CFD FLOW ANALYSIS OF A REFRIGERANT INSIDE ADIABATIC CAPILLARY TUBE

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ABSTRACT:

Capillary tubes are widely used as a refrigerant flow control device in small refrigeration systems. Since the flow behavior inside the capillary tube is complex, many physical models are necessary to predict the characteristics of the refrigerant flow in a capillary tube. The refrigerant leaves the compressor at high pressure and temperature and enters the condenser. After leaving the condenser the refrigerant is at medium temperature and high pressure and then it enters the Capillary tube. In the Capillary tubes the pressure and the temperature of the refrigerant is reduced drastically and suddenly. Thus, us it is the throttling valve where the temperature of the refrigerant is reduced and it is then able to produce the cooling effect in the evaporator of the refrigerator or the cooling coil of the air conditioner. In the present investigation, an attempt is made to analyse the flow Analysis of the refrigerant inside a straight capillary tube and coiled capillary tube for adiabatic flow conditions. The proposed model can predict flow characteristics in adiabatic capillary tubes for a given mass flow rate.

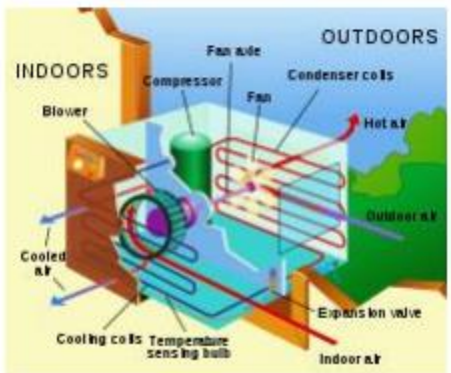
In this thesis, the CFD analysis is to determine the heat transfer rate, pressure drop, velocity, mass flow rate and heat transfer coefficient for the fluids R134A and R-22 with capillary tube and coiled capillary tube of inner diameter 1.27 mm and outer diameter 2 mm used the same model to study the flow characteristics of refrigerant in ANSYS software. Thermal analysis is to determine the temperature distribution and heat flux for copper and aluminum as tube materials. 3D modeling is done in CATIA software and analysis is done in ANSYS software.

Keywords: *CFD, Fluid Flow, ANSYS, Refrigeration.*

1. INTRODUCTION

Air conditioning system

An air conditioner 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.



Air Conditioning System

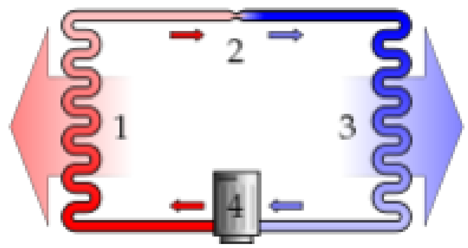
A simple stylized diagram of the refrigeration cycle:

1) Condensing coil,

2) Expansion valve,

3) Evaporator coil,

4) Compressor.



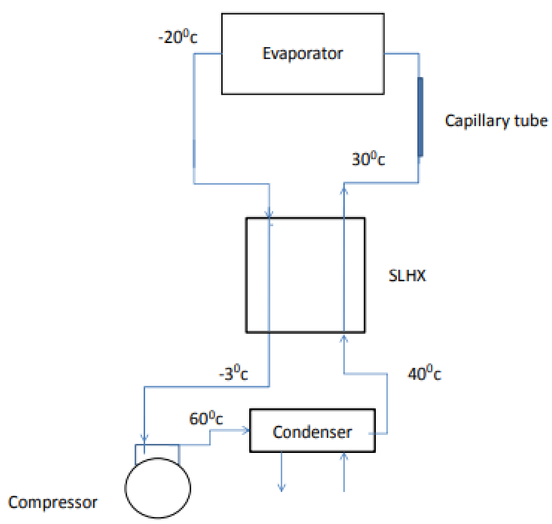
Refrigeration cycle

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. A refrigerator works in much the same way, as it pumps the heat out of the interior and into the room in which it stands. This cycle takes advantage of the way phase changes work, where latent heat is released at a constant temperature during a liquid/gas phase change, and where varying the pressure of a pure substance also varies its condensation/boiling point. By placing the condenser (where the heat is rejected) inside a compartment, and the evaporator (which absorbs heat) in the ambient environment (such as outside), or merely running a normal air conditioners refrigerant in the opposite direction, the overall effect is the opposite, and the compartment is heated. This is usually called a heat pump, and is capable of heating a home to comfortable temperatures (25 °C;

70 °F), even when the outside air is below the freezing point of water (0 °C; 32 °F).

DESIGN CONDITION FOR THE CAPILLARY TUBE

Design a capillary tube used in a specially arranged vapour compression refrigeration system (VCRS) between a suction line heat exchanger (SLHX) as condensate sub-cooler and evaporator outlet as vapour super heater



OBJECTIVES

- To conduct experiment on adiabatic condition capillary tube.
- To develop simulation models for helical capillary using ANSYS CFD module.
- To design a helical coiled capillary tube to replace the existing straight capillary tube with same length and diameter.

LITERATURE REVIEW

A Capillary Tube-Refrigerant Charge Design Methodology for Household Refrigerators-Part II: Equivalent Diameter and Test Procedure

In the first part of this work an experimental apparatus was designed and constructed to map the energy consumption of a household refrigerator subjected to several combinations of refrigerant charge and expansion restriction. In the second part, the expansion restriction imposed by the pair metering valve-capillary tube was converted into an equivalent tube diameter applying two different procedures: dry nitrogen flow and mathematical modeling. An empirical correlation to estimate the energy consumption based on the capillary tube inner diameter and refrigerant charge was also developed and used during the minimization process. Different strategies were also explored in order to reduce the amount of experiments to a minimum. It was found that at least 14 data points, collected with three different refrigerant charges, are required to ensure the convergence of the energy consumption minimization process.

Theoretical Design of adiabatic capillary tube of a domestic refrigerator using refrigerant R-600a

This paper develops a more accurate theoretical procedure for the design of adiabatic capillary tube of a domestic refrigerator considering a rigorous pressure drop analysis on the refrigerant R-600a while expanding through that tube accompanied with phase change through flash vaporization. Here this eliminates the contradiction of existing concepts on the negative value of the frictional pressure drop after a short distance of expansion due to a large part contribution of the actual pressure drop towards the momentum gain pressure drop. Also this verifies that the momentum gain through phase change is by consumption of internal energy part of the enthalpy and no part of the actual pressure drop energy is used in this respect. So with the concept of nearly total pressure drop being used in overcoming the friction the design of an adiabatic capillary tube of available I mm diameter for 0.1 ton refrigeration capacity has been carried out here. This design procedure causes some increase in the required length of the capillary for a given refrigeration capacity due to the omission of momentum pressure drop concept of different references, but is more accurate with consideration of actual changes involved in the expansion. The procedure is applicable for any other refrigerant of any refrigeration capacity

An Experimental and Theoretical Analysis of Capillary Tube-Suction Li ne Heat Exchangers

This report describes the complete process of testing capillary tube-suction line heat exchangers (CfSLHX). and presents preliminary data for non-adiabatic flow of R-134a in the capillary tube, as well as the comparison between the experimental data and simulation results. Mass flow rate is proportional to cross-sectional area, so manufacturer-specified tolerances of ±O.OOl" correspond to mass flow uncertainties up to 10%. Therefore a laminar water test method was developed for determining diameter much more accurately. Nitrogen tests are subject to greater uncertainty, and were found to be incapable of discerning tube roughness. Three two-phase friction factor correlations were examined and compared to the data. Three CTSLHX's were tested over a range of subcooled inlet temperatures and pressures, and mass flows measured with a coriolis meter. Hysteresis was observed; mass flow is multivalued and depends on whether the flash point is moving upstream or downstream. The same effect was observed in an operating refrigerator, affecting its thermodynamic cycle efficiency by 3%.

METHODOLOGY

In all of these approaches the same basic procedure is followed.

- During preprocessing
- The geometry (physical bounds) of the problem is defined.
- The volume occupied by the fluid is divided into discrete cells (the mesh). The mesh may be uniform or non-uniform
- Boundary conditions are defined. This involves specifying the fluid behaviour and properties at the boundaries of the problem. For transient problems, the initial conditions are also defined.
- The simulation is started and the equations are solved iteratively as a steady-state or transient.
- Finally a postprocessor is used for the analysis and visualization of the resulting solution.

CATIA SOFT WARE

It is one of the leading 3D software used by organizations in multiple industries ranging from aerospace, automobile to consumer products. CATIA is a multi-platform 3D software suite developed by Dassault Systems, encompassing CAD, CAM as well as CAE. Dassault is a French engineering giant active in the field of aviation, 3D design, 3D digital mock-ups, and product lifecycle management (PLM) software. CATIA is a solid modelling tool that unites the 3D parametric features with 2D tools and also addresses every design-to-manufacturing process. In addition to creating solid models and assemblies, CATIA also provides generating orthographic, section, auxiliary, isometric or detailed 2D drawing views. It is also possible to generate model dimensions and create reference dimensions in the drawing views. The bi-directionally associative property of CATIA ensures that the modifications made in the model are reflected in the drawing views and vice-versa. The first release of CATIA was way back in 1977, and the software suite is still going strong more than 30 years later. While CATIA V6 is just being released, the most popular version of CATIA is V5 which was introduced in 1998. That said, it is important to note that each version of CATIA introduces considerable additional functionality. For example, V4 (introduced in 1992) offered enhancements to the Assembly Modeling Product including easy-to-use graphical tree-based assembly management. V5 and V6 saw changes in the way data is handled. Dassault Systemes typically offers new updates, releases and bug fixes for each version. The CATIA software is written in C++. It runs on both Unix and Windows.

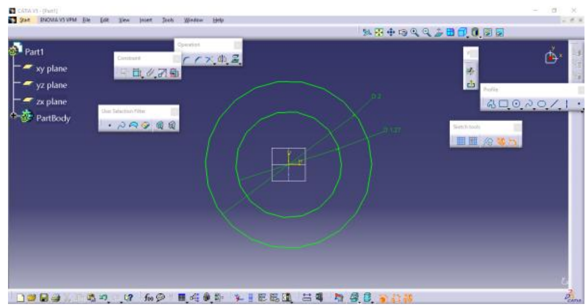
Part Design: The most essential workbench needed for solid modelling. This CATIA module makes it possible to design precise 3D mechanical parts with an intuitive and flexible user interface, from sketching in an assembly context to iterative detailed design.

Generative Shape Design: allows you to quickly model both simple and complex shapes using wireframe and surface features. It provides a large set of tools for creating and editing shape designs. Though not essential, knowledge of Part Design will be very handy in better utilization of this module.

Assembly: The basics of product structure, constraints, and moving assemblies and parts can be learned quickly. This is the workbench that allows connecting all the parts to form a machine or a component. Kinematic Simulation: Kinematics involves an assembly of parts that are connected together by a series of joints, referred to as a mechanism. These join

MODELLING AND ANALYSIS

2d model for straight tube

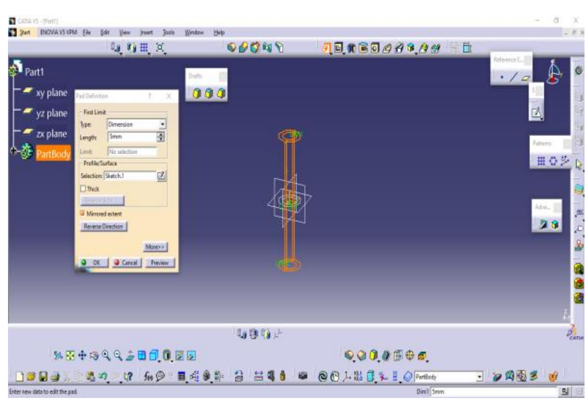


Straight tube capillary model designed in CATIA software. In CATIA software we have mainly 4 modules

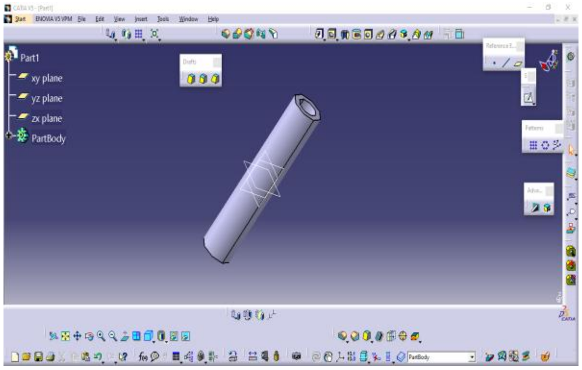
The modules are:

1. Sketcher
2. Part
3. Assembly
4. Drafting

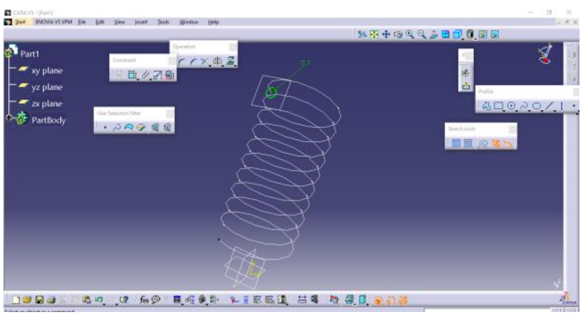
Here sketcher is used to develop the 2d drawings. Part module is used to convert the 2d drawing into 3d modeling. Assembly is used to combine the different parts. In capillary tube we have a main modules and sub modules.



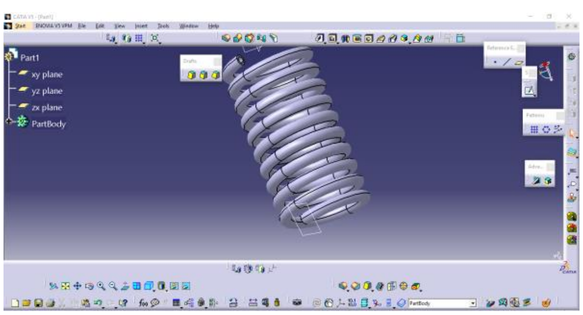
3d model straight tube



2D model of helix type capillary tube



3D model of helix type capillary tube



INTRODUCTION TO CFD

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

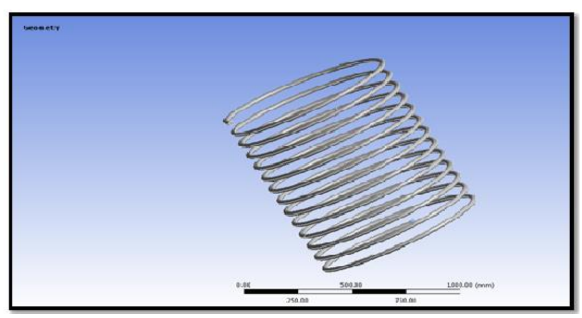
CFD ANALYSIS OF HELICALLY COILED CAPILLARY TUBES

FLUID – R134A

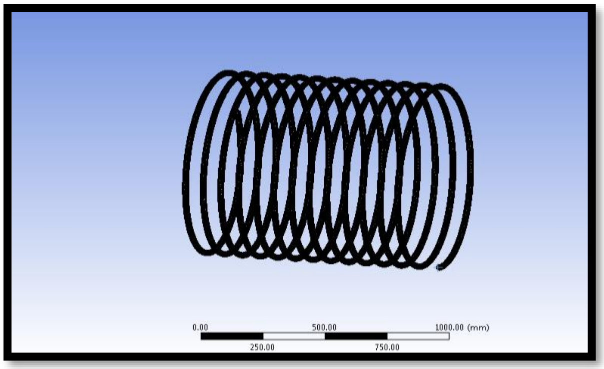
COIL DIAMETER-2mm

Material- copper

Import geometry

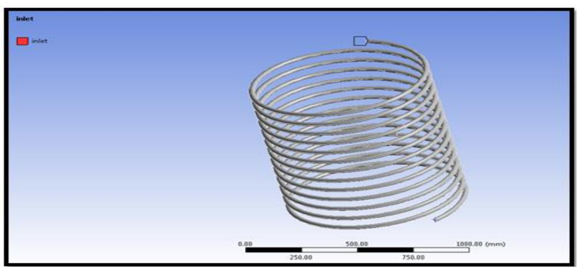


Meshing

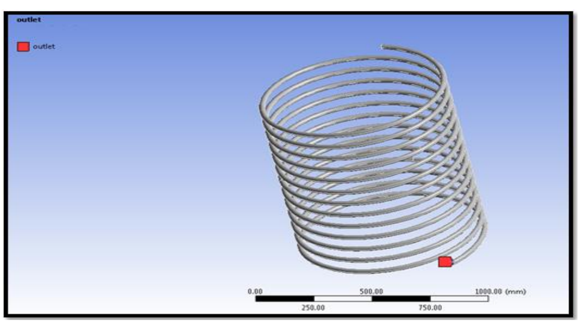


Boundary conditions

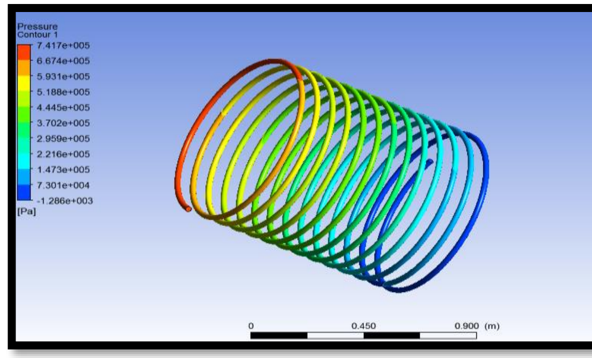
Inlet



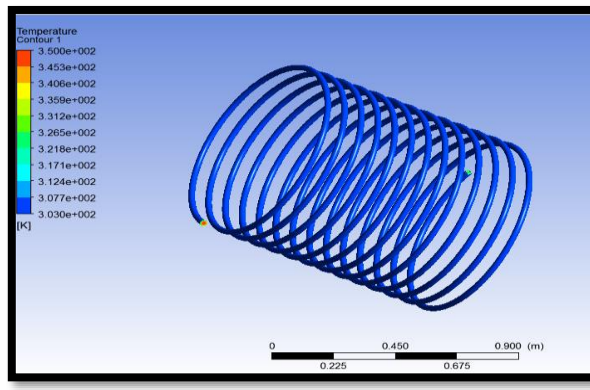
Outlet



Pressure



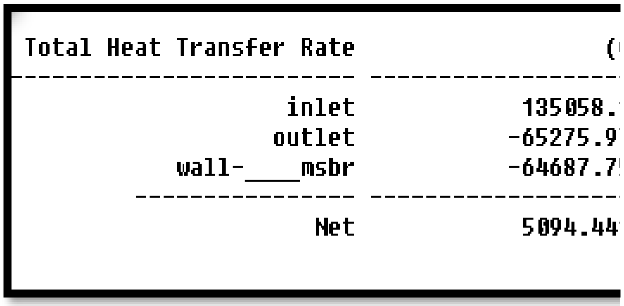
Temperature



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



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Total Heat Transfer Rate                          (
-------------------------  ------------------
                    inlet             135058.
                   outlet            -65275.9
             wall-____msbr           -64687.7
         ----------------  ------------------
                      Net              5094.44
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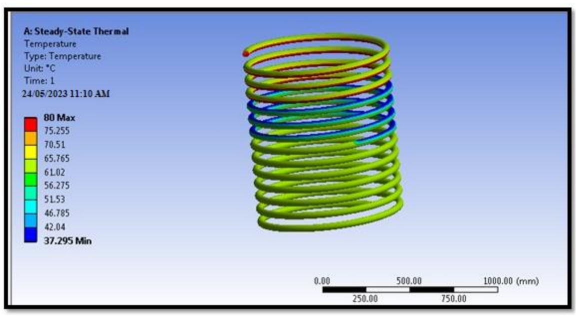
THERMAL ANALYSIS

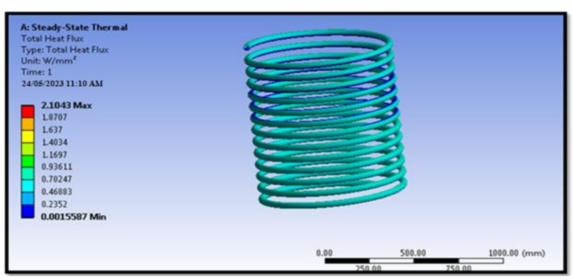
MATERIAL- COPPER

COIL DIAMETER-2mm

TEMPERATURE



HEAT FLUX



Result table

CFD results

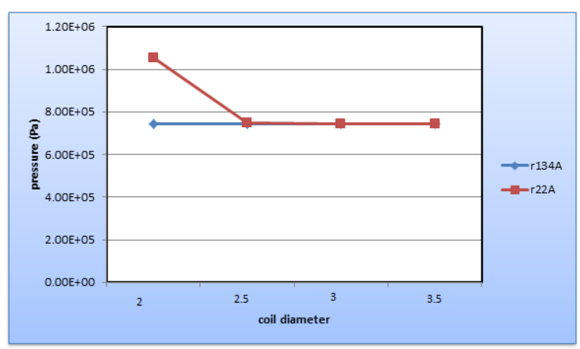
Fluid	Coil dia. (mm)	Pressure (Pa)	Temperature (k)	Mass flow rate(Kg/sec)	Heat transfer rate(w)
R134	2	7.417e+05	3.50e+02	0.1981647	5094.4414
	2.5	7.431e+05	3.50e+02	0.088071	4438.2969
	3	7.430e+05	3.50e+02	0.30208788	17768.25
	3.5	7.436e+05	3.50e+02	1.477181	79467.406
R22	2	1.052e+06	3.50e+02	0.2952	15173.382
	2.5	7.471e+05	3.50e+02	0.1247	6491.99
	3	7.440e+05	3.50e+02	0.06250	3696.4023
	3.5	7.451e+05	3.50e+02	0.58710	30365.797

Thermal results

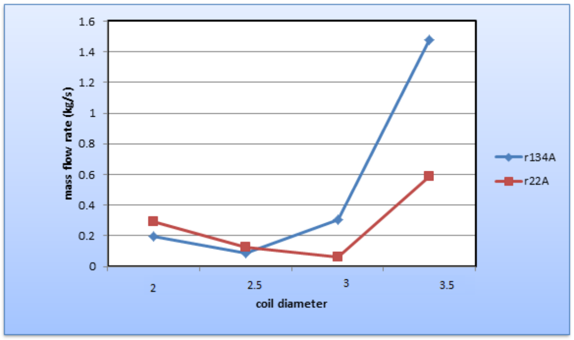
Coil dia.(mm)	Material	Temperature (^0C)		Heat flux (w/mm^2)
		Min.	Max.	
2	Aluminum	31.91	80	1.1332
2.5		31.184	80	1.1881
3		30.487	80	1.0534
3.5		30.18	80.123	1.0099
2	Copper	37.25	80	2.1043
2.5		35.322	80	2.2149
3		32.955	80	1.9819
3.5		33.0	80.063	1.903

GRAPHS

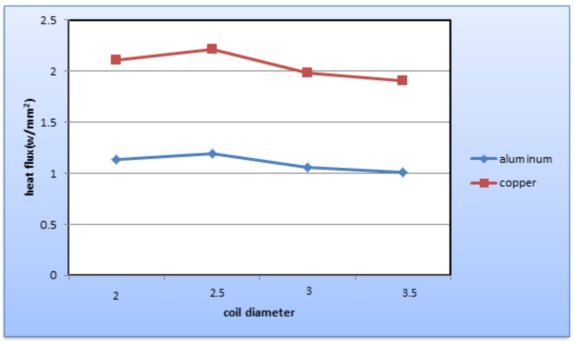
Pressure plot



Mass flow rate plot



Heat flux plot



CONCLUSION

In the present investigation, an attempt is made to analyse the flow Analysis of the refrigerant inside a straight capillary tube and coiled capillary tube for adiabatic flow conditions. The proposed model can predict flow characteristics in adiabatic capillary tubes for a given mass flow rate. In this thesis, the effects of the relevant parameters on the flow characteristic of R134a and R-22 flowing through adiabatic helical coiled tubes were analytical studied. The helical coiled 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. 2mm 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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