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Optimization of Direct Expansion (DX) Cooling Coils To Improve Energy Efficiency

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Abstract

In this thesis, tube row number of a direct expansion (DX) cooling coil to minimize the entropy generation in the DX cooling in the A/C system so that energy consumption is decreased is optimized. This is done by performing CFD and Thermal analysis. Tube row number 8 & 10 for varying air mass flow rates 0.3Kg/s, 0.5Kg/s, 0.7Kg/s, are investigated analytically.3D models of the direct expansion cooling coils with different tube rows are done in Creo 2.0. CFD and Thermal analysis is performed in Ansys to determine optimal number of tube rowsto minimize entropy.

I. Introduction

There are 2 kinds of central air-conditioning systems: Direct Expansion (DX) kind of central AC plants and Chilled Water kind of the central AC plants. Within the DX system, to cool room or area the air used is passed directly on the cooling coil of the refrigeration plant. In chilled water system case, the cooling system is employed to 1st chill the water, that is then utilized chill the air utilized for cooling the rooms or areas.

Direct Expansion (DX) Type of Central Air Conditioning Plant

In the direct expansion or DX forms of AC plants the air utilized for cooling area is chilled by the refrigerant directly within the air handling unit cooling coil unit. The cooling efficiency is higher for DX plants because the air is cooled by the refrigerant directly. However, it's not continuously possible to hold the piping of the refrigerant to the massive distances thence, the DX form of central air-conditioning system is typically utilized for cooling the rooms on the only one floor or small buildings.

Basic Working of cooling coil

The air cooling coil with DXutilizes a thermostatic expansion valve and these coils are utilized in the majority of comfort AC applications principally, below a hundred tons capacity. DX coils are utilized in refrigeration applications like product coolers for cold storages and blast freezers in addition as in equipment of industrial cooling.

Fig.1. A typical DX air cooling coil

II. Literature Review

The work done by Ramesh S P [1], deals with energy consumption reduction by optimizing the variable speed motor run air cooled DX cooling by modeling and simulation utilizing MATLAB/SIMULINK.In a building commercially used for Indian climatical condition the simulation results indicate that variable-speed fan control strategy contributive to most of the savings. This has resulted in energy saving considerably with improved performance of the DXAC system while not compromising the occupants comfort level.The work done by Liang Xia [2], Efficient A/C system is the key to energy consumption reduction in building operation. So as to reduce the energy consumption in an A/C system, a way to calculate the optimum tube row no. of a DX cooling coil to minimize the entropy generation within the DX cooling that functioned as evaporator within the A/C system was developed. Based on the entropy generation decrease (EGM) approach the optimum tube row numbers were determined5 -9 tube row numbers were found to be the optimum tube row number of a DX cooling coil under conventional operational conditions. The optimum tube row range was less once the inlet water temperature and mass flow rate were increased.

III. Modeling and Analysis of Direct Expansion (DX) Cooling Coils

Assembly of Cooling Coil Evaporator

Tube Rows = 08

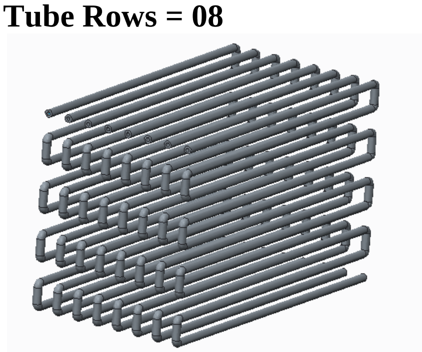

Fig.2. Cooling Coil model with 8 tube rows

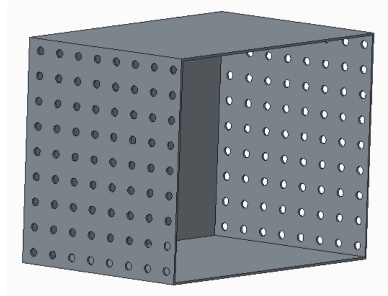

Fig.3. Outer body in which cooling coils are inserted

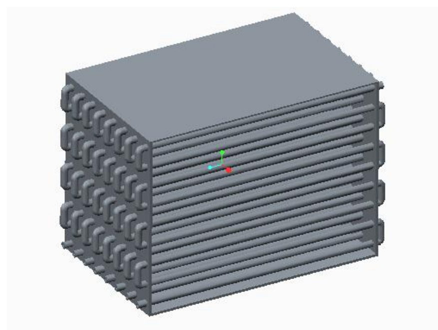

Fig.4. Final Model of Cooling coil evaporatorwith 8 tube rows

IV. Boundary Conditions To Perform Analysis

For CFD analysis, the input parameters of cooling coils are analyzed for a different mass flow rates as an input inlet values of 0.3kg/s,0.5kg/s and 0.7kg/s. The values are taken from the journal paper, **"Optimizations of Direct Expansion (DX) Cooling Coils Aiming to Building Energy Efficiency", by Liang Xia1, Tong Yang, Yuen Chan, Llewellyn Tang, Yung-Tsang Chen as specified in references [01].**

CFD Analysis

Fluid - r22 refrigerent

Mass flow rate - 0.3kg/s
Tube rows - 8

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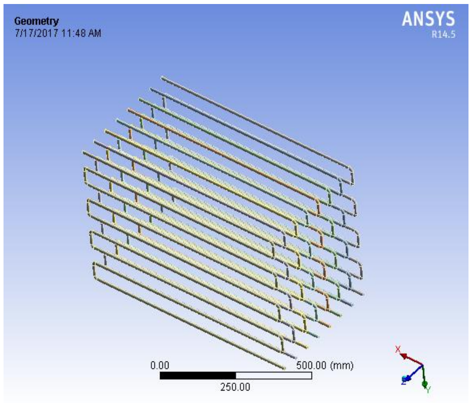

Fig.5. Imported model

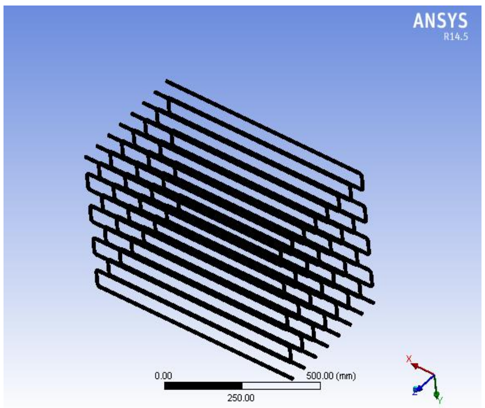

Fig.6. Meshed model

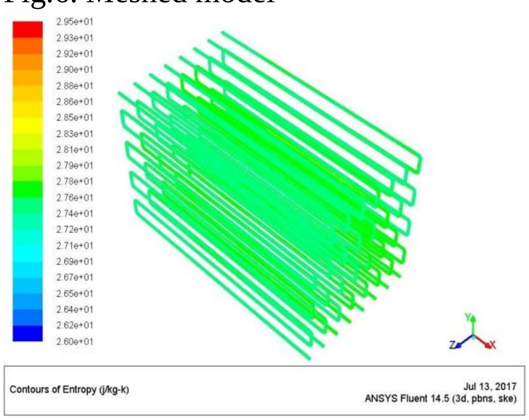

Fig.6. Contours of Entropy

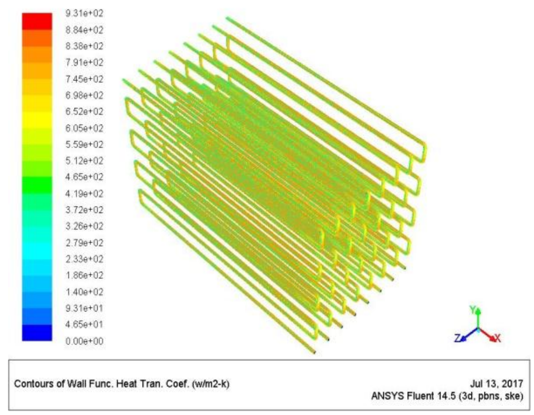

Fig.7. Wall Function Heat Transfer Coefficient

	Total Heat Transfer Rate	(w)
in	430.12479	
out	-426.41959	
wall-____msbr		0
	Net	3.7052002

Tube Rows - 10

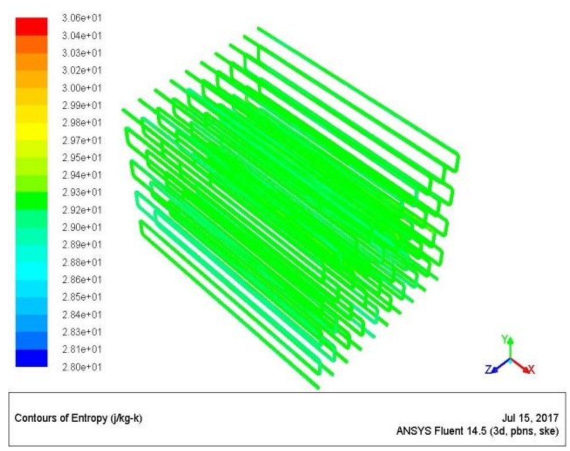

Fig.8. Contours of Entropy

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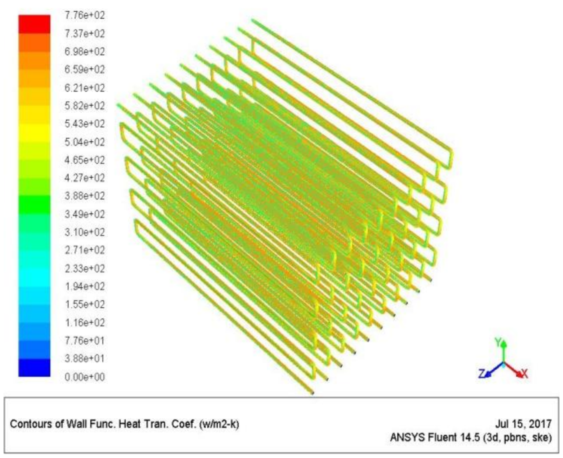

Fig.9. Wall Function Heat Transfer Coefficient

Total Heat Transfer Rate (w)

in	430.124
out	430.218
wall-____msbr	0
Net	0.0941467

V. Thermal analysis of cooling coils

Material – aluminum & copper

Fluid - r22

Mass flow rate - 0.3 kg/s

Tube rows - 8

To perform thermal analysis, temperature and heat transfer coefficient values are taken from the results of CFD analysis.

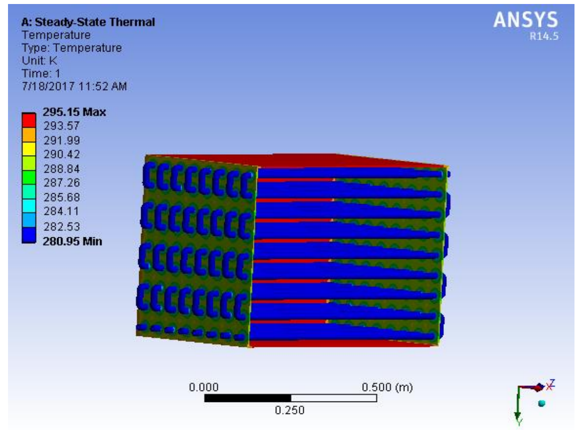

Fig.10. Temperature distribution for 8 no. of tube rows using R22 at MFR – 0.3Kg/s

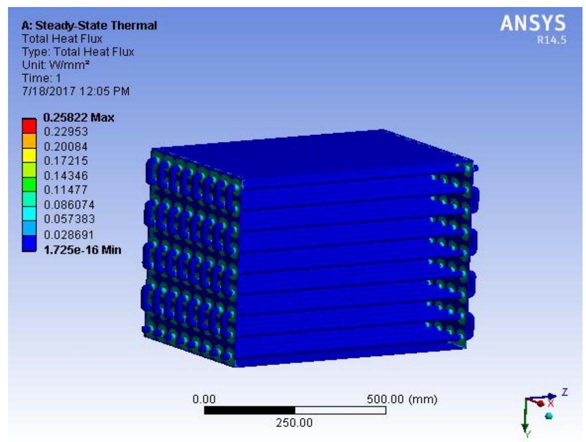

Fig.11. Heat flux for 8 no. of tube rows using R22 at MFR – 0.3Kg/s

TUBE ROWS - 10

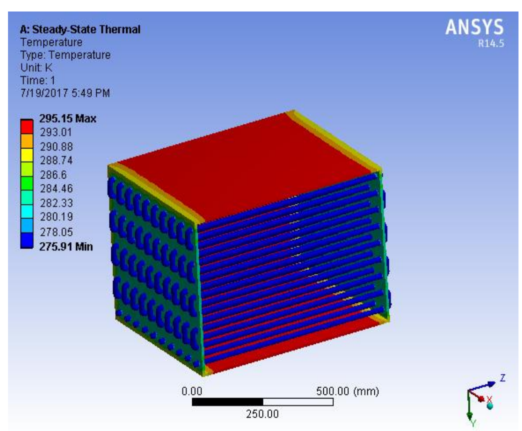

Fig.12. Temperature Distribution for 10 no. of tube rows using R22 at MFR – 0.3Kg/s

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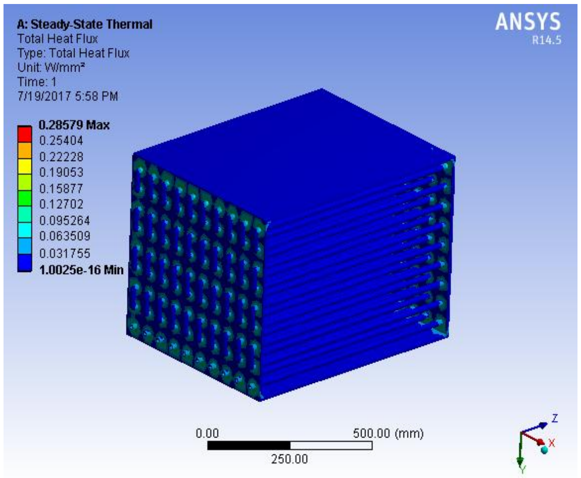


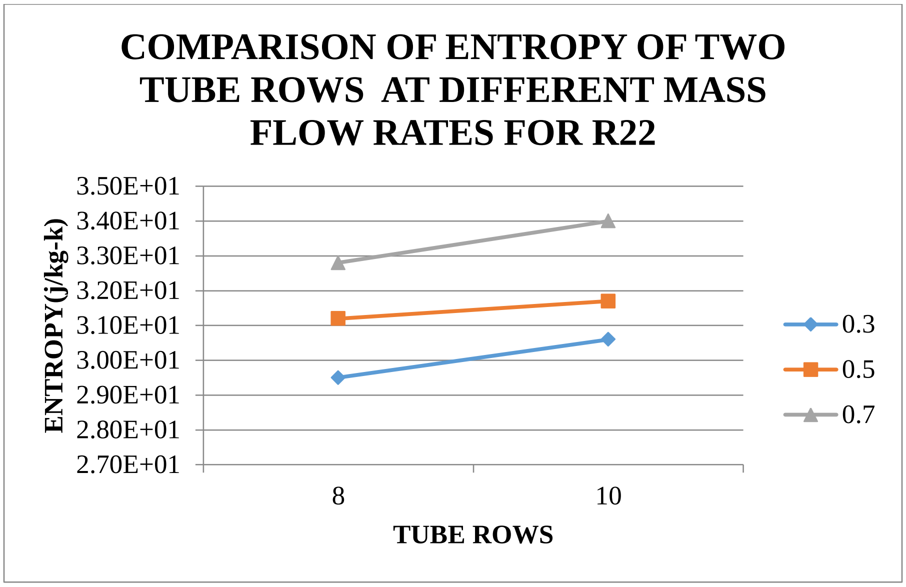
Fig.13. Heat flux for 10 no. of tube rows using R22 at MFR – 0.3Kg/s

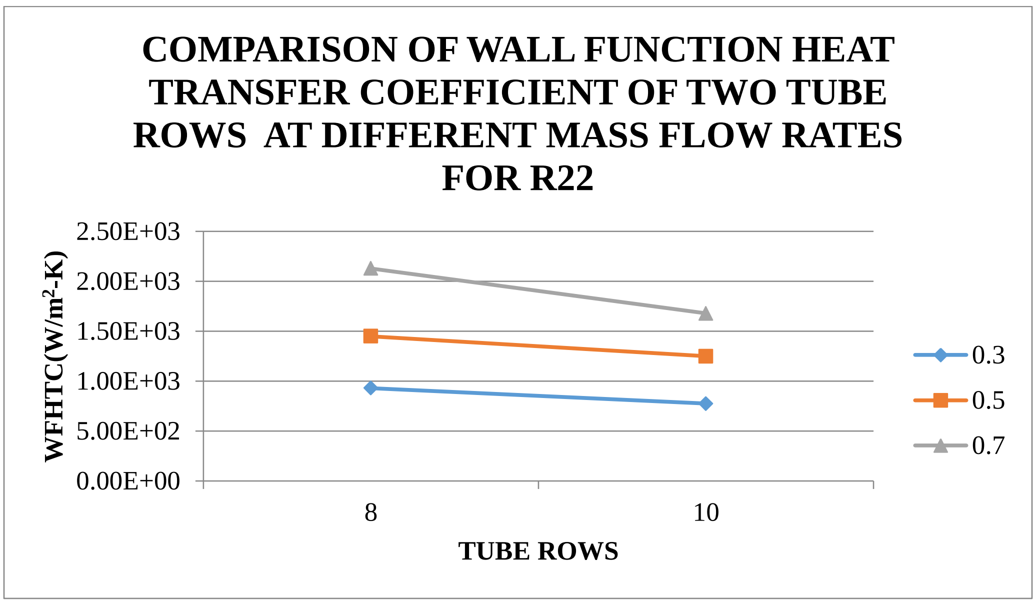
VI. Results table

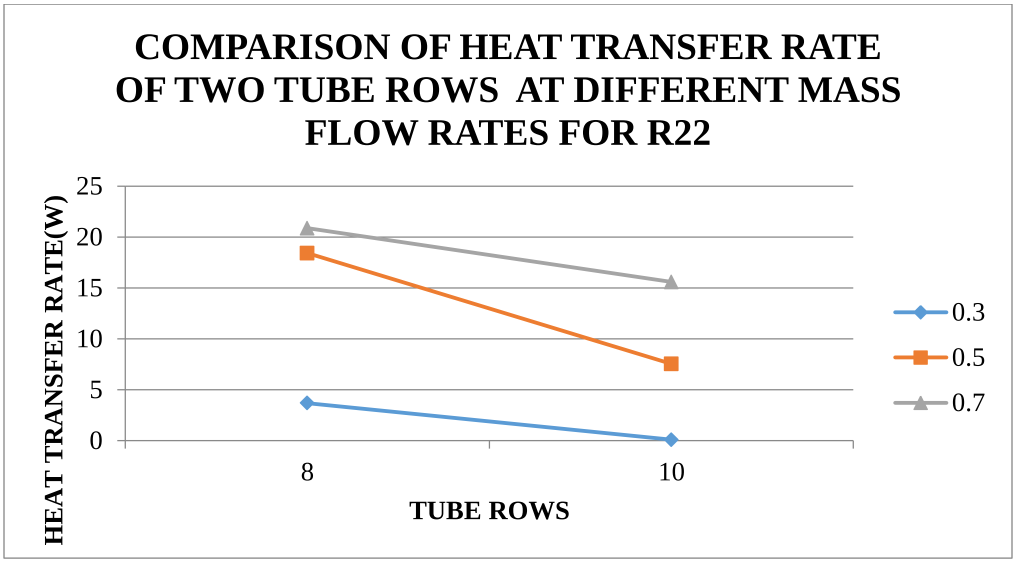
CFD analysis

R22 refrigerant

Tube Rows	Mass Flow Rates (kg/s)	Pressure (Pa)	Temperature (K)	Entropy (j/kg-k)	Wall Function Heat transfer co-efficient (W/m^2-K)	Heat transfer rate (W)	Mass flow rate (Kg/s)
8	0.3	2.29e+03	3.00e+02	2.95e+01	9.31e+02	3.7052002	0.002621889
	0.5	8.98e+03	3.00e+02	3.12e+01	1.45e+03	18.424011	0.012906432
	0.7	1.36e+04	3.00e+02	3.28e+01	2.13e+03	20.884155	0.100949194
10	0.3	1.65e+03	3.00e+02	3.06e+01	7.76e+02	0.0941467	8.165836e-05
	0.5	5.06e+03	3.00e+02	3.17e+01	1.25e+03	7.5567627	0.005328655
	0.7	1.03e+04	3.00e+02	3.40e+01	1.68e+03	15.595886	0.014474154


COMPARISON OF ENTROPY OF TWO TUBE ROWS AT DIFFERENT MASS FLOW RATES FOR R22
ENTROPY(j/kg-k)
3.50E+01
3.40E+01
3.30E+01
3.20E+01
3.10E+01
3.00E+01
2.90E+01
2.80E+01
2.70E+01
8
10
TUBE ROWS
0.3
0.5
0.7


COMPARISON OF WALL FUNCTION HEAT TRANSFER COEFFICIENT OF TWO TUBE ROWS AT DIFFERENT MASS FLOW RATES FOR R22
WFHTC(W/m2-K)
2.50E+03
2.00E+03
1.50E+03
1.00E+03
5.00E+02
0.00E+00
8
10
TUBE ROWS
0.3
0.5
0.7



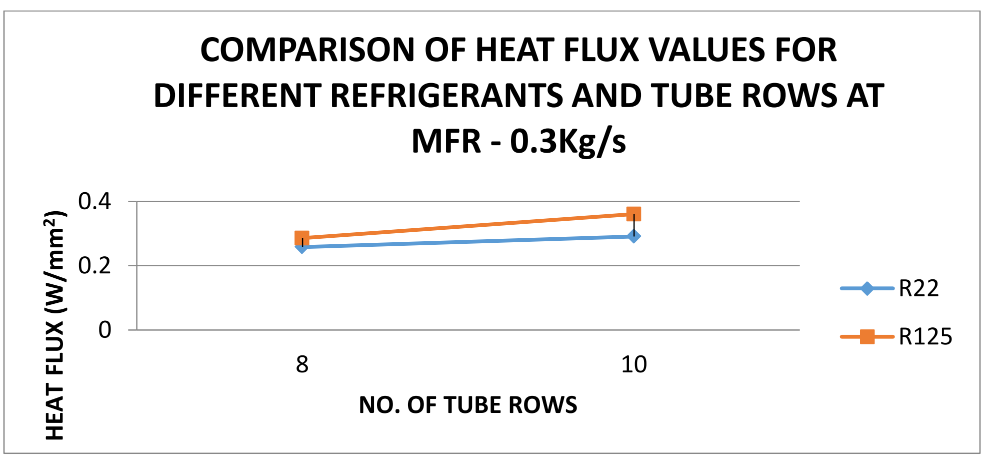
R125 REFRIGERANT

Tube Rows	Mass Flow Rates (kg/s)	Pressure (Pa)	Temperature (K)	Entropy (j/kg-k)	Heat transfer co-efficient (W/m^2-K)	Heat transfer rate (W)	Mass flow rate (Kg/s)
08	0.3	4.32e+03	3.00e+02	3.27e+01	1.16e+03	3.4985046	0.002114117
	0.5	9.75e+03	3.00e+02	3.47e+01	1.67e+03	9.7776489	0.012787879
	0.7	3.82e+04	3.00e+02	3.63e+01	2.37e+03	25.862061	0.110535121
10	0.3	1.66e+03	3.00e+02	3.42e+01	9.37e+02	0.54205322	0.000350952
	0.5	3.72e+03	3.00e+02	3.68e+01	1.52e+03	2.1353394	0.005808234
	0.7	1.33e+04	3.00e+02	3.86e+01	2.02e+03	17.484497	0.015593708

THERMAL ANALYSIS

REFRIGERANT	Tube Rows	Mass Flow Rates (kg/s)	Temperature (K)	Total Heat Flux (W/mm^2)

R22	**08**	0.3	295.15	0.25822
		0.5	295.15	0.32606
		0.7	295.15	0.38652
	10	0.3	295.15	0.29144
		0.5	295.15	0.34823
		0.7	295.15	0.40328
REFRIGERANT	**Tube Rows**	**Mass Flow Rates (kg/s)**	**Temperature (K)**	**Total Heat Flux (W/mm^2)**
R125	**08**	0.3	295.15	0.28579
		0.5	295.15	0.33782
		0.7	295.15	0.37242
	10	0.3	295.15	0.30579
		0.5	295.15	0.36052
		0.7	295.15	0.39488



Conclusion

By observing CFD analysis results, the entropy value is increasing by increasing the mass flow rates and is more for 10 no. of tube rows. For mass flow rate of 0.3Kg/s, the entropy value is increasing by about 3.6% for 10 no. of tube rows when compared with 8 no. of tube rows for R22 refrigerant, increasing by about 5.6% for 10 no. of tube rows when compared with 8 no. of tube rows for R125 refrigerant. Heat Transfer Coefficient and Heat Transfer Rate are increasing by increase of mass flow rates and more when 8 no. of tube rows is used. For mass flow rate of 0.7Kg/s, the heat transfer coefficient value is increasing by about 21% for 8 no. of tube rows when compared with 10 no. of tube rows for R22 refrigerant, increasing by about 14% for 8 no. of tube rows when compared with 10 no. of tube rows for R125 refrigerant. The heat transfer rate value is increasing by about 25% for 8 no. of tube rows when compared with 10 no. of tube rows for R22 refrigerant, increasing by about 32% for 8 no. of tube rows when compared with 10 no. of tube rows for R125 refrigerant. When compared the values between refrigerants, entropy value is less when R22 is used but heat transfer coefficient and heat transfer rate are more when R125 is used. By observing thermal analysis results, the heat flux (i.e) heat transfer rate is more for mass flow rate 0.7Kg/s, 10 no. of tube rows and when R125 is used. So it can be concluded that using 8 no. of tube rows and R22 refrigerant is better when entropy reduction is considered. Reduction in entropy reduces the energy consumption in the AC system.

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