OPTIMAL SELECTION OF REFRIGERANT AND CONDENSR MATERIAL FOR VAPOR COMPRESSION REFRIGERATON SYSTEM

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ABSTRACT

An Experimental Analysis is done of the refrigerator condenser by varying the fins spacing of the condenser. vapour compression refrigeration system is a cycle in which domestic refrigerator works. it consist of compressor, condenser expansion valve and evaporator . The performance of the system depends on the performance of all the components of the system. The main objective of the present work is to increase the performance of the condenser by increasing the heat transfer rate through the condenser. Heat transfer rate can be increased by the extended surfaces called fins. Heat transfer rate is also depends on the spacing between the fins of the condenser.

Keywords— *Domestic refrigerator, condenser, refrigerant, heat flux, temperature gradient*

INTRODUCTION

Refrigerating systems has emerged as a important necessity of human life in present century. Today, these systems are used in many applications. Present research work is devoted to analysis of an important part of refrigerant system, condenser under different material constraints, and refrigerants. Details of introduction to the research work are presented in upcoming sections.

In a vapor compression refrigeration system, vapor alternately undergoes a change of phase from vapor to liquid and liquid to vapor during the completion of a cycle. The latent heat of vaporization is utilized for carrying big amount heat from the refrigerator. In such systems, the working fluid do not leave the system but remains in flowing condition and experiences alternate processes of condensation and re-evaporation. During the process of evaporation, it absorbs its latent heat from primary fluid (brine), while during condensation, it gives out its latent heat to the circulating water of the cooler. Refrigerants may be considered as blood of any refrigeration system. It flows in all the portions of the circuit, and is responsible for the transfer of heat from lower level to upper level. In evaporator heat carried by products, occupants, and other items, is absorbed by the refrigerant due to which it gets evaporated at very low temperature. These evaporated vapors enter the compressor. Compressor increases pressure, and in turn temperature of the vapors by transferring the vapors from lower temperature to higher temperature. From exit of the compressor, high pressure superheated or saturated vapors enter the condenser where latent heat carried by them is removed by its transfer to a cooling medium (air, water, or any other medium). As a result, refrigerant in the form of saturated or sub cooled liquid is obtained at the exit of the condenser. From exit of the condenser, vapors enter in a throttling device (preferably, a capillary tube or any other device), due to which its state gets converted, and low pressure wet refrigerant is obtained at the entry of evaporator, and in this manner the cycle repeats itself again and again.

VAPOR COMPRESSION REFRIGERATION SYSTEM:

The domestic refrigerator is one found in almost all the homes for storing food, vegetables, fruits, beverages, and much more. The parts of domestic refrigerator can be categorized into two categories: internal and external. The schematic view of the system is shown in Figure 2.1. All the principal parts are shown in the diagram, and path of the refrigerant flow is also shown on the diagram. High pressure and low pressure sides are connected by control valve. Some of the liquid evaporates passing through the expansion valve, but greater portion is vaporized in the evaporator at low pressure (low temperature). The liquid refrigerant absorbs its latent heat of vaporization from

materials kept for cooling purposes. The function of the compressor is to increase the pressure and temperature of the refrigerant above atmospheric which will be ready to dissipate its latent4heat in the condenser. In passing through the condenser, the refrigerant gives up the heat which absorbed in the evaporator plus the heat equivalent of the work done upon it by the compressor. This heat is transferred to the air or water which is used as cooling medium in the condenser.
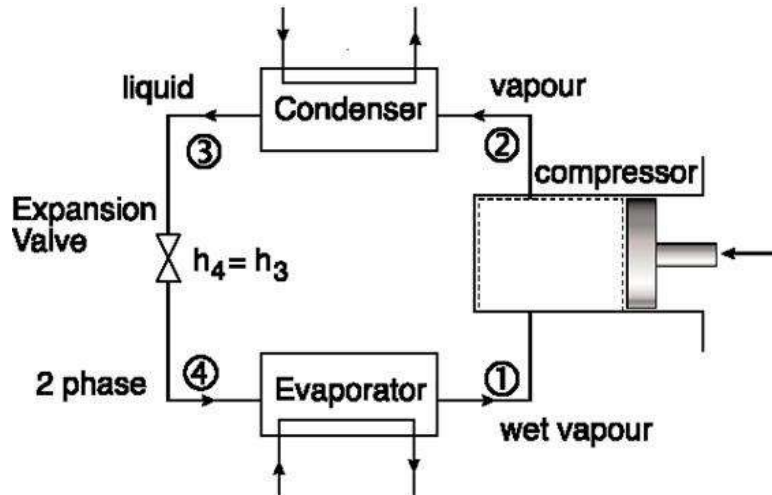
Vapor Compression Refrigeration System

METHODS TO INCREASE COP OF THE VAPOR COMPRESSION REFRIGERATION SYSTEM

Following techniques are generally used for the purpose of increasing the coefficient of performance of a vapor compression refrigeration system.
1. Under-cooling of liquid refrigerant;
2. Two stage compression of the refrigerant; and
3. Superheating of the refrigerant.
SPECIFICATIONS OF A DOMESTIC REFRIGERATOR
Following are the specifications of a domestic refrigerator.
1. Compressor H.P. = 1/6 to 1/8;
2. Capillary = 0.82 mm diameter;
3. Lubricating oil = R-43, and R-45 (H.P. zeric), Gargoyle Asetic (Indian oil);
4. Normal refrigerant charge = 160-190 grams for 165 liters capacity but varies as per capacity;
5. Power consumption = 3-4 kW-hr for 286 liters capacity refrigerator per day and 2-3kW-hr for 165 liters capacity unit;
6. Maximum running time = 40-60% of day time for small refrigerator, and 60-80% for bigger one;
7. Maximum evaporator temperature = $-17^{o}C \pm 2^{o}C$;
8. Temperature in Tray = $0^{o}C$ or below;
9. Suction pressure = 0.7 – 0.85 bar; and
10. Discharge pressure = 12 – 13 bar.

TYPES OF COOLING MEDIUM

The cooling mediums provided by nature are air and water. Both can be used as cooling medium either separately or combined as per the availability and requirement. Air cooled condensers are designed for condensing temperatures of 15-20 degrees above the temperature of the entering air and 6-12 degrees above if water is used as cooling medium. The condensing temperatures adopted with air as cooling medium is 55-60 degrees where with water it is 31-37 degrees. The temperature of condensing with water also depends upon the purity of water. The temperature adopted may be 2-4 degrees above the temperature used with clean water if the available water is dirty. Whenever the temperature of atmospheric air is 40 degrees, water is often available at $25^{o}C$; therefore choice also depends

upon the temperature of the available source. Few more factors considered with air or water cooled condensers are listed below:

TYPE OF REFRIGERANT

The heat transfer coefficient of condensing side mostly depends upon the properties of the refrigerant as density, conductivity, viscosity, and latent heat. As their properties are different for different refrigerants, so that transfer coefficients are also considerably different. The condensing surface required for chlorinated refrigerants is much greater than ammonia due to poor physical properties and the heat transfer coefficient also depends upon the purity of the refrigerant as free from oil and air because oil presence with the refrigerant gives more resistance for heat transfer. This factor is more noticeable with chlorinated refrigerants. The presence of air also reduces the rate of heat transfer rapidly and reduction depends upon the percentage of air presented.

LITERATURE REVIEW

Mallik arjun & Malipatil 2014 In the research work, heat transfer by convection in the case of condensers is analyzed and attempts are made to improve it. For this purpose an air-cooled condenser of finned type used in vapor compression air conditioning system is highlighted, and computational fluid dynamics (CFD) approach is being applied to it for the purpose of determining the better design and material. The materials used for tubes are copper, for fins are Aluminum 1100, Aluminum 6063, and Magnesium alloy. The targeted refrigerants for this purpose are HCFC, and 404R

Ram Mohan Gupta 2013The research work is based on determining optimum inclination of condenser tubing with respect to the horizontal, and investigating the rate of heat transfer. During the research, researchers found that if some angle of inclination is provided to tubing, heat transfer increases, and for this purpose heat transfer at different inclinations is accomplished. Results of the research work show that the rate of heat transfer increases for the backward to upward tube arrangement

Nadadari &Venkateswarlu 2015 The researchers investigate about the definition of a condenser. They report that in systems involving heat transfer, a condenser may be considered as a unit which condenses a substance from its gaseous state to liquid state, traditionally by cooling it. During this process, latent heat is given up by substance, and transfers to the coolant of the condenser. The basic objective of the research work is to design, develop, and utilize the highly-efficient heat transfer in a condenser used in air conditioning purposes. In the research work, heat transfer is investigated for finding the optimum material and refrigerant in vapor compression refrigeration system. The materials used for tubing are Copper and Aluminum alloy 1100 and for fins are Al 1050, and Al1100. The refriger¬ants options considered by the researchers are R-12, R-22, and R-134A. For this purpose, 3D model is developed on Pro/Engineer and analysis is done in ANSYS.

Diwan and Sahu 2016 In the research work, design of shell and tube type heat exchanger with helical baffle is accomplished with the help of modeling software CATIA, and analysis software ANSYS. With the help of ANSYS, study of flow and temperature fields is conducted inside the shell. The highlighted heat exchanger consists of 27 tubes, a shell of length 5,490 mm, and diameter 540 mm. The helix angle of baffle varies from 0o to 20o. Simulation of the device shows the variation of temperature and heat flux throughout the surface. Simulation also shows that the flow pattern in the shell side of the heat exchanger using continuous type of baffles tends to be rotational, and helical, based on the geometry of the baffles, which, in turn, gives rise to significant increase in heat transfer coefficient per unit pressure drop in the condenser.

Sai Krishna *et al.* 2013 In the research work, researchers advocate the superiority of plate heat exchangers by stating that for many industrial applications, plate heat exchangers are superior over other types. Present research work aims at designing an optimal plate type of heat exchanger used in refrigeration purposes. The research work contains, both, theoretical as well as simulation analysis for a parallel flow type of heat exchanger. The working fluids used are CO_2 and R134a. On theoretical part, researchers find very less pressure drop. In the next stage of the research, CFD analysis on ANSYS software is carried out on the basis of investigated inlet conditions like mass flow rate, and temperatures and pressures of cold and hot fluids. In ANSYS, design of a multi-pass plate heat exchanger is optimized with the help of variables like number of passes for hot and cold streams, number of plates, type of plates, and size of plates. The selection of suitable material is accomplished on the basis of thermal ageing of materials, temperature stresses, and failure modes, previously reported by other researchers. In the research work, the researchers has also formulated some basic equations regarding, heat transfer, overall heat transfer coefficient, and pressure drop.

Yadav *et al.* 2015 Present research work is devoted to modeling and simulation of a house hold refrigerator. In the research work, the vapor compression refrigeration system consisting of evaporator, compressor, condenser, and expansion device is modeled using 3D modeling software Pro-E wild fire 5, and thermal analysis is performed on different parts of the modeled system with the help of ANSYS 14. In the research work, refrigerants used are HCFC, HFC-152A, and 404R, also, the commonly used tube material copper is replaced with A, and, Al6061.

METHODOLOGY

In the present research work ANSYS R 15.0 simulation software was used for the purpose of simulation, and obtainment of results. Details of software are presented in succeeding section.

ANSYS is considered as one of the renounced tools in the field of simulation, developed by ANSYS Inc., USA. It can be used successfully for the purpose of simulating problems of thermal analysis, structural analysis, computational fluid dynamics, harmonic analysis, modal analysis, transient dynamics, buckling, and other categories. In addition to this, software also offers the facility to develop simple models.

- Offers excellent simulation facility;
- Easy modules for different types of complex analysis like modal, transient, etc;
- Offers different theoretical perspective to solve a problem with different inbuilt models;
- Simple parts can be easily created;
- Inbuilt library to offer material properties; and
- Better graphics facilities.

The following points describe the setup and solution steps used in ANSYS.
- Preparation;
- Creating a Fluent Fluid Flow Analysis System in ANSYS Workbench;
- Creating the Geometry in ANSYS Design Modeler;
- Meshing the Geometry in the ANSYS Meshing Application;
- Setting Up the CFD Simulation in ANSYS Fluent;
- Displaying Results in ANSYS Fluent and CFD-Post;
- Duplicating the Fluent-Based Fluid Flow Analysis System;
- Changing the Geometry in ANSYS Design Modeler;
- Updating the Mesh in the ANSYS Meshing Application;
- Calculating a New Solution in ANSYS Fluent; and
- Comparing the Results of both systems in CFD-Post.

MODEL FORMULATION

S.No	Dimension	Value
1.	Length	9.14 m
2.	Outer diameter	9.52 mm
3.	Inner diameter	8.91 mm
4.	Number of turns	06

With the help of dimensions shown in Table 5.1, first of all, a model of condenser was prepared using ANSYS R 15.0
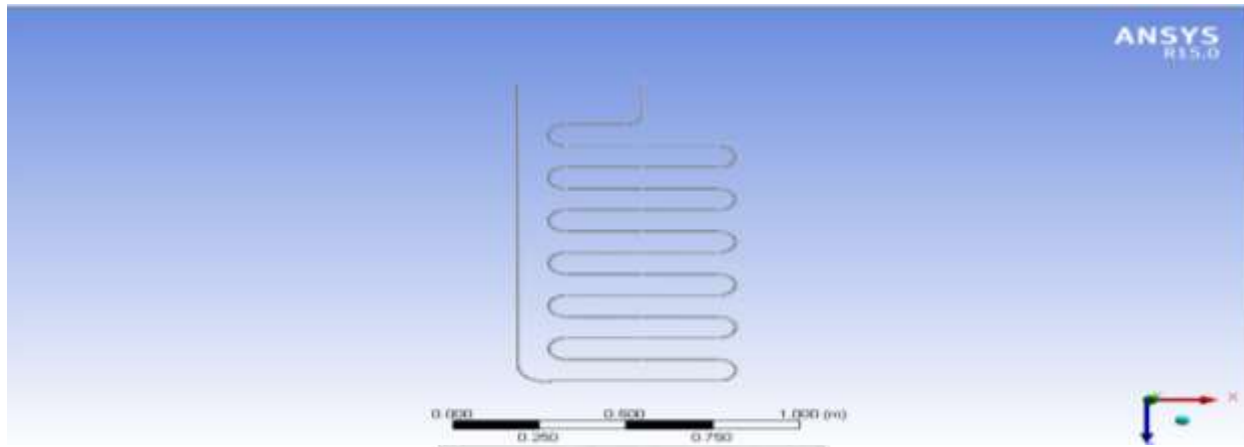
Solution of the Model

After formulation of model, its solution was derived. For this purpose, first of all meshing of the model was carried out. With the help of meshing, a body can be made deformable due to which, it can show changes in its properties, dimensions, stress levels, etc. Figure 4.2 shows the mesh diagram for the condenser.
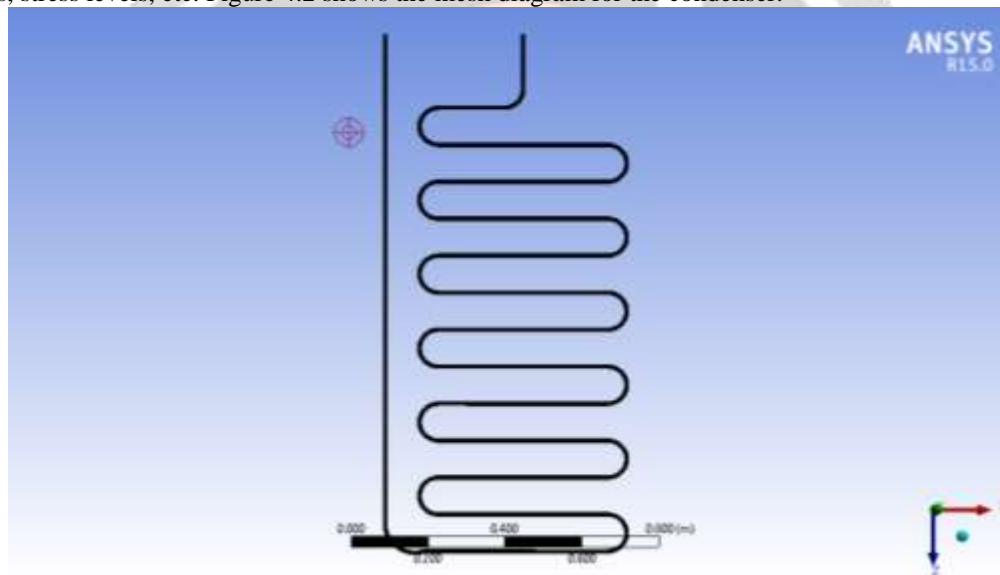
Mesh structure of Condenser Coil

In next step values of heat flux and thermal gradient for different combinations of materials and refrigerants were calculated. For this purpose, based on literature survey, following parameters were used.

Parameters used in finding values of Heat Flux and Thermal Gradient

S.No	Parameter	Value
1.	Type of load	Thermal
2.	Area temperature	313k
3.	Bulk temperature	303k
4.	Temperature gradient type	Vector sum

Table 4.3 shows different properties of refrigerants used for obtainment of results.

Table 5.3: Properties of Refrigerants

S. No	Temp.	Property	Refrigerant			
			R22	R404	R152A	R134
1.	303K	Density	7.06 kg/m³	8 kg/m³	2.739 kg/m³	8.42 kg/m³
		Viscosity	12.8 microPa-s	13.5 microPa-s	15.10.84 microPa-s	12 microPa-s
		Sp. Heat	0.6496 kJ/kg·K	0.88 kJ/kg.K	0.0706kJ/kg.K	0.833kJ/kg·K
		Thermal Conductivity	0.0109 W/m-K	0.0172 W/m-K	0.129 W/m-K	0.0138 W/m-K
2.	313K	Density	6.81 kg/m³	7.71 kg/m³	3.174 kg/m³	8.12 kg/m³
		Viscosity	13.3 microPa-s	14 microPa-s	10.64 microPa-s	12.4 microPa-s
		Sp. Heat	0.853 kJ/kg·K	0.95 kJ/kg.K	0.0895 kJ/kg.K	0.7334 kJ/kg·K
		Thermal Conductivity	0.0115 W/m-K	0.0181 W/m-K	0.143 W/m-K	0.0146 W/m-K

RESULTS AND DISCUSSION

Following are the results obtained from calculations for thermal gradient by using software ANSYS to show the performance of the domestic refrigerator by replacing the refrigerant and the condenser material
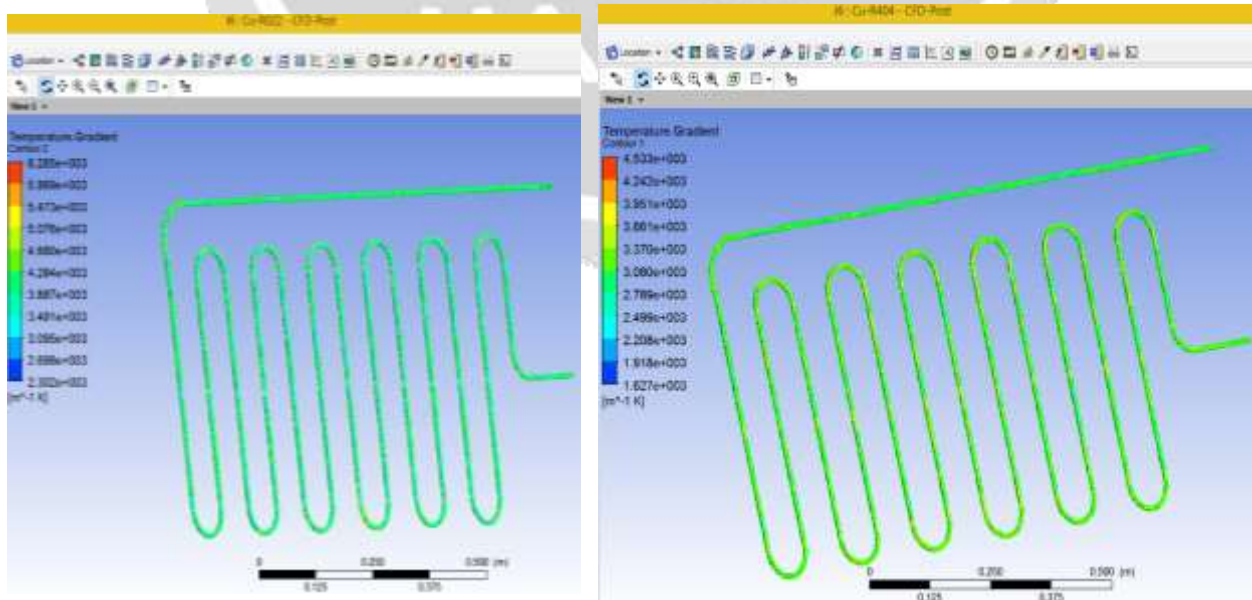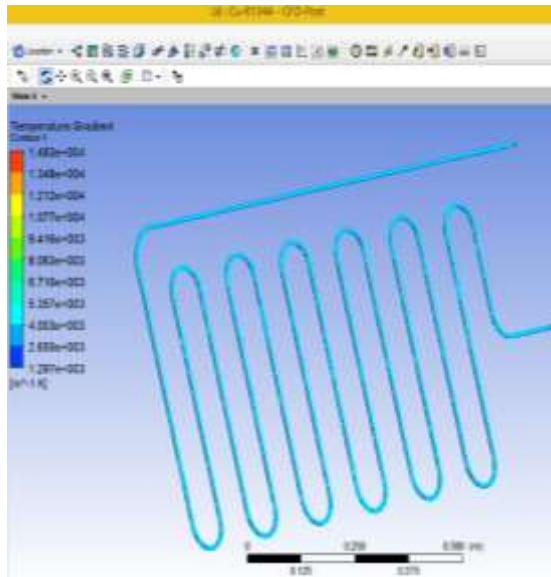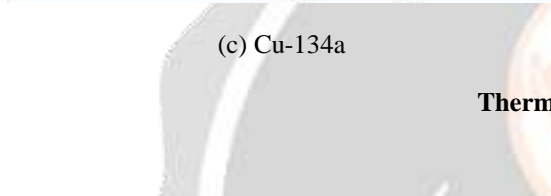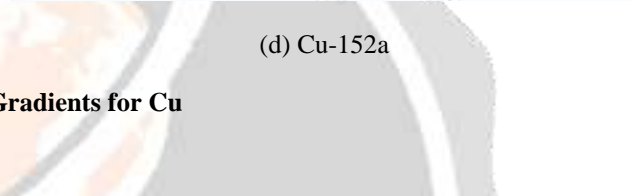
(a) Cu- R22   (b) Cu-R404
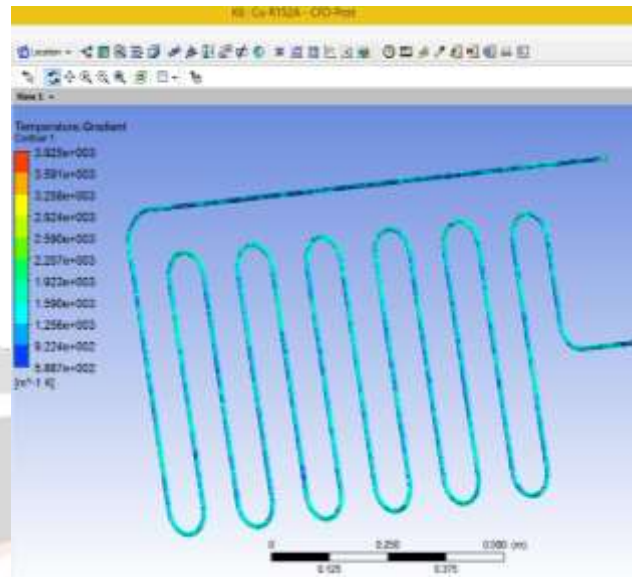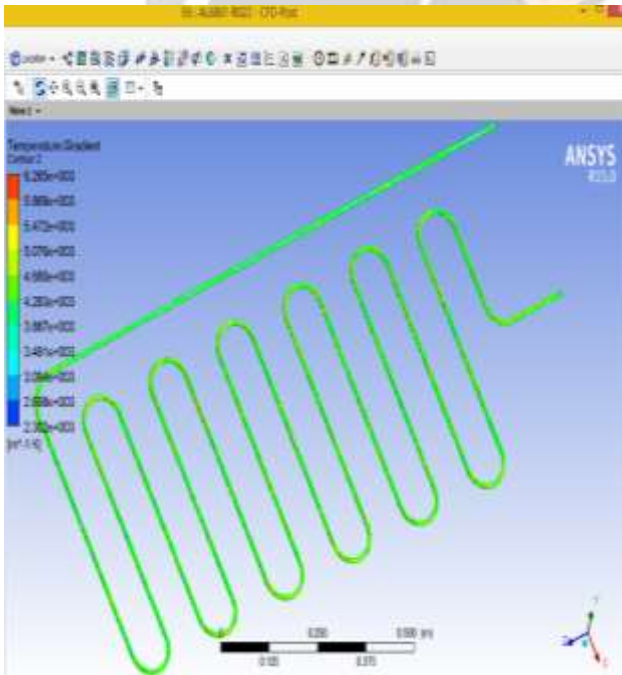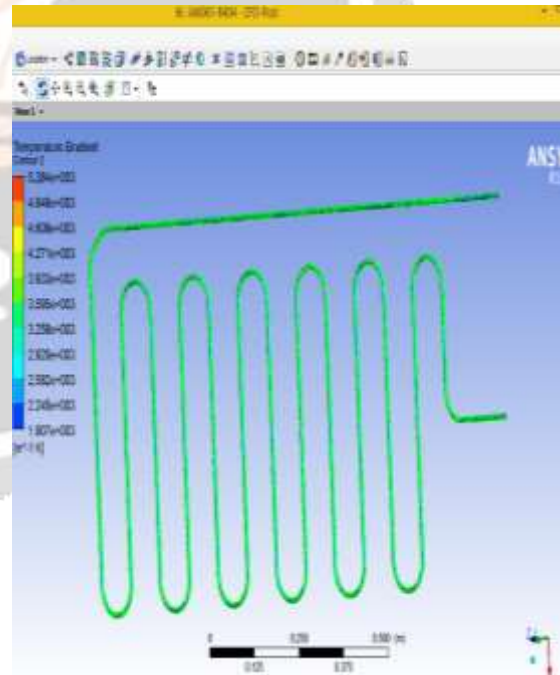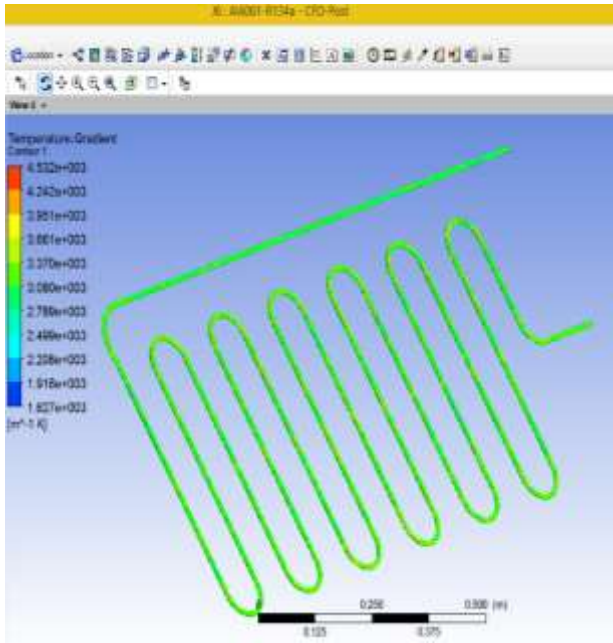

(c) Cu-134a   (d) Cu-152a
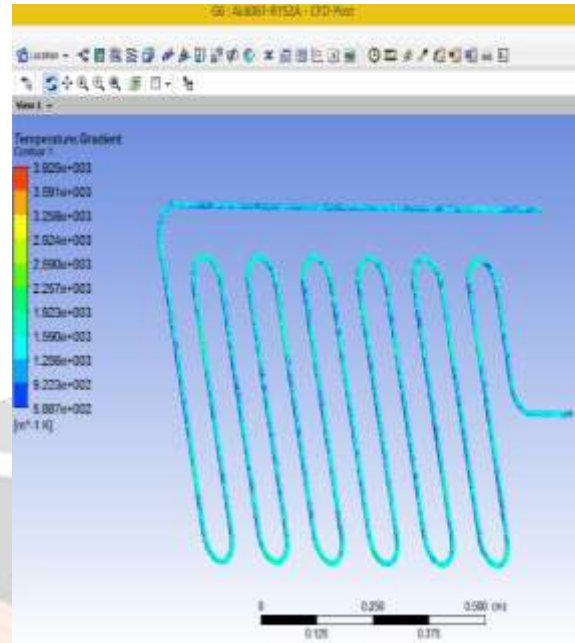
Thermal Gradients for Cu

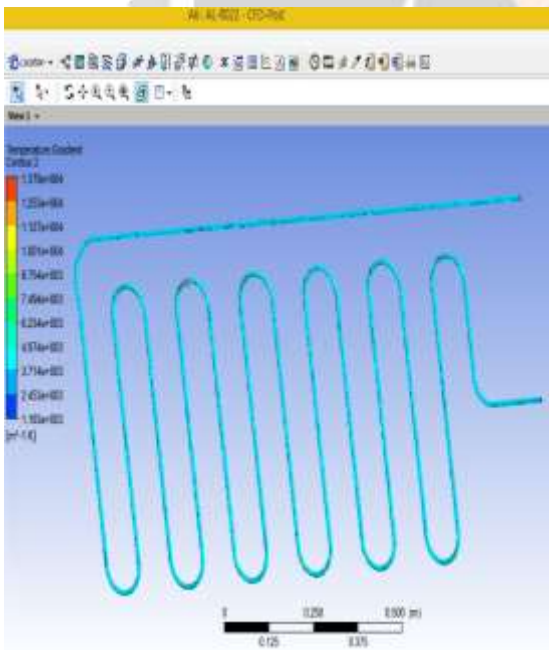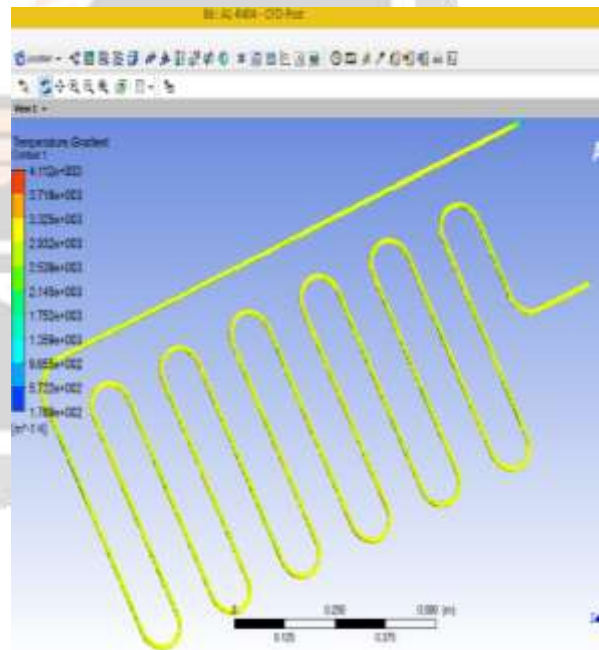(a) Al6061-R22   (b) Al6061-R404
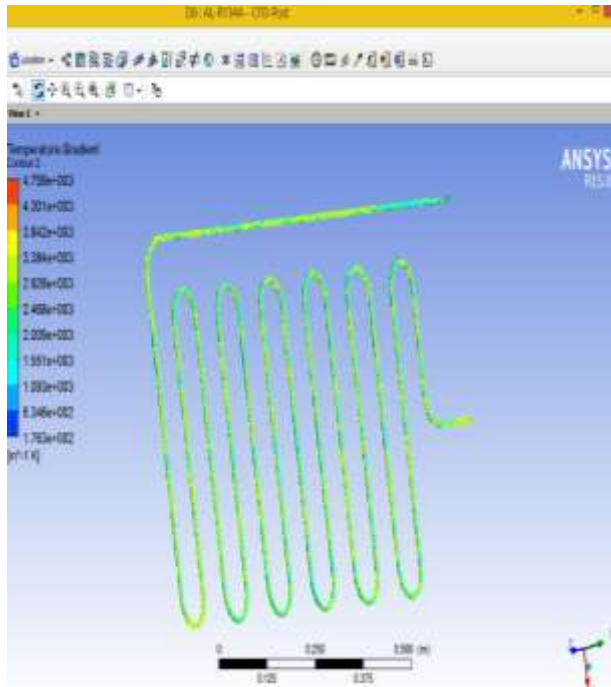
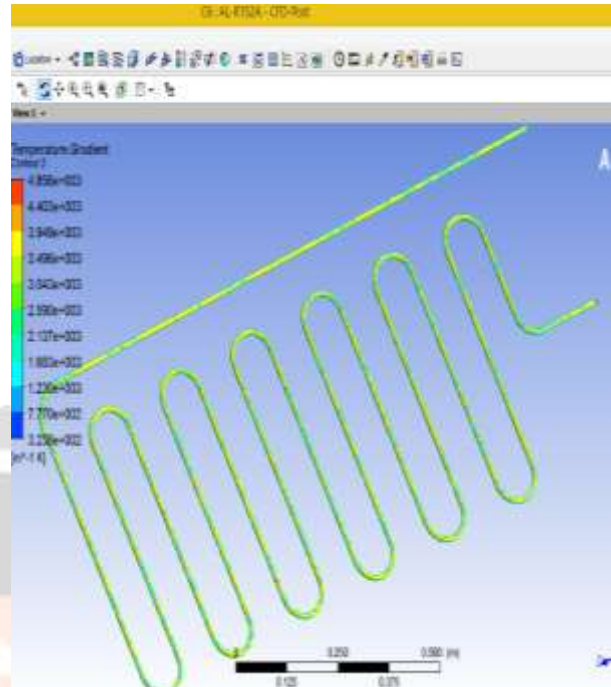(c) Al6061-134a

(d) Al6061-152a

Thermal Gradients for Al6061

(a) Al-R22

(b) Al-R404

(c) Al-134a   (d) Al-152a

Thermal Gradients for Al

shows the summary of results obtained for thermal gradients.

Thermal Gradient Values (in e+0.003)

S.No	Material	Refrigerant			
		R022	R404	R134a	R152A
1.	Al	4.000	3.325	2.926	3.043
2.	Al6061	4.283	3.933	3.661	1.256
3.	Cu	4.284	3.370	4.003	1.256

Graphical representations of above results are as follows.
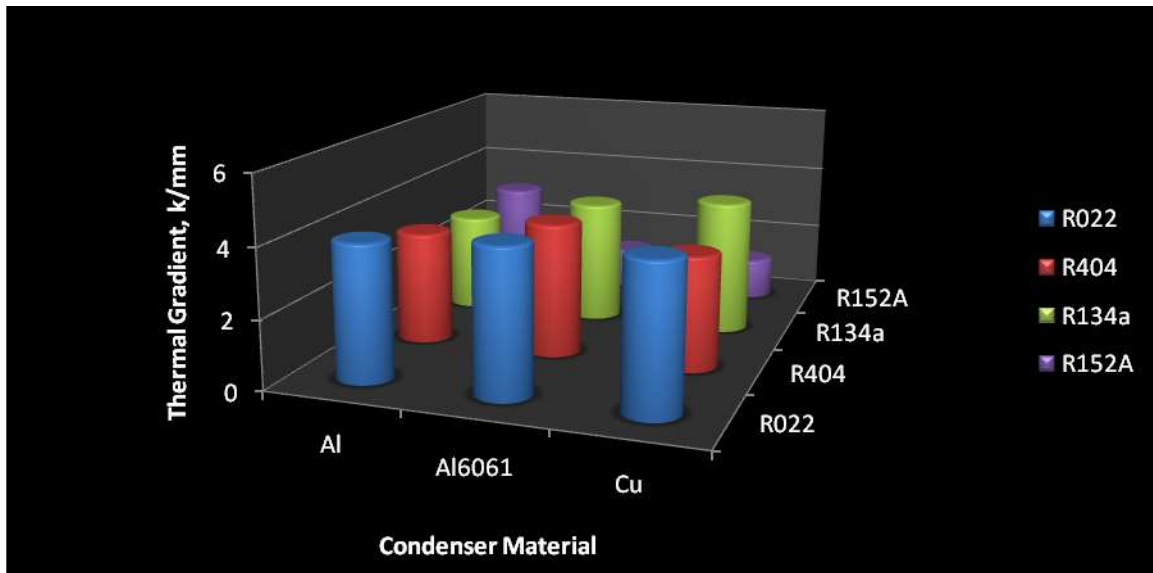
Graphical Representation of Thermal Gradient Values

The reasons behind such results are the material properties of both the alternatives. Due to greater thermal conductivity of copper than aluminum 6061, greater heat can be carried by copper, and due to this fact, value of heat flux for copper is greatest.

On the other hand, aluminum 6061 shows the greatest thermal gradient in two the available options. The reason behind this behavior is the fact that heat dissipation of rate of aluminum 6061 is greater, due to which it can dissipate maximum amount of heat due to its light weight. So therefore, considering both the requirements, Al6061 should be considered as the replacement of copper. show the ranking earned by different refrigerants on different criteria.

Ranking of refrigerants for Thermal Gradient Criteria

S.No	Refrigerant	Rank	Frequency
1.	R022	1	3
2.	R404	2	2
3.	R134a	3	2
4.	R152a	4	2 (much difference from R134a)

In the absence of Al6061 considering heat flux criteria, Cu may be used. With copper, in order to enhance heat dissipation rate, if a fan is used along the Cu, its heat dissipation rate may be enhanced, in order to take advantage of high thermal conductivity, R404 is suggested as refrigerant as R022 should be avoided due to its. Analysis of Al condenser with different refrigerants also shows maximum thermal gradient with R404 (neglecting R022), but the refrigerant does not support for the criteria of heat flux. Therefore its use is not suggested. shows the suggested arrangements along with rankings.

CONCLUSIONS

Present research work is devoted to selection of improved condenser material and refrigerant for a vapor compression refrigeration system. In the research work, *three* different materials for condensers, namely, aluminum, aluminum 6061 alloy, and copper were considered. At the same time, *four* different types of refrigerants namely, R022, R404, R152a, and R134a were tested for investigative *two* parameters namely, thermal gradient, and heat flux. As a results obtained, copper scored maximum for heat flux, and aluminum 6061 for thermal gradient. In case of refrigerants, refrigerant R22 scored maximum values in both the criteria. Following are the conclusions drawn out of the research:

1. Copper offers maximum heat flux;
2. Aluminum 6061offers maximum thermal gradient; and
3. Refrigerant R022 scores maximum for both, heat flux, and thermal gradient criteria, but cannot be recommended due to toxicity.

LIMITATIONS AND FUTURE SCOPE OF THE RESEARCH

Following are the limitations of the present research work:

1. The research work is limited to a particular set of materials;
2. The research work is limited to a particular set of refrigerants; and
3. The work is also made limited to the investigations on heat flux, and thermal gradients.

Following points represent the future scope of the research work;

1. An extensive research consisting of broader set of materials is still pending;
2. A broader research, considering different classes of refrigerants can be initiated;
3. A detailed research focusing on a broader set of thermal properties is still awaited.

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