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Analytical Investigation of R134a Flowing Through Adiabatic Helically Coiled Capillary Tubes

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Abstract: Capillary tubes are used as expansion device in low capacity refrigeration machines like domestic refrigerators and window type air conditioners. The advantages of the capillary tube over other expansion devices are simple, inexpensive and cause compressor to start at low torque as the pressure across the capillary tube equalize during the off-cycle. The flow characteristics of refrigerants through capillary tubes have been studied extensively in past six decades, both experimentally and analytically, most of these studies mainly focused on straight capillary tubes. In this thesis, the effects of the relevant parameters on the flow characteristic of R134a and R-22 flowing through adiabatic helical capillary tubes were experimentally studied. The capillary tubes' diameter, coil diameter, and parameters relating to flow conditions such as inlet pressures and degree of sub cooling were the major parameters investigated. In this thesis, the CFD analysis is to determine the heat transfer rate, pressure drop, velocity, mass flow rate and heat transfer coefficient for the fluids R134A and R-22 with different tube and coil diameters. Thermal analysis is to determine the temperature distribution and heat flux for copper and aluminum as tube materials.3D modeling is done pro-engineer and analysis is done in ANSYS software.

Keywords: finite element analysis, capillary tube, refrigerants, heat transfer rate.

I. INTRODUCTION

A capillary tube is a long, narrow tube of constant diameter. The word “capillary” is a misnomer since surface tension is not important in refrigeration application of capillary tubes.

A simple vapour compression refrigeration system consists of mainly five components namely compressor, condenser, expansion device, evaporator and a filter/drier[1]. The following study is focused towards finding out the effect of the capillary tube on the performance of the refrigeration system. A capillary tube is a small diameter tube which is used for the expansion of the flowing fluid. The pressure difference between the entry and exit ends of the capillary tube is always equal to the pressure difference between the condenser and the evaporator.

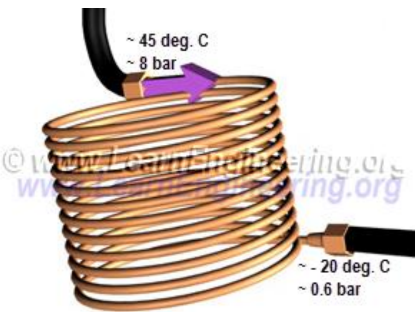

Fig 1: capillary tube

The diameter of the capillary tube used in the refrigeration appliances varies from 0.5mm to 2.3mm. The effect of the capillary tube has been investigated by many researchers in the past and encouraging results were obtained.

II. LITERATURE REVIEW

AN EXPERIMENTAL STUDY OF THE EFFECT OF CAPILLARY TUBE DIAMETER AND CONFIGURATION ON THE PERFORMANCE OF A SIMPLE VAPOUR COMPRESSION REFRIGERATION SYSTEM

The study of the expansion device in the simple vapour compression refrigeration system is necessary in order to understand the parameters which can enhance the overall performance [1] [2] of the system. The experimental study was done on the capillary tubes of 31 gauge, 36 gauge and 40 gauge and each test section was studied with three distinct configurations i.e. helical coiled, straight coiled and serpentine coiled configuration. The effect of the configuration and the capillary tube diameter on the overall performance of the system was studied. The findings of the experimental study revealed that the mass flow rate is maximum for the straight configuration and is least for the helical coiled configuration. The refrigeration effect was found to be maximum for the helical coiled configuration and was found to be least for straight coiled

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configuration. The compressor work was found to reduce as the load was increased on the system. Decreasing the capillary tube diameter increased the mass flow rate in the system and decreased the refrigeration effect produced[3].

III. PROBLEM DESCRIPTION

The objective of this project is to make a 3D model of the capillary tube and study the CFD and thermal behavior of the capillary tube by performing the finite element analysis.3D modeling software (PRO-Engineer) was used for designing and analysis software (ANSYS) was used for CFD and thermal analysis.

The methodology followed in the project is as follows:

- Create a 3D model of the capillary tube assembly using parametric software pro-engineer.
- Convert the surface model into Para solid file and import the model into ANSYS to do analysis.
- Perform thermal analysis on the capillary tube assembly for thermal loads.
- Perform CFD analysis on the existing model of the surface capillary tube for pressure inlet to find out the mass flow rate, heat transfer rate, pressure drop.

IV. INTRODUCTION TO CAD/CAE

Computer-aided design (**CAD**), also known as **computer-aided design and drafting** (**CADD**), is the use of computer technology for the process of design and design-documentation.

INTRODUCTION TO FINITE ELEMENT METHOD:

Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.

V. RESULTS AND DISCUSSIONS:

MODELLING AND ANALYSIS

3D MODEL

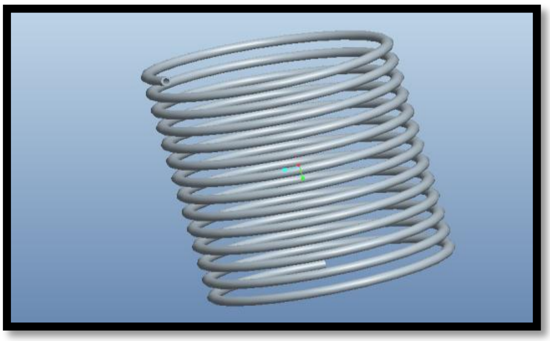


Fig 2 pro-e model

CFD ANALYSIS OF HELICALLY COILED CAPILLARY TUBES

FLUID – R134A

COIL DIAMETER-25mm

→→Ansys → workbench→ select analysis system → fluid flow fluent → double click

→→Select geometry → right click → import geometry → select browse →open part → ok

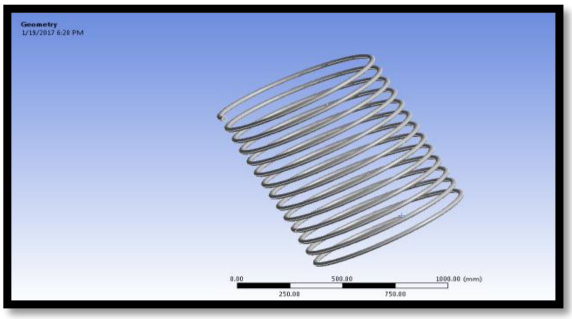


Fig 3 imported model

→→ select mesh on work bench → right click →edit → select mesh on left side part tree → right click → generate mesh →

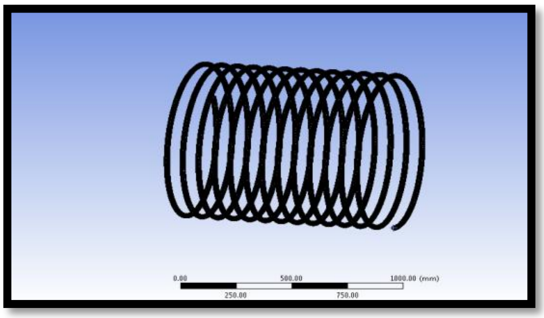
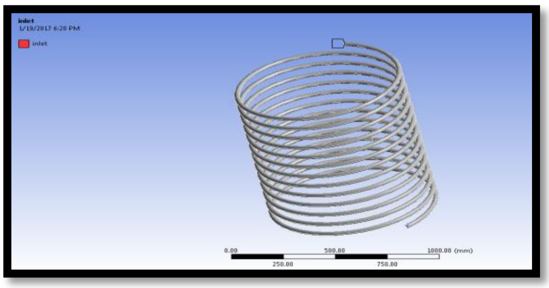


Fig 4 meshed model

The model is designed with the help of pro-e and then import on ANSYS for Meshing and analysis. The analysis by CFD is used in order to calculating pressure profile and temperature distribution. For meshing, the fluid ring is divided into two connected volumes. Then all thickness edges are meshed with 360 intervals. A tetrahedral structure mesh is used. So the total number of nodes and elements is 6576 and 3344.

Select faces → right click → create named section → enter name → water inlet Select faces → right click → create named section → enter name → water outlet



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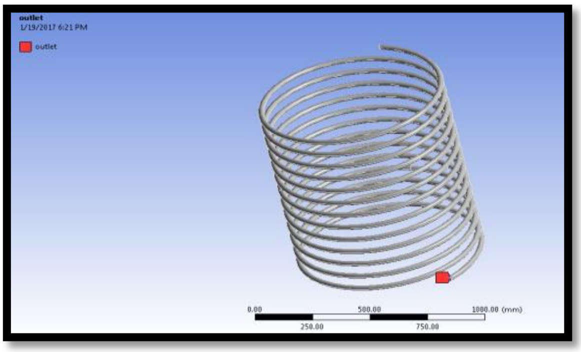

Fig 5 inlet and outlet conditions

Model → energy equation → on.
Viscous → edit → k- epsilon
Enhanced Wall Treatment → ok
Materials → new → create or edit → specify fluid material or specify properties → ok
Select air and water
Boundary conditions → select water inlet → Edit → Enter pressure → 750KPA and Inlet Temperature – 353K
Solution → Solution Initialization → Hybrid Initialization →done
Run calculations → no of iterations = 50 → calculate → calculation complete
→→ **Results** → **graphics and animations** → **contours** → **setup**

PRESSURE

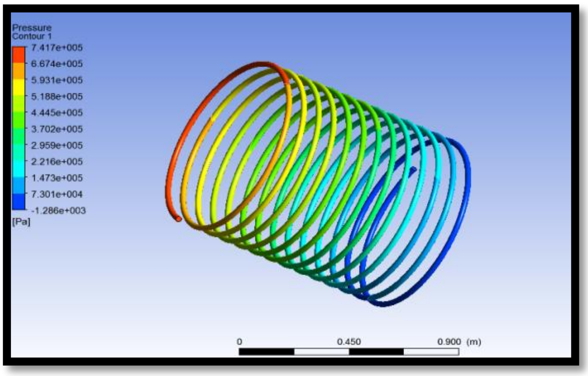

Fig 6 pressure

TEMPERATURE

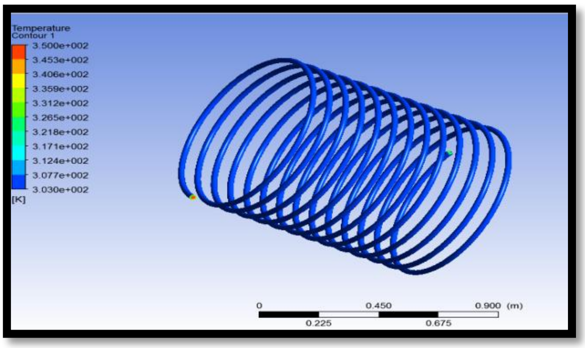

Fig 7 temperature

MASS FLOW RATE

Mass Flow Rate	(kg/s)
inlet	2.5915148
interior-____msbr	21561.639
outlet	-2.3933501
wall-____msbr	0
Net	0.1981647

HEAT TRANSFER RATE

Total Heat Transfer Rate	(w)
inlet	135058.17
outlet	-65275.977
wall-____msbr	-64687.754
Net	5094.4414

THERMAL ANALYSIS OF HELICALLY COILED CAPILLARY TUBES

MATERIAL-ALUMINUM

Open work bench 14.5>select **steady state thermal** in analysis systems>select geometry>right click on the geometry>import geometry>select **IGES** file>open

IMPORTED MODEL

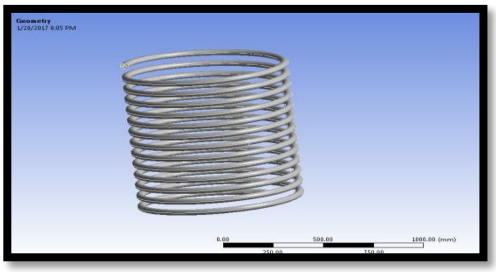

Fig 8 imported model

MESHED MODEL

Fig 9 meshed model

Finite element analysis or FEA representing a real project as a "mesh" a series of small, regularly shaped tetrahedron connected elements, as shown in the above fig.And then setting up and solving huge arrays of simultaneous equations. The finer the mesh, the more accurate the results but more computing power is required.

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BOUNDARY CONDITIONS

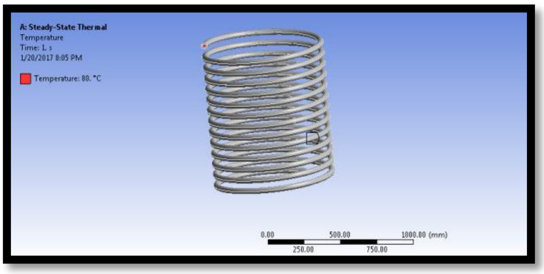

Fig 10 temperature

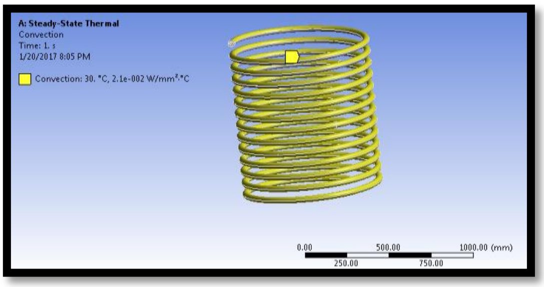

Fig11 convection

T =353K
Select steady state thermal >right click>insert>select convection> enter film coefficient value Select steady state thermal >right click>insert>select heat flux
Select steady state thermal >right click>solve
Solution>right click on solution>insert>select temperature
Heat transfer co-efficient values are taken from CFD analysis at different velocities

MATERIAL- ALUMINUM COIL DIAMETER-25mm

TEMPERATURE

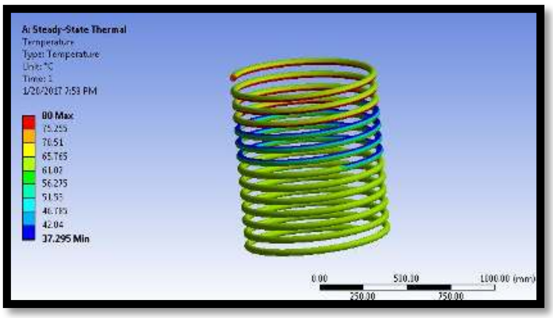

Fig 12 temperature distribution

HEAT FLUX

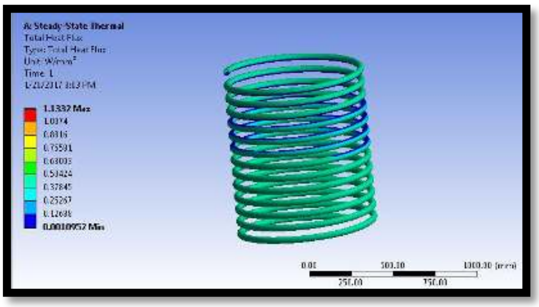

Fig 13 heat flux

COIL DIAMETER-30mm

TEMPERATURE

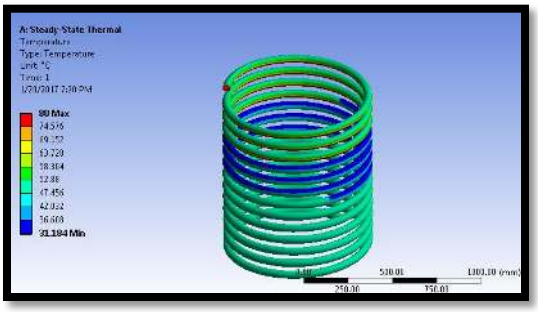

Fig 14 temperature distribution

HEAT FLUX

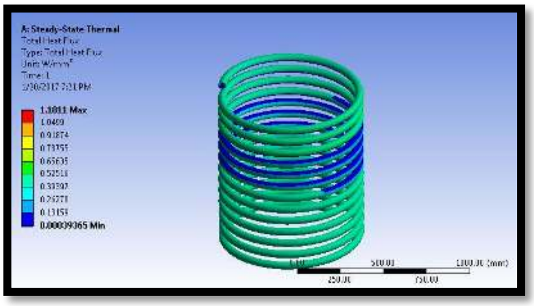

Fig 15 heat flux

COIL DIAMETER-40mm

TEMPERATURE

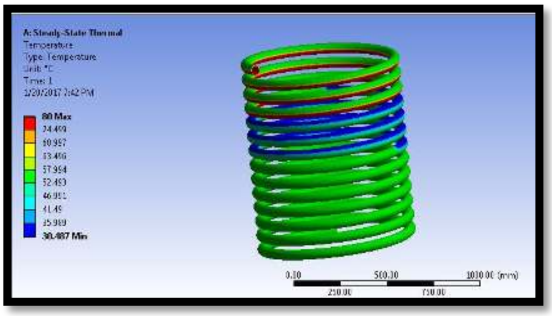

Fig 16 temperature distribution

HEAT FLUX

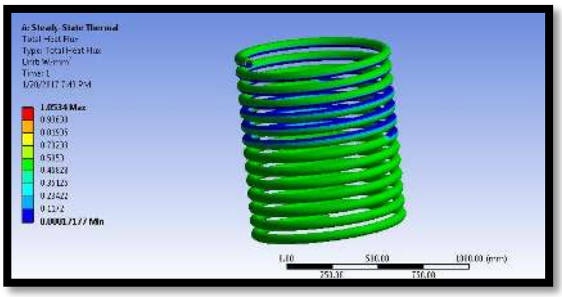

Fig 17 heat flux

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COIL DIAMETER-50mm

TEMPERATURE

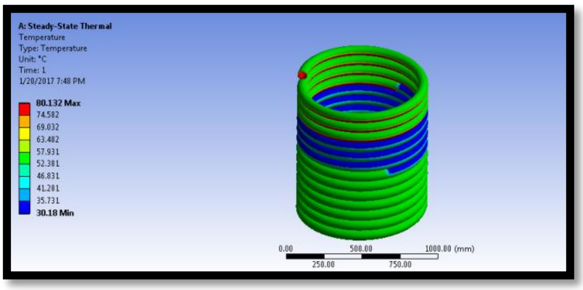


Fig 18 temperature distribution

HEAT FLUX

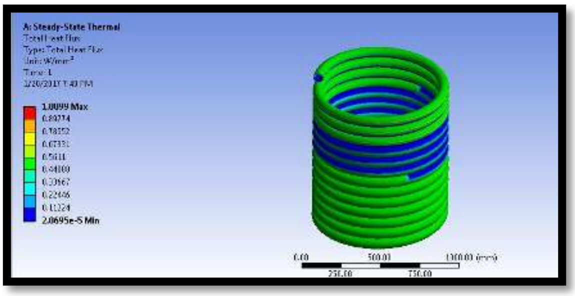


Fig 19 heat flux

MATERIAL- COPPER
COIL DIAMETER-25mm

TEMPERATURE

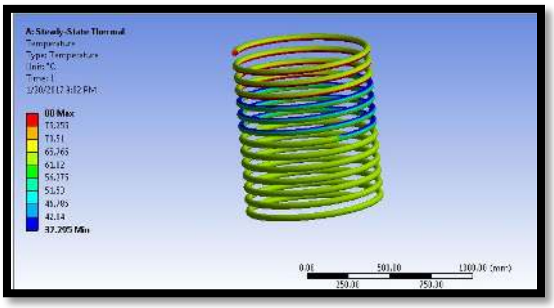


Fig 20 temperature distribution

HEAT FLUX

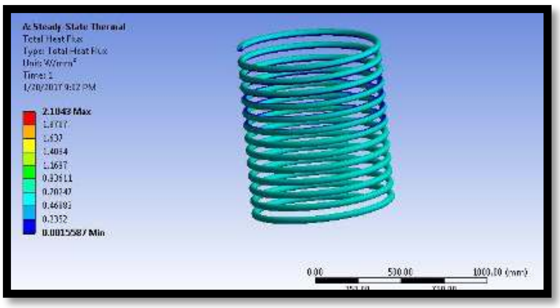


Fig 21 heat flux

RESULT TABLES

CFD ANALYSIS RESULTS

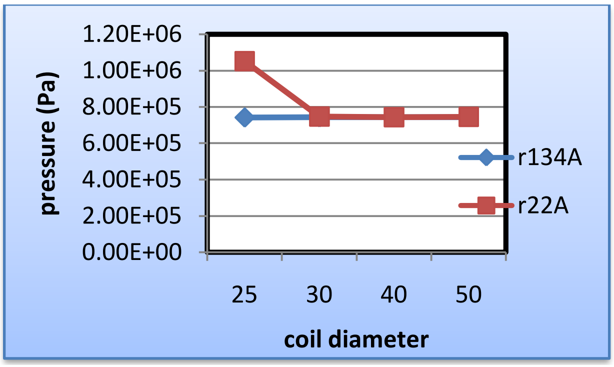
Fluid	Coil dia. (mm)	Pressure (Pa)	Temperature (k)	Mass flow rate(Kg/sec)	Heat transfer rate(w)
R134A	25	7.417e+05	3.50e+02	0.1981647	5094.4414
	30	7.431e+05	3.50e+02	0.088071	4438.2969
	40	7.430e+05	3.50e+02	0.30208788	17768.25
	50	7.436e+05	3.50e+02	1.477181	79467.406
R22A	25	1.052e+06	3.50e+02	0.2952	15173.382
	30	7.471e+05	3.50e+02	0.1247	6491.99
	40	7.440e+05	3.50e+02	0.06250	3696.4023
	50	7.451e+05	3.50e+02	0.58710	30365.797

THERMAL RESULT TABLE

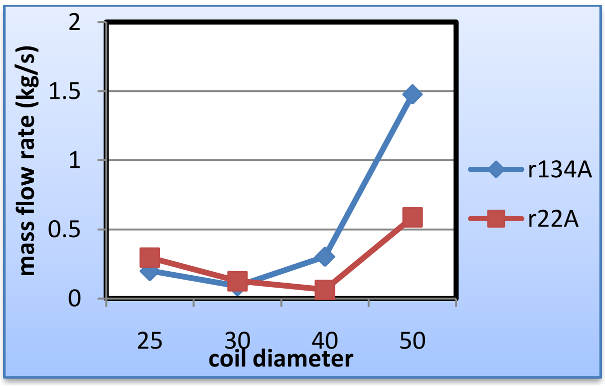
Coil dia.(mm)	Material	Temperature (^{0}C)		Heat flux (w/mm^2)
		Min.	Max.	
25	Aluminum	31.91	80	1.1332
30		31.184	80	1.1881
40		30.487	80	1.0534
50		30.18	80.123	1.0099
25	Copper	37.25	80	2.1043
30		35.322	80	2.2149
40		32.955	80	1.9819
50		33.0	80.063	1.903

GRAPHS

Pressure plot



Mass flow rate plot



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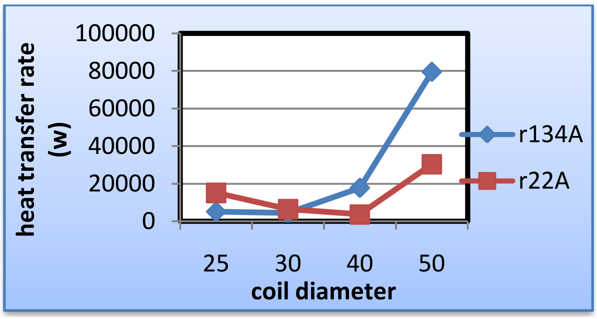
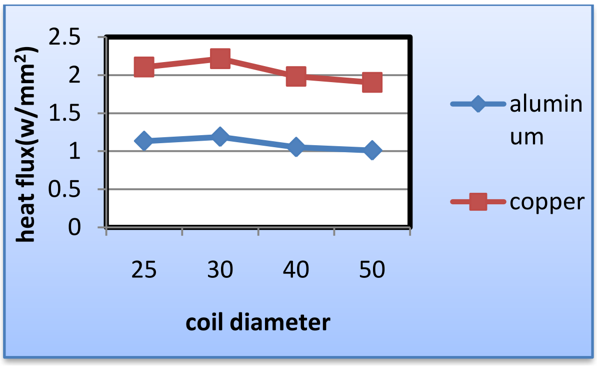
Heat transfer rate plot



Heat flux plot



CONCLUSION

In this thesis, the effects of the relevant parameters on the flow characteristic of R134a and R-22 flowing through adiabatic helical capillary tubes were experimentally studied. The capillary tubes' diameter, coil diameter, and parameters relating to flow conditions such as inlet pressures and degree of sub cooling were the major parameters investigated. By observing the CFD analysis the pressure drop value is increased at coil dia. 25mm by the fluid R22A. By observing the thermal analysis, the Heat flux value is more for copper when we compare with aluminum material. So we can conclude the copper material and fluid R22A better for capillary tube.

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