cooling fluid pollution
- Versatility for any facility site & plot planning configuration since cooling equipment does not have to be near a cooling water supply.
- Maintenance cost reduction
- Easy to install
- Small environmental effect as a water-cooled condenser owing to the removal of a supply of supplemental water that saves water

- Without use of chemicals for membrane technology and thus no fire prevention system. [1].

II. LITERATURE REVIEW

Liang-Liang-Shaoa et al. [2]In this paper, a distributed-parameter model was created to accurately size serpentine microchannel condensers. Airborne maldistribution is considered. Validating the model shows that experimental data are in good accord. The heating and pressure decrease forecasts are within a 10 percent error margin. Further research demonstrates the impact on condenser performance of the pass number and airside maldistribution.

GundaMaderet al. [3]presented Themicro channels and tubing evaporators' transient behavior is compared. The creation of refrigeration framework control calculations requires models which are capable of mimicking temporary behavior with reasonable time and effort to be computed. The condensers and evaporators are the most artichoke elements in these frameworks, especially for the structuring and tuning controllers of cooling frameworks the transient conduct of the evaporator is vital. The results are provisionally approved on a test platform.

Salvador,M.W. et al. [4]Presented Compact heat exchangers display condensation. A model is developed for the research of conservative heat exchangers which function as either evaporators or condensers. This study just covers the shown accumulation. The research also examines other links utilized to calculate the coefficient of refrigerant side warming. They are evaluated by comparing the expected knowledge with the test data. R134a and R410A, using air as an alternate liquid, are the work liquids used in tests. The trial department is shown quickly, and lastly some loose ends.

PegaHrnjak, et al.[5]Reports Micro-channel Charging minimization heat exchangers for air-cooled smelling condensers and chillers The results of a model alkaline chiller with an air-cooled condenser and a plate evaporator are discussed in this document.

G.B. Ribeiro et al.[[7]Presented Effectiveness of metal smear microchannel condensers: application in small scale cooling frames. Ready to use. The purpose of this study is to determine the warm-water performance of microchannel condensers with open-cell metal froths to optimize the air-side warmth. Three different pore densities of copper metal sparkling structures (10 and 20 PPI) and porosity (0,893 and 0,947) have been tested. For execution correlation purposes also a typical condensing surface with copper plain blades was tested. The research was conducted at 45 _C consolidating temperature. The rate of streaming from the airside was 1.4 10 3 through 3.3 10 3 m3/s (the speed of the face was 2.1e4.9 m/s).

Zhang Huiyong, et al.[[8] This study provides a condenser for residential refrigerators with a hypothetical model for evaluation of their exposure. The model was used to obtain the optimal plan parameters for a variety of cylinder counts and configurations. The results show that with the number of cylinders and the width of the cylinder, the needed cylinder tallness in the descending region decreases

III. OBJECTIVES OF THIS WORK

Our objective is to analyze the cooling efficiency of refrigerator condensers by increasing the surface area of fins and changing the geometric configuration.

- CAD modeling of refrigerator condenser using Creo 2.0 software
- CFD analysis of base design without fins with R134 using ANSYS CFX
- CFD analysis of design with fins with R134 refrigerant using ANSYS CFX
- CFD analysis of base design without fins with R11 refrigerant using ANSYS CFX
- CFD analysis of design with fins with R11 refrigerant using ANSYS CFX
- Comparative analysis of different designs and refrigerants by parameters of heat rejection and efficiency.

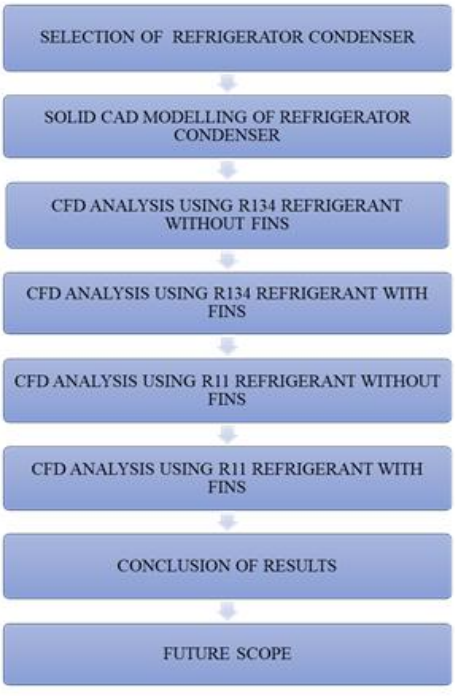


Figure 1: Proposed flow chart

IV. PROPOSED WORK

A. Problem Statement

The cooling efficiency of refrigerator condensers is highly dependent on the surface area of fins. As there is no fan (no forced convection) heat dissipation is low. Therefore, to get maximum cooling efficiency it is necessary to increase surface area.

B. Methodology Flow Chart

The methodology flow chart of research is shown below:

C. CAD Modeling

The condenser CAD model is created using sketch-based, PTC-Developed parameter 3D modeling software with parent-child and bidirectional association characteristics. The Dimensions of the condenser are given below.

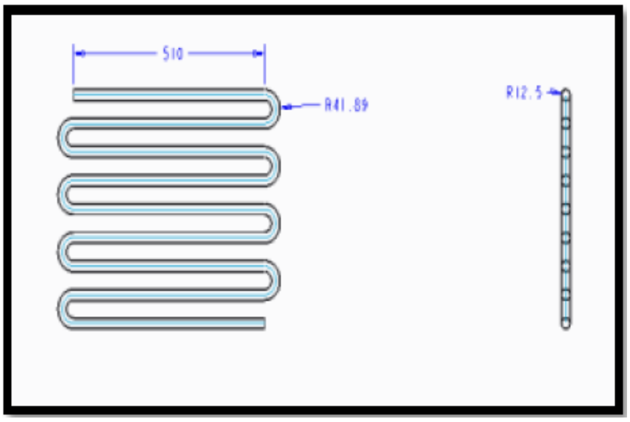


Figure 2: Dimensions of condenser Tubes without fins

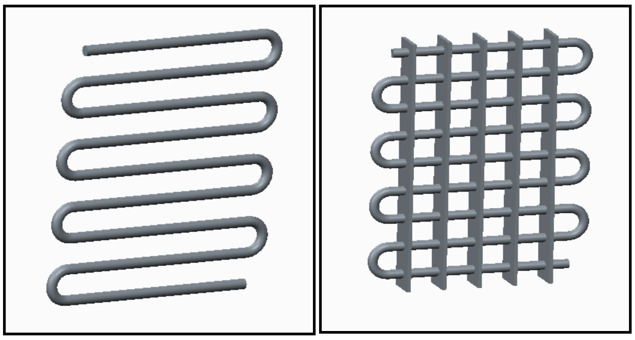


Figure 3: CAD model condenser Tubes with and without fins

The CAD model of condenser fins is shown in figure 3 above. The 1^{sT}Design shows condenser Tubes without fins and the 3^{nD}model shows condenser Tubes with fins.

Table 1: Material Used

Tube Material	Aluminum
Fin Material	Aluminum

Table 2: Aluminum Material Properties

Density	2702
Specific of heatcapacity	903 J/Kg K
Thermal of conductivity	273 W/mK

- **Importing CAD Modeling in ANSYS**

as described in figure 4 below, the cad model produced in creo is imported into Ansys. Geometrical errors, hard edges, and sleeves are examined in the cad model, etc.

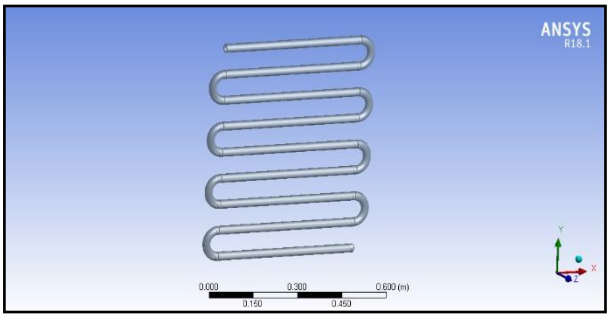


Figure4: imported cad model in Ansys

D. MESHING

The CAD model established is meshed using hexahedral elements &fine sizing as presented in figure 5. the element sizing selected is fine sizing and transition set to slow, span angle center set to fine, growth rate default, smoothing medium. The no. of elements produced is 101050 &the no. of nodes produced is 159704.

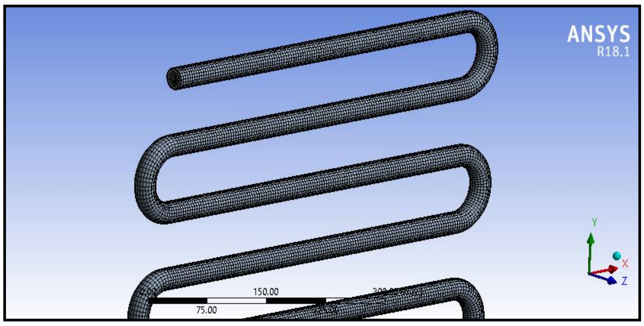
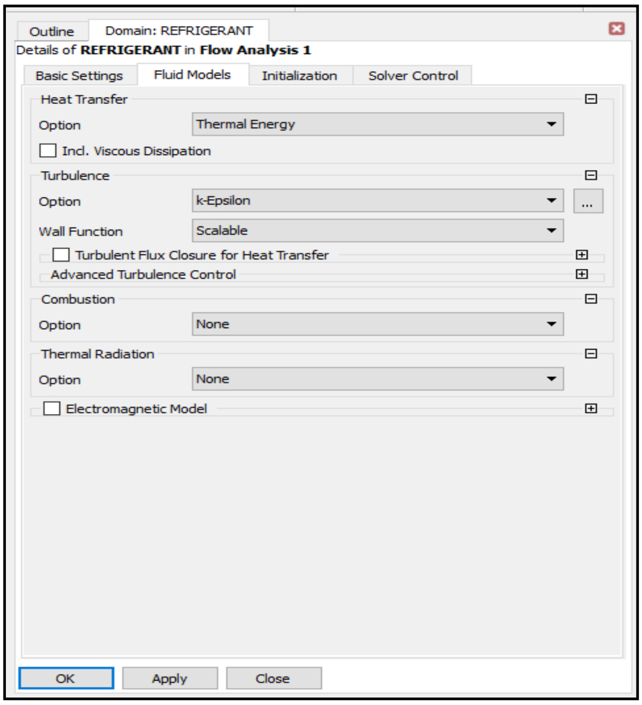


Figure 5: Meshed model in ANSYS

E. Boundary and Load Conditions

The boundary & load conditions are assigned with details shown below. The domain inside is defined as a fluid domain with r134al as fluid and morphology as a continuous fluid. the reference pressures are set to 482630 n/m^2. The energy model is set to k-epsilon and the wall function set to scalable.



Outline | Domain: REFRIGERANT

Details of **REFRIGERANT** in **Flow Analysis 1**

Basic Settings | Fluid Models | Initialization | Solver Control

Heat Transfer
Option: Thermal Energy
☐ Incl. Viscous Dissipation

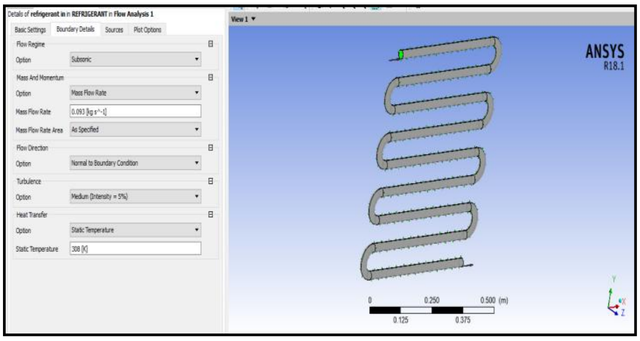
Turbulence
Option: k-Epsilon
Wall Function: Scalable
☐ Turbulent Flux Closure for Heat Transfer
Advanced Turbulence Control

Combustion
Option: None

Thermal Radiation
Option: None

☐ Electromagnetic Model

Figure 6: definition domain in ANSYS software



Details of **refrigerant in** in **REFRIGERANT** in **Flow Analysis 1**

Basic Settings | Boundary Details | Sources | Plot Options

Flow Regime
Option: Subsonic

Mass And Momentum
Option: Mass Flow Rate
Mass Flow Rate: 0.093 [kg s^-1]
Mass Flow Rate Area: As Specified

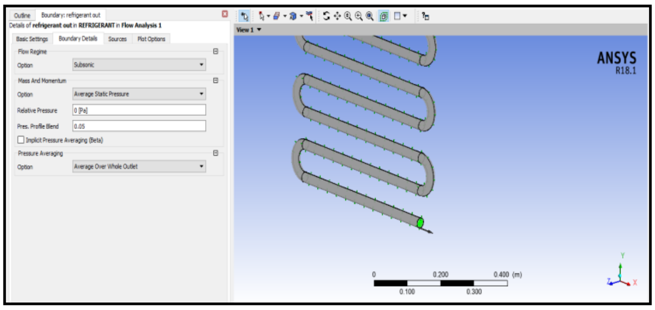
Flow Direction
Option: Normal to Boundary Condition

Turbulence
Option: Medium (Intensity = 5%)

Heat Transfer
Option: Static Temperature
Static Temperature: 308 [K]

Figure 7: Inlet boundary condition in ANSYS software

The inlet condition of boundary is defined for the condenser is shown in figure 7above. The inlet flow mass rate is set to .093 kg/s and a temperature of 308k.



Outline | Boundary: refrigerant out

Details of **refrigerant out** in **REFRIGERANT** in **Flow Analysis 1**

Basic Settings | Boundary Details | Sources | Plot Options

Flow Regime
Option: Subsonic

Mass And Momentum
Option: Average Static Pressure
Relative Pressure: 0 [Pa]
Pres. Profile Blend: 0.05
☐ Implicit Pressure Averaging (Beta)

Pressure Averaging
Option: Average Over Whole Outlet

Figure 8: outlet boundary condition in ANSYS software

The outlet boundary condition is set for the condenser as shown in figure 8 above. the relative pressure difference is set to 0 pa and pressure is averaged over the outlet.

A. Solution Stage

The solver is configured at a maximum iteration of 1e-4 and 100 rms. advection system is adjusted too high resolution and conservative timescale. matrix, multiplication, and reversion of the worldwide stiffness matrix as a rigidity matrix element.

V. RESULTS AND DISCUSSION

The CFD analysis is conducted using different refrigerant types (R134 and R11) and different condenser designs (without fins and with fins). the results are discussed in the next section.

Table3: Refrigerant Properties

Refrigerant Name	**Specific heat capacity (j/kg k)**
R134	1280.5
R11	840

B. CFD Analysis Using R134 Refrigerant Without Fins

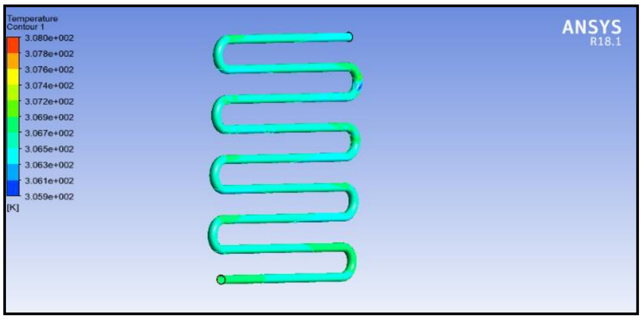


Figure9: Temperature Plot Using R134 Refrigerant and Without Fin Condenser

The temperature contour for r134 refrigerant and without fins condenser type is shown in figure 9 above. plot 5207 shows the temperature on the outer surface of the condenser reaches 306k and the higher temperature is near the refrigerant inlet.

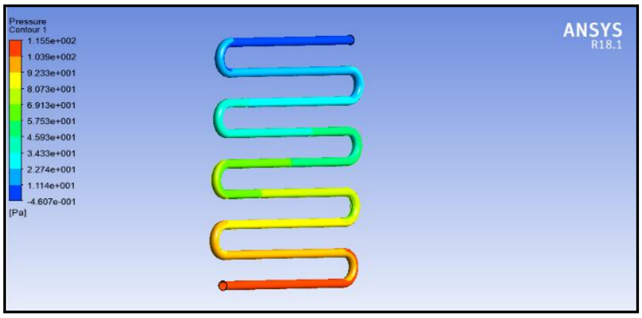


Figure 10: pressure plot using R134 refrigerant and without fin condenser

The pressure plot across the condenser is shown in the figure 10above. the maximum pressure is near the refrigerant inlet with a magnitude of 155 pa and reduces on moving towards the outlet of the condenser. the pressure reduces to 103.9 pa in the next coil of tubes and subsequently to 11.1 pa on the last coil or condenser.

C. CFD Analysis Using R134 Refrigerant with Fins

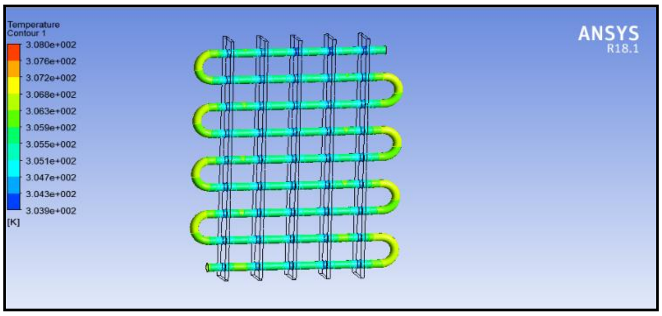


Figure11: temperature plot using R134 refrigerant and with fin condenser

The temperature contour for R134 refrigerant and with fins condenser type is shown in figure 11 above. the plot shows the temperature on the outer surface of the condenser reaches 305k and the higher temperature is near the refrigerant inlet.

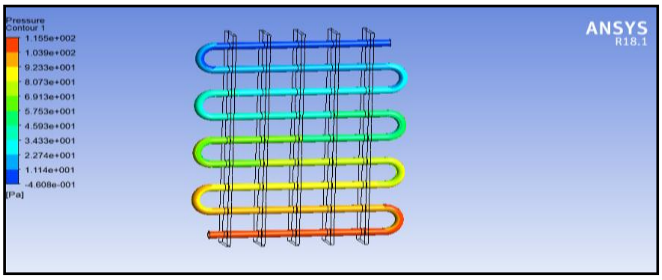


Figure 12: pressure plot using R134 refrigerant and with fin condenser

The pressure plot across the condenser is shown in figure 12 above. the maximum pressure is near the refrigerant inlet with a magnitude of 155 pa and reduces on moving towards the outlet of the condenser. the pressure reduces to 103.9 pa in the next coil of tubes and subsequently to 11.14 pa on the last coil or condenser.

D. CFD Analysis Using R11 Refrigerant Without Fins

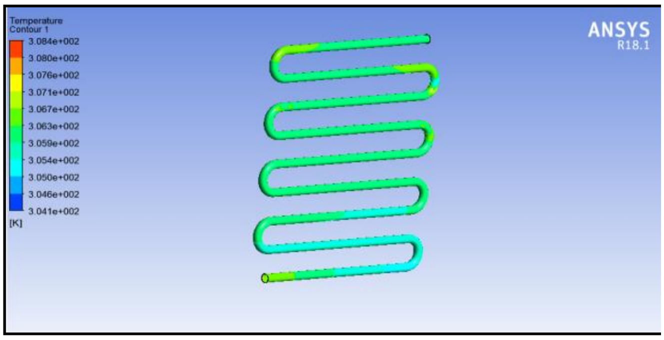


Figure13: temperature plot using R11 refrigerant and without fin condenser

The temperature contour for R11 refrigerant and with fins condenser type is shown in figure 13 above. the plot shows the temperature on the outer surface of the condenser reaches 304k and the higher temperature is near the refrigerant inlet.

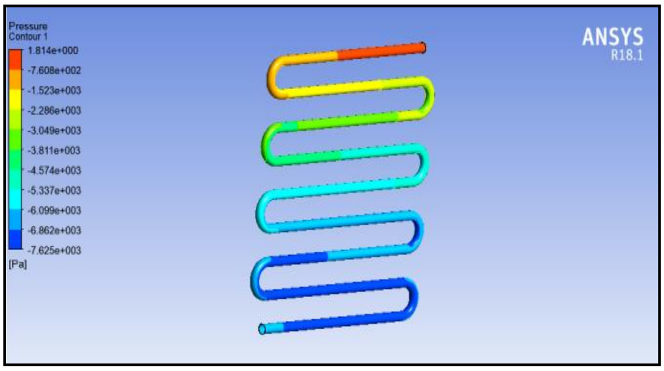


Figure14: pressure plot using R11 refrigerant and without fin condenser

The pressure plot across the condenser is shown in figure 14 above. the maximum pressure is near the refrigerant inlet with a magnitude of 1.81 pa and reduces on moving towards the outlet of the condenser. the pressure reduces to 162.5 pa in the next coil of tubes and subsequently to 11.14 pa on the last coil or condenser.

E. CFD Analysis Using R11 Refrigerant With Fins

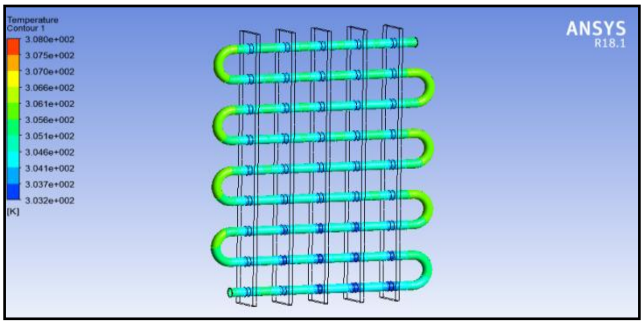


Figure 15: temperature plot using R11 refrigerant and with fin condenser

the temperature contour for R11 refrigerant and with fins condenser type is shown in figure 15 above. the plot shows the temperature on an outer surface of condenser reaches 306.1k and a higher temperature is near the refrigerant inlet.

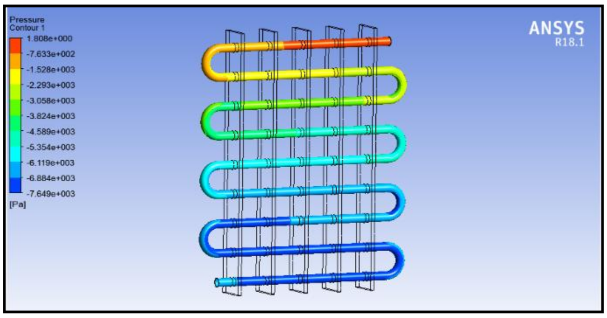


Figure16: pressure plot using R11 refrigerant and without fin condenser

The pressure plot across the condenser is shown in figure 16 above. the maximum pressure is near the refrigerant inlet with a magnitude of 1.81 pa and reduces on moving towards the outlet of the condenser. the pressure reduces to

152.5 pa in the next coil of tubes and subsequently to 11.14 pa on the last coil or condenser.

Table 4: heat flow and temperature table for both designs and refrigerants

Refrigerant And Design Type	**mass flow in (kg/s)**	**temp in (k)**	**temp out(k)**	**temperature difference**	**heat flow = m c_p * ΔT**
r134 without fins	.001	308	307.66	.34	.4353
r134 with fins	.001	308	307.37	.63	.8067
r11 without fins	.008	308	307.42	.58	3.897
r11 with fins	.008	308	307.008	.992	6.666

The 1st comparative studies are made based on heat rejection between 2 designs of the condenser (with fins and without fins). The 2nd comparative studies are made based on temperature drop between 2 designs of the condenser (with fins and without fins). Thecomparative charts are shown in the next section.

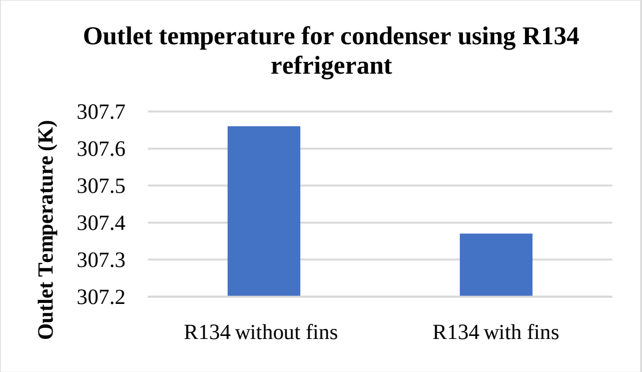


Figure 17: outlet temperature for 2 designs of condenser using R134 refrigerant

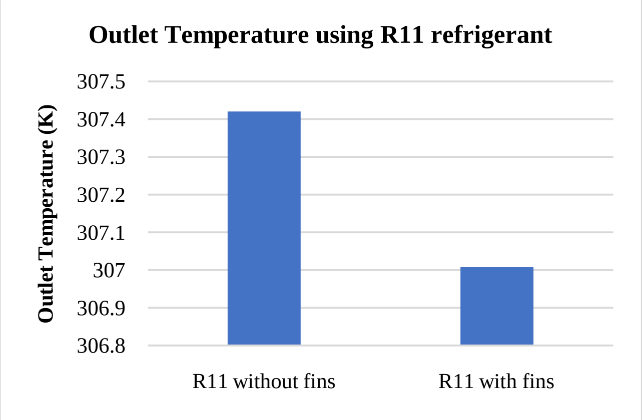


Figure18: outlet temperature for 2 designs of condenser using R11 refrigerant

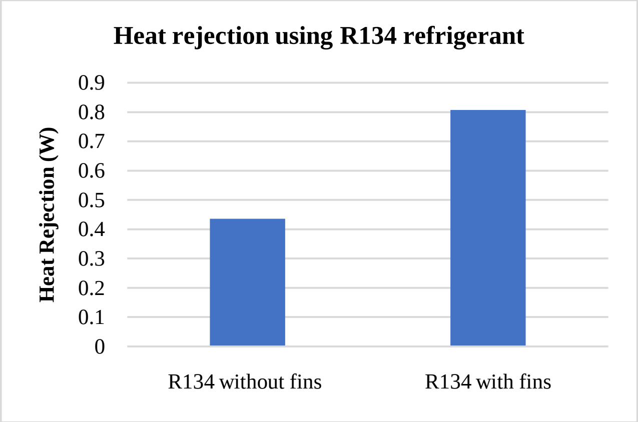


Figure19: heat rejection for 2 designs of condenser using R134 refrigerant

The comparative chart shows that heat rejection using fin geometry for r134 refrigerant is higher as compared to condenser design without fins. the magnitude of heat rejection is .435w for design without fins and .806w for design with fins.

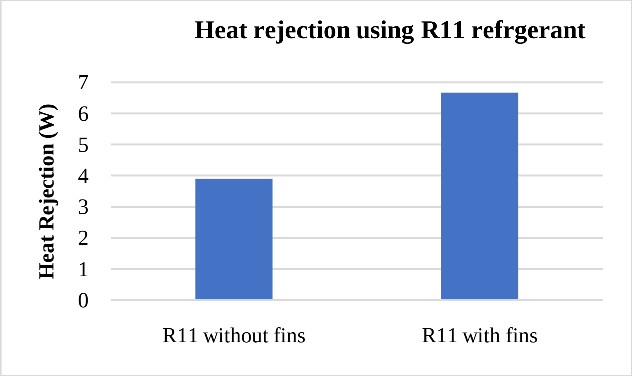


Figure20: Heat Rejection for 2 designs of condenser using r11 refrigerant

The comparative chart shows that heat rejection using fin geometry is higher as compared to condenser design without fins for r11 refrigerant. the magnitude of heat rejection is 3.897w for design without fins and 6.666w for design with fins.

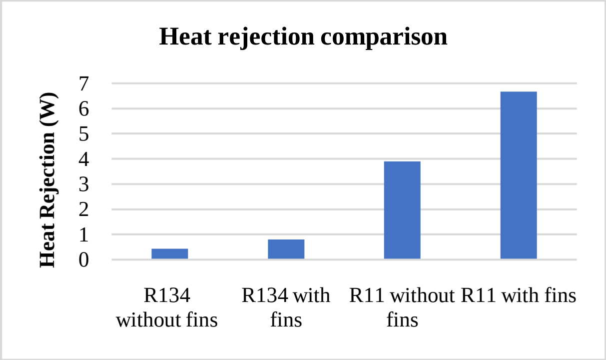


Figure21: heat rejection comparison for all designs

The comparative chart of heat rejection for all designs using different refrigerants is shown in the figure 21above. The maximum heat rejection is seen in r11 with fins followed by r11 without fins. The r134 refrigerant without fins has the lowest heat rejection rates as compared to other designs with fins.

VI. CONCLUSION

The recent research investigates the impact of fins and refrigerant properties on heat rejection and temperature drop characteristics of the condenser. TheCFD technique employed for analysis has proved to be a viable option for substituting conventional experimental techniques which are costly and time-consuming also.

- The temperature drop attained using rectangular fins is higher for both refrigerants r134 and r11 as compared to designs without fins. The drop is almost 90%.
- The two variable (k-epsilon) turbulence model used for analysis has provided a reasonably good prediction of the flow of fluid along with pressure drop and temperature drop characteristics.
- The heat rejection using fin geometry for r134 refrigerant is higher as compared to condenser design without fins. Themagnitude of heat rejection is .435w for design without fins and .806w for design with fins.
- The heat rejection using fin geometry is higher as compared to condenser design without fins for r11 refrigerant. Themagnitude of heat rejection is 3.897w for design without fins and 6.666w for design with fins.
- The maximum heat rejection is seen in r11 with fins followed by r11 without fins. The r134 refrigerant without fins has the lowest heat rejection rates as compared to other designs with fins.

VII. FUTURE SCOPE

- This study was limited to pure refrigerants only.
- IT sometimes calculates its heat absorption capacity over/under. Thedifferences for the heat transfer coefficient with the selected correspondence can be attributed. Although there were considered the existing correlations with the least variations for the actual heat transmission for the evaporator and condenser, for a particular application with the selected refrigerant, it required the signature of tailor-made correlations.
- The tolerance of condenser capacity needs considerably more than the capacity of evaporator. it means that the predicted capacity does not fit well and it also depends on the efficiency of the compressor. The input parameter is a supposed value for compressor efficiency. Therefore the features of the compressor must first be researched and a fair assumption must be established for better prediction.

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