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Optimization of Material to Improve Heat Transfer in Air Cooled Condenser by Using CFD Analysis

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ABSTRACT: The performance of a cross-flow, micro-channel condenser of a vapour compression refrigeration system subjected to the maldistribution of air flow has been studied analytically.

The performance of condenser is studied analytically by changing fins materials when using R22 and R407c. Especially, the material with high thermal conductivity is used as fins material. In this thesis like copper aluminium and brass are chosen to analyse the performance of fin materials on condenser efficiency.

To evaluate heat transfer rate and heat transfer coefficient for the fluids R-22 and R407c with different fins materials ANSYS software is used. Thermal analysis is to determine the temperature distribution and heat flux for all three materials. 3D modelling is done by Creo-parametric.

By comparing results of aluminium and brass with copper fins of condenser, it is observed that using copper as a fin material for high cooling capacity and COP of the condenser when using refrigerant R407c. In steady state thermal analysis thermal error and total heat flux for copper having the significant variation i.e., thermal error = 0.0074696 and total heat flux = 22752 W/m². While considering fluent analysis for R22 and R407c it is absorbed that contours of enthalpy and contours of static temperature for R407c is giving better results i.e., contours of enthalpy 4200 J/kg and contours of static temperature 309 k

I. INTRODUCTION

There are two types of air conditioner fins: condenser fins and evaporator fins. Each performs a similar job of allowing air to flow smoothly through and out of an air conditioner, while each does this in a unique way. Compressor fins are located on the outdoor portion of an air conditioner near the compressor is something that looks like a grill with metal fins all along it. These air conditioner fins are a part of the condenser that assists heat in moving away from the air conditioner so that the heat disperses more quickly. 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. A diagram of the refrigeration cycle Air-cooled finned-tube condensers are widely used in refrigeration and air-conditioning applications. For the same amount of heat transfer, the operation of air cooled condensers is more economic as compared with water cooled condensers. Typically air-cooled condensers are of the round tube and fin type. To improve the performance of air-cooled condensers multiple techniques can be achieved such as enhancements on inner pipe surface, changing the tube geometry from round to flat shape and external fins A micro-channel flat tubes heat exchanger is one of the potential alternatives for replacing the conventional finned tube heat exchangers.

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II. LITERATURE REVIEW

REVIEWS ON RECENT MATERIALS OF COOLING FINS OF CONDENSER:

The majority of the research work focused condenser fins efficiency. But in this thesis discusses the single air-cooled. The refrigerant used in this heat exchanger is R22. Compare the analytical results value of existing system with new modified system. Here using different materials like Copper Aluminium and brass as condenser fin materials and analysis is done at constant air flow.

INVESTIGATION ON CONDENSER FINS:

Jameel and Syed (1999) have developed a thermodynamic model to simulate the working of actual refrigeration system. Simple cycle used for the analysis showed that the super heating has more influence on the COP of the system. Using this model, the COP and other system parameters were calculated with $\pm 2\%$ accuracy. **Liang and Wong (2001)** conducted experiments and developed a model to exploit the possibility of applying the equilibrium two-phase drift flux model to simulate the flow of refrigerant R134a in the capillary tube expansion device. The details of flow characteristics of R134a in a capillary tube, such as distribution of pressure, void fraction, dryness fraction, phase's velocities and their drift velocity relative to the center of the mass of the mixture are presented. **Corberan et al (2004)** predicted a model to calculate the mass flow rate of refrigerant in a capillary tube by means of the conservation equations (mass, momentum and energy) over individual control volumes and included in IMST-ART, software for simulation and design of refrigeration equipment. The addition of capillary tube model allows calculating the superheat at the evaporator giving the capillary tube geometry. A simulation with different operative conditions and capillary geometry is done and the results are compared for R22 with those given by ASHRAE correlations. **Li et al (2004)** presented a general model format for Adjustable Throat Area Expansion Valves (ATAEV), including TEV and EEV that utilizes manufacturer's rating data. Model structures for three types of valve geometries are derived. The model format for ATAEV was validated by using manufacturer performance rating data and the flow through the adjustable area expansion device is not choked. Two model formats and parameter estimation procedures were considered and their predictions were compared with laboratory measurements. The non linear modeling approach only requires data at a rating condition to obtain parameters and gave good predictions over a wide range of operating conditions when compared with laboratory data.

Sarntichartsak et al (2007) conducted experiments on inverter air conditioner with variation of capillary tube using R22 and R407C and predicted model. The two zone model, the distributed model and combined model were compared to estimate the optimal charge inventory. The model prediction agrees with the experimental data in the range of 40 -50 HZ. **Beghi et al (2009)** reported some results of a research project aimed at deriving simple, high-performance, adaptive and robust control algorithms for EEV to control dry expansion evaporators superheat temperature. The adaptation scheme is based on the on-line identification of simplified, first order plus dead time (FODPT) model of the process. The Zhaung-Atherton method is then used to derive a new set of Proportional Integral-Derivatives (PID) parameters, which allow the system to improve the closed-loop performance. The control algorithm has been evaluated by restoring to a detailed, a particular virtual prototyping software environment. The algorithm exhibits better performance than other auto tuning approaches, such as the one based on relay feedback. The performance has been evaluated by resorting to standard indexes such as Integral Squared Error (ISE) and Integral Squared Time Weighted Error (ISTE). **S.S. Hu and B.J. Huang** investigated of a high-efficiency split residential water cooled air conditioner that utilizes cellulose pad as the filling material of the cooling tower. The cooling tower performance is improved due to good water wet ability of the cellulose pad that causes a uniform water film over the entire surface of the pads and a perfect contact between water and cooling air. The cooling tower is integrated with the condensing unit of the Rankine cycle in structure design to form a vintegral-type outdoor unit.

DESIGN CALCULATIONS OF CONDENSER:

Dimensions of the condenser tube made up of copper:

1. Diameter of tube =10mm
2. Length of the condenser =300mm
3. Height of the condenser =30mm

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4. Pitch value = 15mm
 5. No. of turns =11
- Dimensions of fins:
1. Height of the fin = 300mm
 2. Thickness of the fin = 1mm
 3. Width= 50mm
 4. No. of fins =10

Condenser tube is designed into two parts later it assembled in pro-e assembling software. Part design and assembled part is indicated below

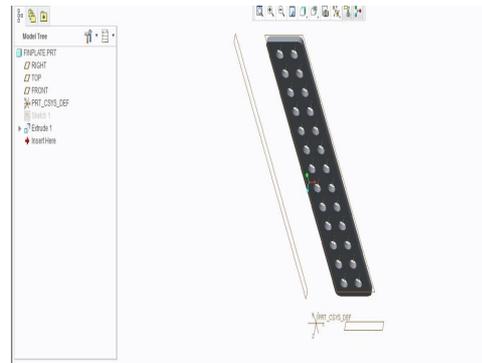
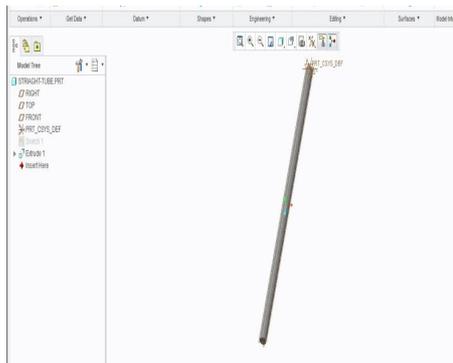


Fig 3.1: Image represents condenser tube of dia 10mm condenser fin plate of 1 mm thickness and 300 mm length.

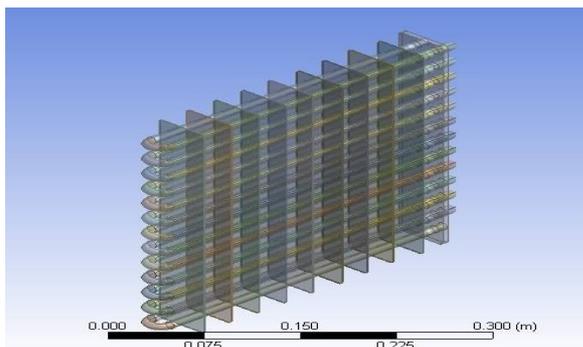


image represents 3D model of condenser.

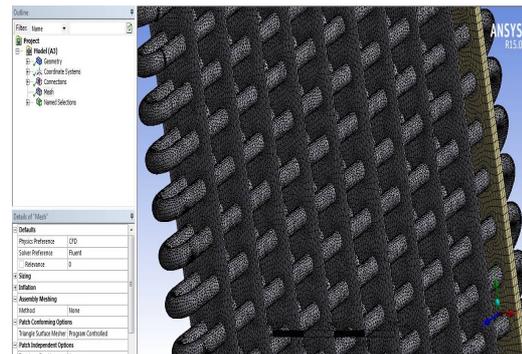


image represents mesh model of condenser

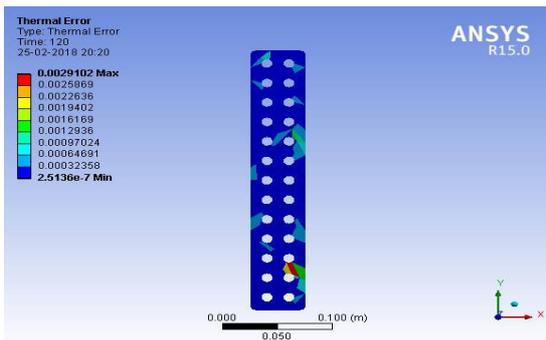
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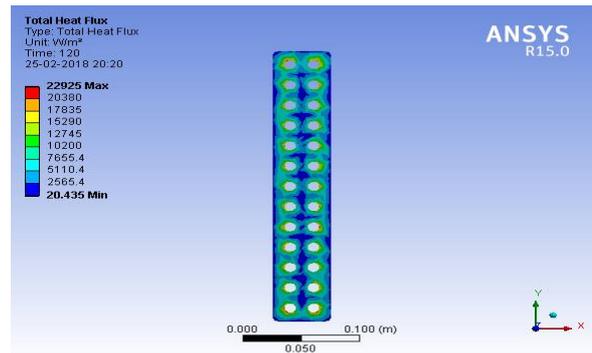
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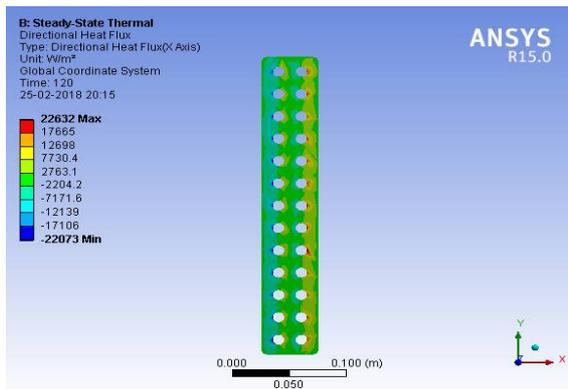
ANALYSIS OF FIN:



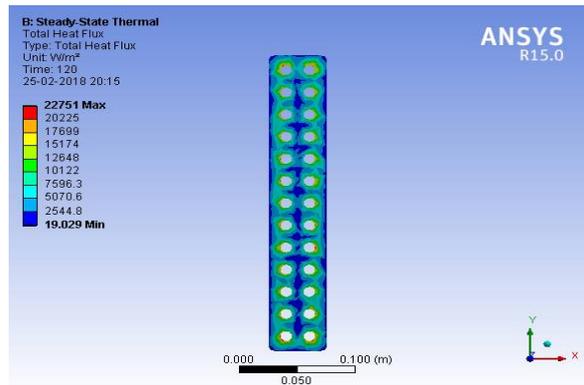
thermal error of Al fin in steady state thermal analysis



heat flux of brass fin in steady state thermal analysis

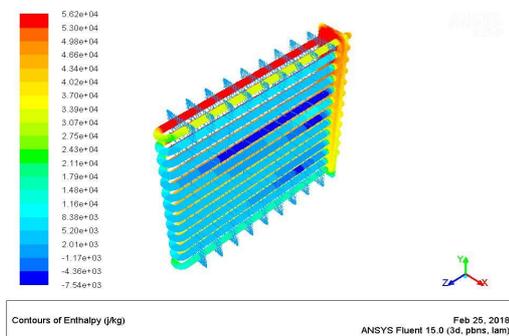


heat flux of copper fin in steady state thermal analysis

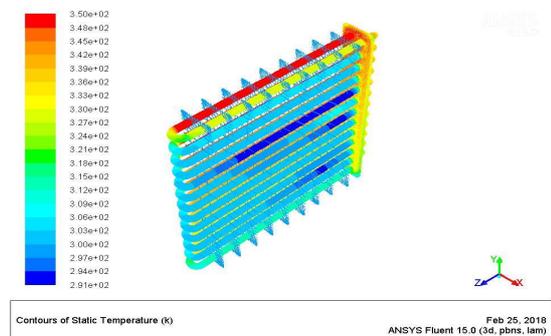


heat flux of copper fin in steady state thermal analysis

ANALYSIS OF CONDENSER:



counters of enthalpy of aluminium fins using R22



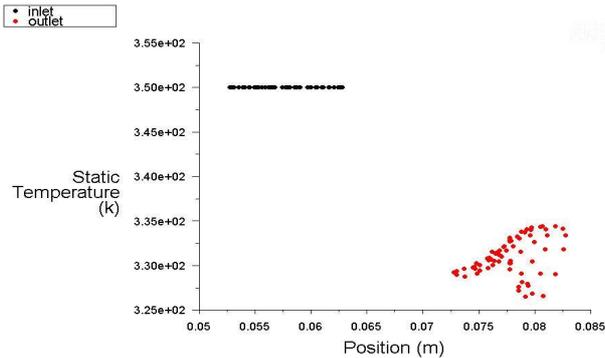
static temperature of aluminium fins while using R22

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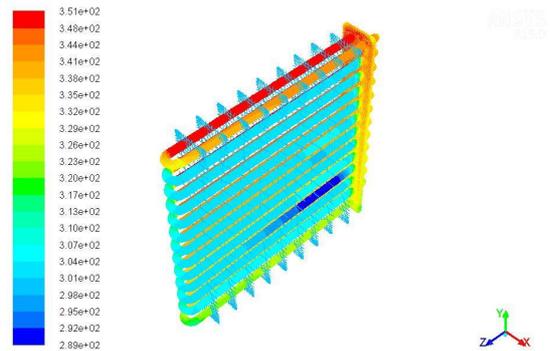
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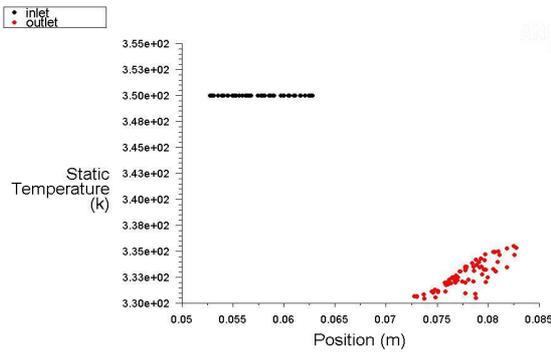
Static Temperature
Feb 25, 2018
ANSYS Fluent 15.0 (3d, pbns, lam)

static temp. vs position in condenser with Al fins using R22



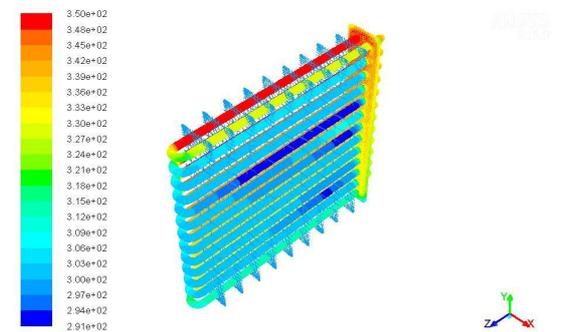
Contours of Static Temperature (k)
Feb 25, 2018
ANSYS Fluent 15.0 (3d, pbns, lam)

static temp. in condenser with Al fins while using R407c



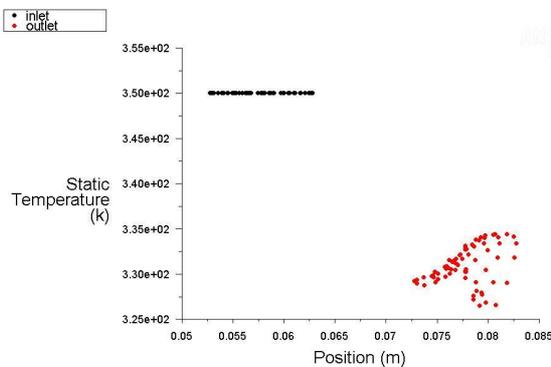
Static Temperature
Feb 25, 2018
ANSYS Fluent 15.0 (3d, pbns, lam)

static temp. vs position in condenser with Al fins using R407c



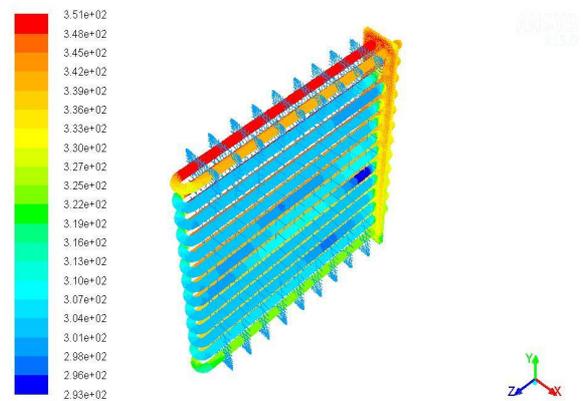
Contours of Static Temperature (k)
Feb 25, 2018
ANSYS Fluent 15.0 (3d, pbns, lam)

static temp in condenser with copper fins using R22



Static Temperature
Feb 25, 2018
ANSYS Fluent 15.0 (3d, pbns, lam)

static temp vs position in condenser with copper fins using R22



Contours of Static Temperature (k)
Feb 25, 2018
ANSYS Fluent 15.0 (3d, pbns, lam)

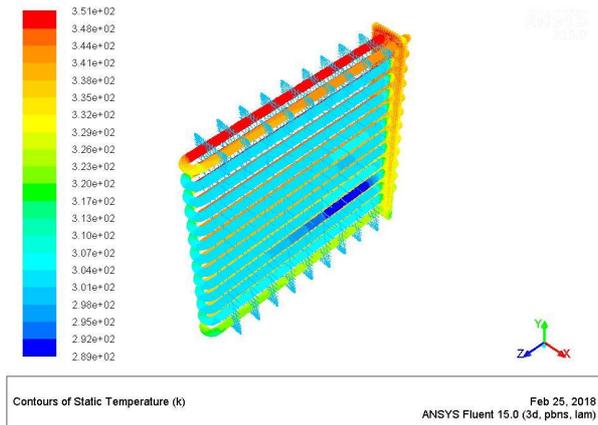
enthalpy in condenser with brass fins using R407c

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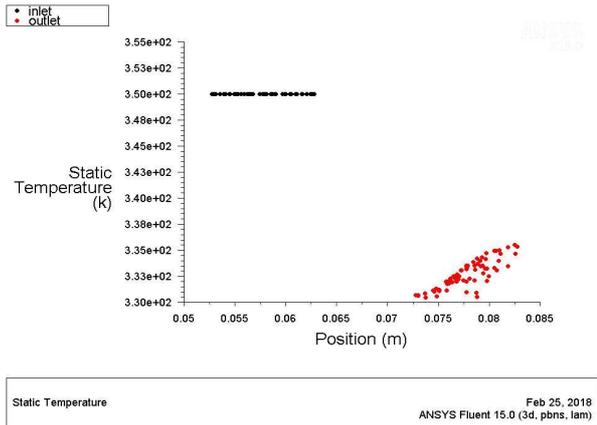
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static temp. in condenser with copper fins while R407c



temp vs position in condenser with copper fins using R407c

III. RESULTS

1.1. Results of Steady state thermal analysis

In this table temperature and heat flux of the material copper is low when compared to and brass. Hence it shows copper is better material when compare to aluminum and brass

Material	Directional heat flux W/m ²	Thermal error	Temperature °C	Total heat flux W/m ²
Aluminium	22806	0.0029102	60	22925
Copper	22632	0.0074696	60	22752
Brass	22810	0.002814	60	22929

Table: 4.1. Table indicating directional heat flux, thermal error, temperature and total heat flux of the materials, copper and brass.

1.2. Results of fluent analysis for R22

this table contours of enthalpy “j/kg” and Contours of static temperature “k” of copper with R22 is far better then and brass. Hence it shows copper is better material when compare to aluminum and brass.

R22		
	Contours of enthalpy j/kg	Contours of static temperature k
Aluminium	1790	318
Copper	1480	312
Brass	1160	315

Table: 4.2. Table indicating Contours of enthalpy j/kg and Contours of static temperature k of the materials, copper and brass when using R22.

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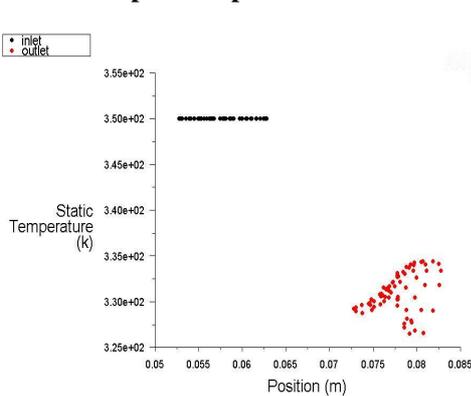
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1.3. Results of fluent analysis for R407c

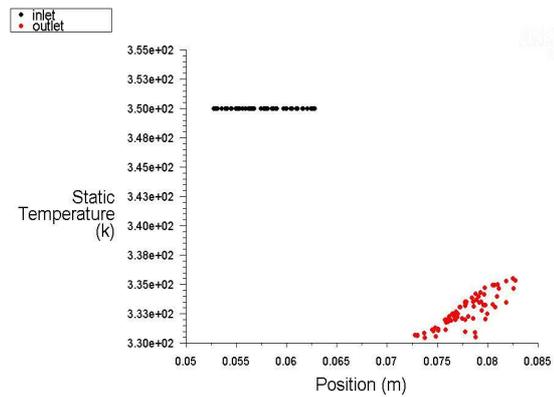
R407c		
	Contours of enthalpy j/kg	Contours of static temperature k
Aluminium	3350	326
Copper	4200	309
Brass	3600	325

Table: 4.3. Table indicating Contours of enthalpy j/kg and Contours of static temperature k of the materials , copper and brass when using R407c

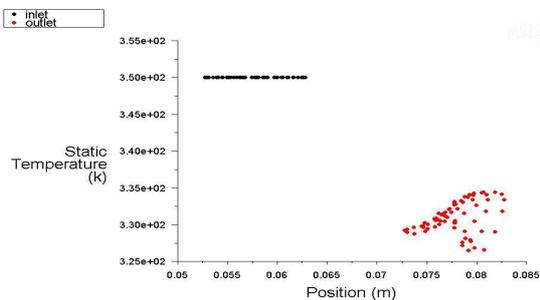
1.4. Graphical representation:



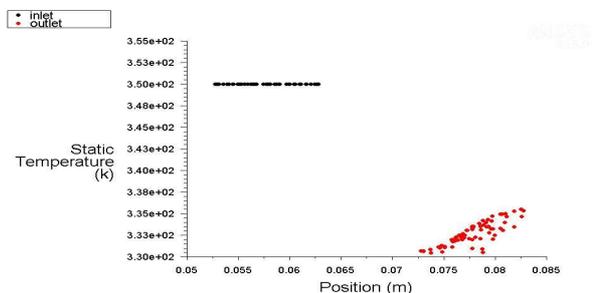
Static Temperature vs Position (m) in condenser with Al fins using R22



Static Temperature vs Position (m) in condenser with Al fins using R407c



Static Temperature vs Position (m) in condenser with copper fins using R22



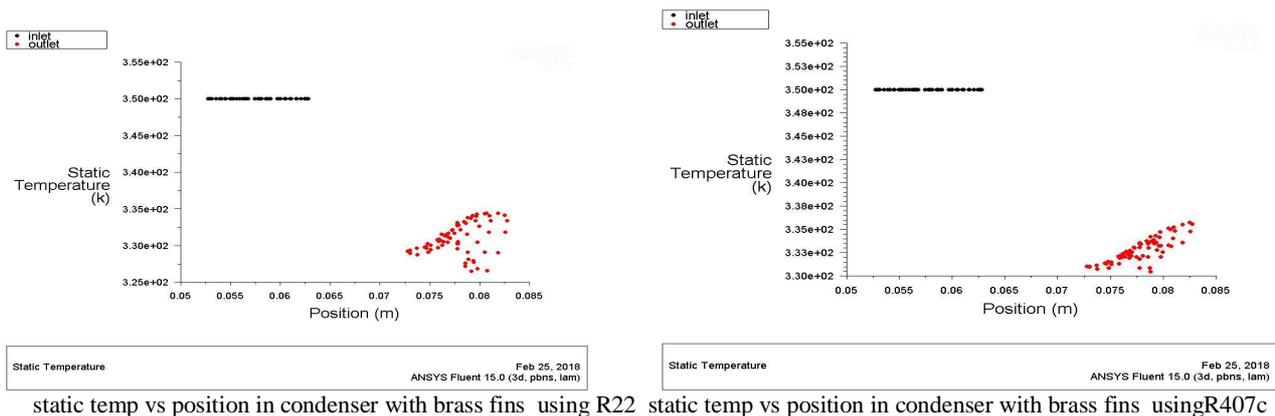
Static Temperature vs Position (m) in condenser with copper fins using R407c

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IV. CONCLUSION

In this paper I have designed an air conditioner condenser. Present used material for fin is aluminium alloy and cooling fluid is HCFC. I have modeled the condenser in 3D modeling software pro-engineering. To optimize the condenser for best result, thermal analysis is done on the condenser. Analysis is done using fin materials like aluminium, copper and brass because of high thermal conductivity. In earlier studies, use of alternative refrigerants plays an important role in forming problems such as global warming and ozone depletion. It is observed that R407c has zero ODP, considerably GWP, low flammable, eco-friendly refrigerant and also observed nearly the same flow characteristics of R22 observed in this thesis.

By observing the thermal analysis results, by using fin material copper thermal flux is more then by using other two materials. Comparing R22 and 407c, R22 has high temperature at 6th turn of coil after 6th turn it gaining energy from surroundings reaches same temperature at the end. For R407c it happens at 11th turn of the coil, So, R407c is better to use with 11 turns for effective condensation. So I conclude that using condenser with fin thickness of 1mm and fin material copper gives better results.

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