Numerical Analysis of Condenser Using ANSYS

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Abstract -*In the current research convective heat transfer characteristics of an air-cooled finned-tube condenser of a vapour compression cycle for air conditioning system. Heat transfer analysis and CFD analysis is done on the condenser to evaluate the better design and refrigerant using R134 and R11 refrigerants. The effect of fins made from Aluminium on condenser design is also analyzed for both the refrigerants (R11 and R134). The CAD model is developed using Creo 2.0 software and CFD analysis is conducted using ANSYS CFX software. Standard k-epsilon turbulence model is used for analysis. Heat rejection rate is determined from theoretical calculations on the basis of simulation results and comparative analysis is made.*

Key Words: *CFD, Condensers, Refrigerant*, ANSYS, R134

1. INTRODUCTION

Condenser as the name suggests is used to condense vapours coming from compressors. The condensers are used for both domestic and commercial refrigeration as well as air conditioning units. The design of condenser resembles that of car radiator. The condensation (gaseous to liquid state) of refrigerants in condenser is achieved by cooling the refrigerants. During the process of condensation, the latent heat is dissipated to coolant used in condenser. The condensers are designed for small size and large size. The small size are compatible and could be held by hand while large size are employed in industrial units for plant operations. In domestic refrigerators the cabin heat is extracted to outside environment by the use of condenser.

2. LITERATURE REVIEW

Vanfossen and Brigham [1] conducted experimental investigation of cylindrical pin fin with varying h/D ratio and its effect on augmentation of HTC is analyzed. The parameters varied are fin height and pin fin diameter. The findings have shown that h/D ratio of 4 gave an increment by 35%.

Tian et al. [2] investigated the wavy fin-and-tube heat exchanger with delta winglets with oblique arrangement of wavy fins. The findings have shown that heat transfer characteristics of finned tube heat exchanger are greatly reduced by fouling.

Feng et al. [3] studied various fin structure and concluded that the discontinuous short-wave fin enhances heat transfer by periodic generation of boundary layer.

Bell and Groll [4] investigated condensers with micro channel to determine effect on air side pressure drop and effect of fouling. The findings have shown that micro channel coil having pitch below 2mm and louvered fin are prone to fouling as compared to larger fin pitch for louvered heat exchangers.

Lijun Yang et al. [5] modelled new wave-finned flat tube bundle where fin surface was rotated to perpendicular to prevents fouling problem. The characteristics of the pressure drop and heat flow rate of the orthogonal and oblique finned tubes with the air velocity at the minimum flow area were compared which shows that orthogonal finned tube has higher heat transfer rate than the oblique finned tube arrangement but at the same time with the penalty of increase in pressure drop, since the length of the orthogonal finned tube was almost twice that of oblique one and hence pressure drop gets increased. Effects of fin pitch were discussed which shows how friction factor (f) varies with the non-dimensional fin pitch at different Re.

3. OBJECTIVE

Our objective of current research is to analyse cooling efficiency of refrigerator condenser by increasing surface area using fins and changing refrigerants. The refrigerants used for analysis are R134 and R11. Numerical Analysis of condenser is conducted using ANSYS CFX software.

4. METHODOLOGY

The CAD model of condenser is developed using Creo 2.0 software which is sketch based, parametric 3d modelling software developed by PTC and having properties of parent child relationship and bidirectional associativity. The dimensions of condenser are given below in figure 1.

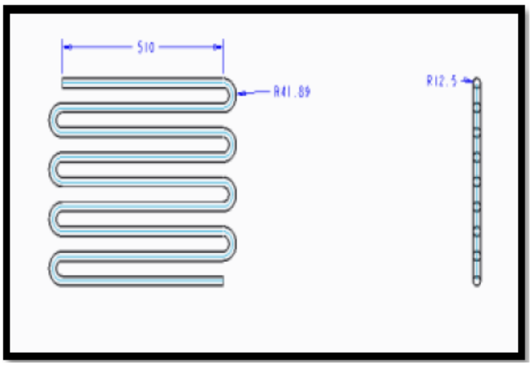

Figure 1: Dimensions of condenser tubes without fins

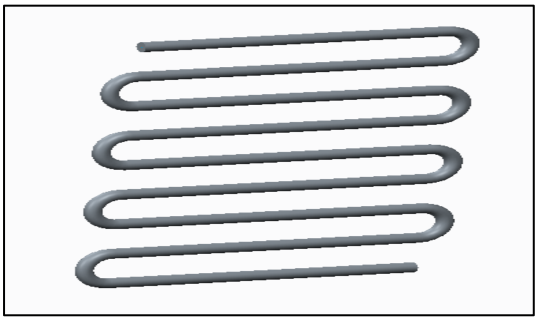

Figure 2: CAD model of condenser tubes without fins

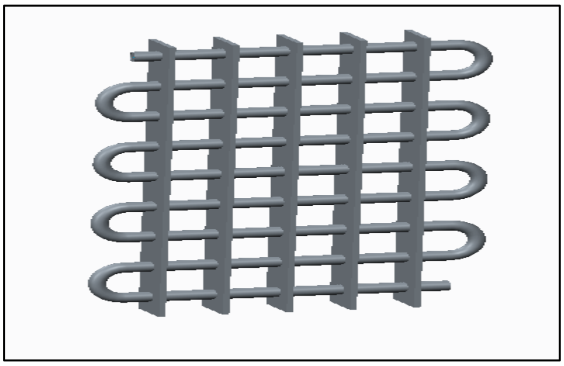

Figure 3: CAD model condenser tubes with and without fins

2 above. The 1st design shows condenser tubes without fins and 2nd model shows condenser tubes with fins as shown in figure 3 above. The CAD model developed in Creo is imported in ANSYS software as shown in figure 4 below. The CAD model is checked for geometric errors, hard edges, sleeves etc.

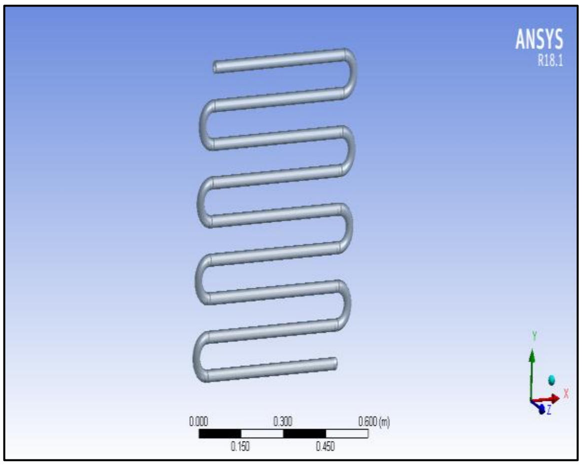

Figure 4: Imported CAD model in ANSYS

The CAD model developed is meshed using hexahedral elements and fine sizing as shown in figure 5 below. The element sizing selected is fine sizing and transition set to slow, span angle center set to fine, growth rate default, smoothing medium. The number of elements generated is 101050 and number of nodes generated is 159704.

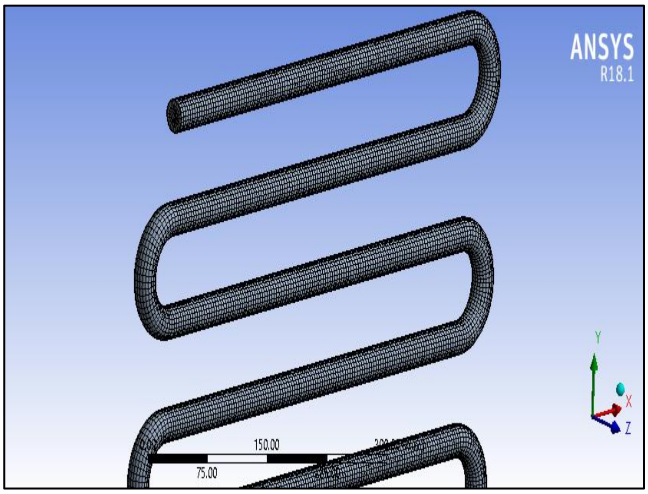

Figure 5: Meshed model in ANSYS

The loads and boundary conditions are assigned with details shown below. The domain inside is defined as fluid domain with R134al as fluid and morphology is continuous fluid. The reference pressure is set to 482630 N/m^2. The energy model is set to k-epsilon and wall function set to scalable.

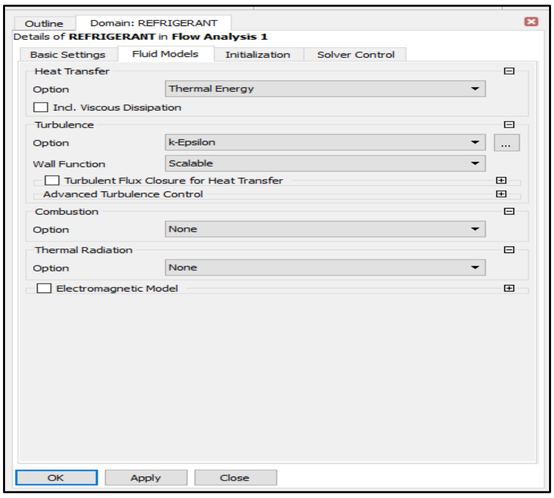

Figure 6: Domain definition in ANSYS software

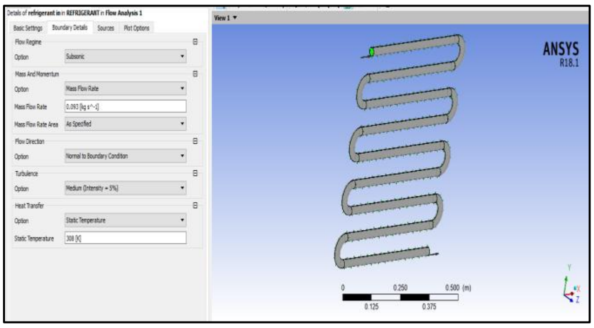

Figure 7: Inlet boundary condition in ANSYS software

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

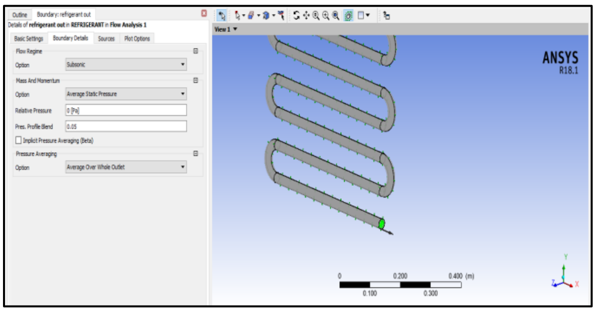

Figure 8: Outlet boundary condition in ANSYS software

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

5. RESULTS AND DISCUSSION

The results obtained from CFD analysis are discussed in this section. The temperature plot, pressure plot and temperature difference are determined.

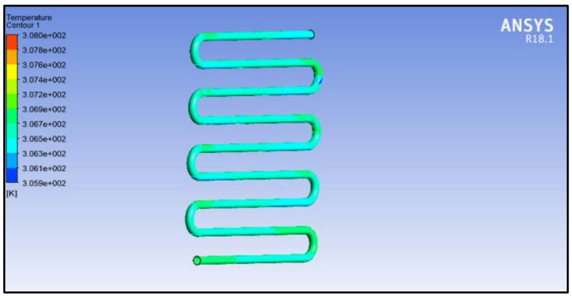

Figure 9: Temperature plot using R134 refrigerant and without fin condenser

The temperature contour for R134 refrigerant and without fins condenser type is shown in figure 9 above. The plot shows the temperature on outer surface of condenser reaches to 306K and higher temperature is near refrigerant inlet.

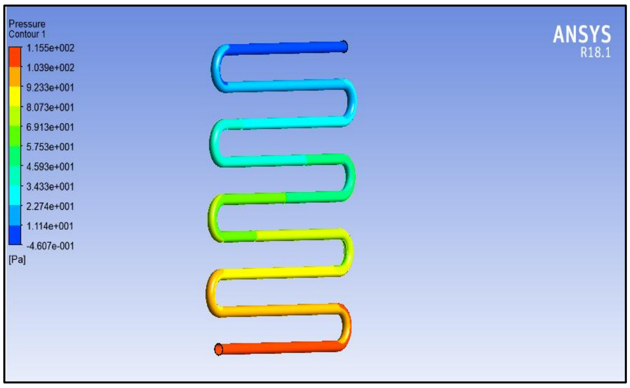

Figure 10: Pressure plot using R134 refrigerant and without fin condenser

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

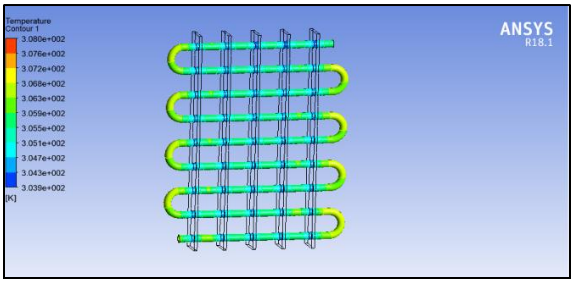

Figure 11: Temperature plot using R134 refrigerant and with fin condenser

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

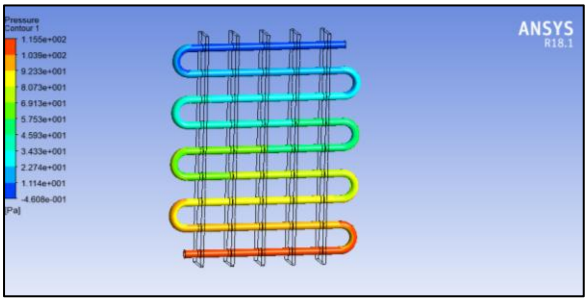

Figure 12: Pressure plot using R134 refrigerant and with fin condenser

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

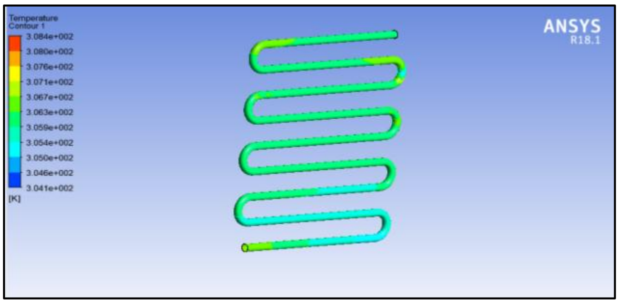

Figure 13: Temperature plot using R11 refrigerant and without fin condenser

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

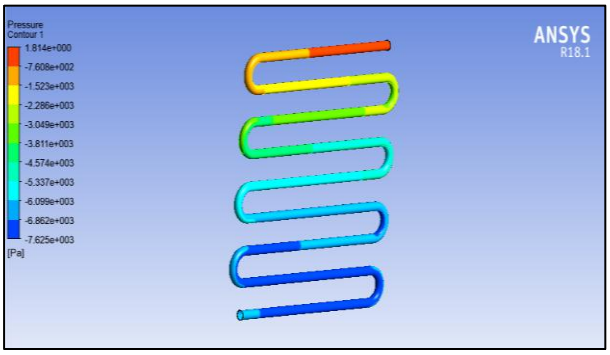

Figure 14: Pressure plot using R11 refrigerant and without fin condenser

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

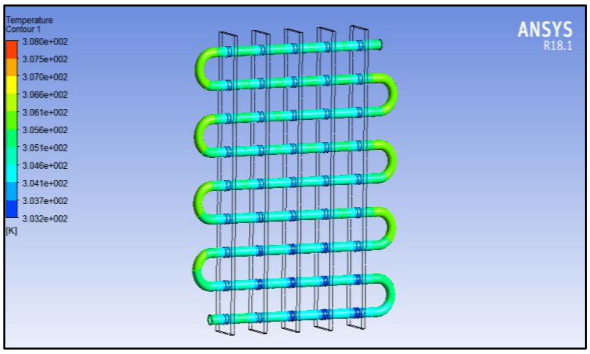

Figure 15: Temperature plot using R11 refrigerant and with fin condenser

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

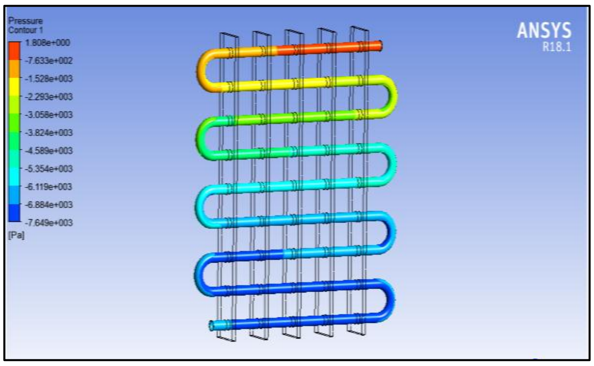

Figure 16: Pressure plot using R11 refrigerant and without fin condenser

The pressure plot across condenser is shown in figure 16 above. The maximum pressure is near refrigerant inlet with magnitude of 1.81 Pa and reduces on moving towards outlet of condenser. The pressure reduces to 152.5 Pa in next coil of tubes and subsequently to 11.14 Pa on last coil of condenser.

Table 5.2: 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
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 on the basis of heat rejection between 2 designs of condenser (with fins and without fins). The 2nd comparative studies are made on the basis of temperature drop between 2 designs of condenser (with fins and without fins). The comparative charts are shown in next section.

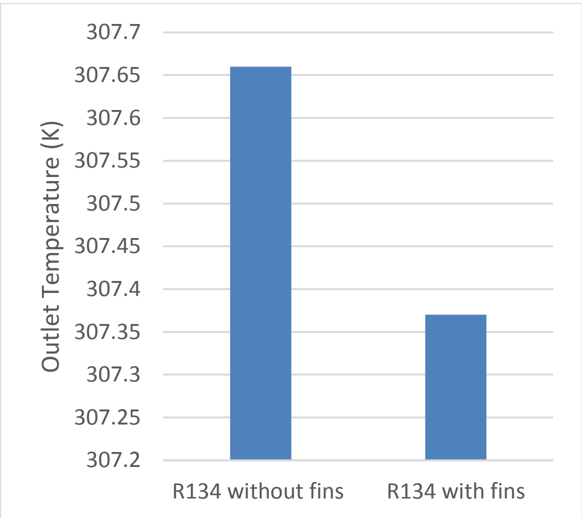

Figure 17: Outlet temperature for 2 designs of condenser using R134 refrigerant

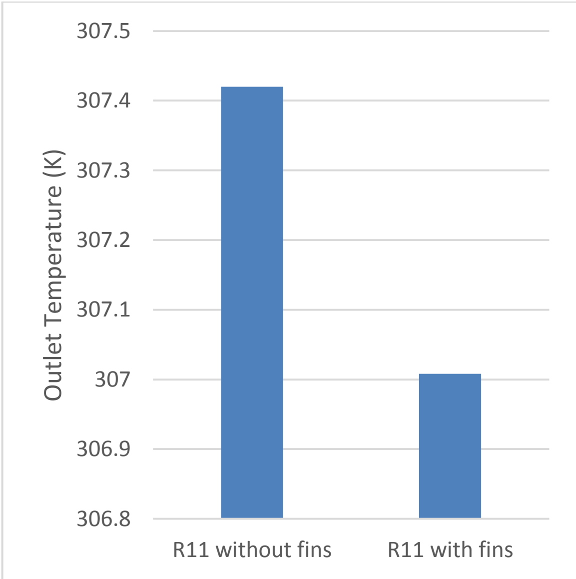

Figure 18: Outlet temperature for 2 designs of condenser using R11 refrigerant

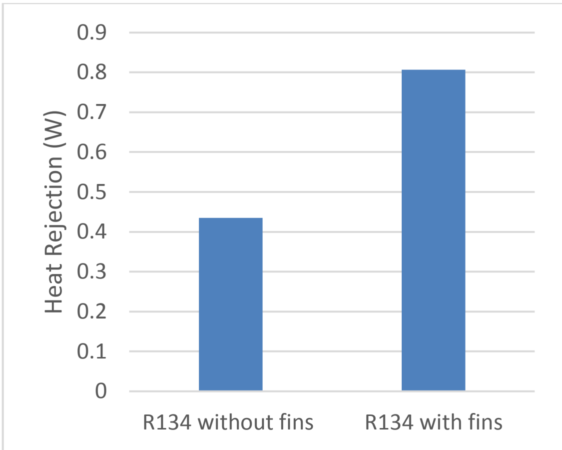

Figure 19: Heat rejection for 2 designs of condenser using R134 refrigerant

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.

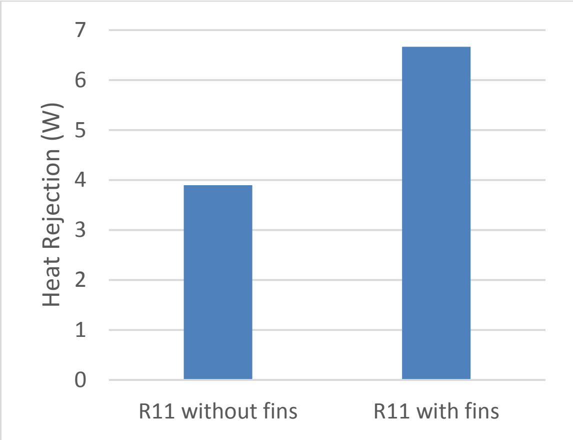

Figure 20: Heat rejection for 2 designs of condenser using R11 refrigerant

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.

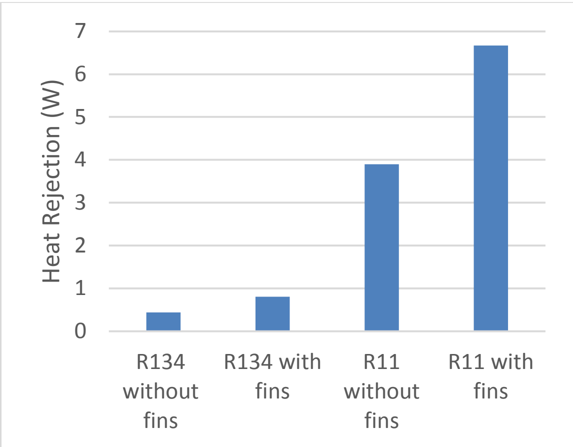

Figure 21: Heat rejection comparison for all designs

The comparative chart of heat rejection for all designs using different refrigerants is shown in figure 21 above. The maximum heat rejection is seen in R11 with fins followed by R11 without fins. The R134 refrigerant without fins has lowest heat rejection rates as compared to other design with fins.

6. CONCLUSION

The current research investigates the effect of fins and refrigerant properties on heat rejection and temperature drop characteristics of condenser. The CFD technique employed for analysis has proved to be viable option for substituting conventional experimental techniques which are costly and time consuming also. The findings from analysis are discussed below.

1> 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%.

2> The two-variable k-epsilon turbulence model used for analysis has provided reasonable good predictions of fluid flow along with pressure drop and temperature drop characteristics.

3> The 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.

4> The 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.

5> The maximum heat rejection is seen in R11 with fins followed by R11 without fins. The R134 refrigerant without fins has lowest heat rejection rates as compared to other design with fins.

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