Comparison on Simulation of Pressure Drop and Velocity Contour between Alternative Refrigerants inside Evaporator Coil using Computational Fluid Dynamics

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***Abstract*:** Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and algorithms to solve and analyze problems that involve fluid flows. The refrigeration and air-conditioning are becoming the vital area of research and development. In this project we are going to simulate, study and compare the pressure drop and flow of the refrigerants R744 and R134a with that of the R12 using CFD.R12 refrigerant is used in 'S' shaped coil of the refrigeration and air-conditioning units. The project is concluded by showing that the alternative refrigerants possess better characteristics in pressure drop and flow pattern than that of the R12 refrigerant.

Keywords: *refrigerants, carnot cycle, pressure drop, flow pattern, gambit, fluent)*

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I.INTRODUCTION

Refrigeration is the science of providing and maintaining temperature below that of surrounding atmosphere. This implies the development of temperature differential rather than the establishment of a given temperature level.

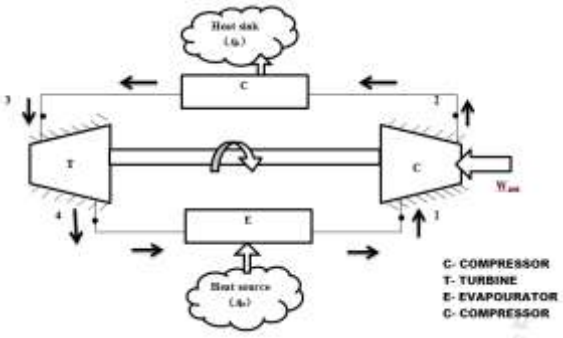
Any substance capable of absorbing heat from another substance can be used as refrigerants .Before the introduction of hydro fluorocarbons in the 1930s the most commonly used refrigerants were air, NH_3, SO_2, CO_2 and CH_3CL. A refrigerant can either be a single chemical compound or a mixture of multiple compounds.

Selection of the refrigerant is based on the suitability of the pressure –temperature relationship. It always has lower thermal conductivity in its vapour state than in its liquid state. It is best to use a refrigerant whose evaporating pressure is higher than that of atmosphere so that air and other non-condensable gases will not leak into the system and increase the condensing pressure. The Montreal protocol and Kyoto summit has agreed that CFC and HCFC refrigerants should be phased out and new 'ozone-friendly refrigerants should be replaced.HFC refrigerants likeR744 and R134a are introduced to replace R12.

In order to achieve optimum performance an accurate design technique is necessary for the prediction of pressure drop and flow pattern through 'S' shaped coil used in refrigeration and air-conditioning systems. GAMBIT and FLUENT can be used as a tool in Computational fluid dynamics to estimate or enhance our understanding of pressurelosses in coil prior to construction.

II.CARNOT REFRIGERATION CYCLE

The carnot cycle considered in the refrigeration system is the reversed carnot cycle. It is only theoretical in conceptions but it serves as an ideal cycle. The performance of the carnot cycle is independent of the physical properties of the working medium.



The basic Carnot refrigeration system for a pure vapour consistsof four components: compressor, condenser, turbine and evaporator.

IV.PRESSURE LOSS IN THE COILS

Pressure drop is a term used to describe the decrease in pressure from one point in a tube to another

point downstream. When a real fluid flows through solid boundaries, there is a pressure drop due to frictional resistance, separation, eddying or formation of vortices. The major losses is due to the frictional resistance between the pipe and the fluid.

A theoretical analysis of S-shaped coil was carried out for the single phase flow and the pressure drop was calculated by summing the frictional pressure loss and geometric pressure loss due to change in momentum within the liquid/Vapour mixture. For calculations pressure loss can be estimated as:

$$\Delta P = \left(\frac{f L_{s,c} \rho u^2}{2D}\right) + \Delta P g_{s,c}$$

Where, $f = 0.25/[\log(\frac{k}{3.7D} + \frac{5.74}{Re^{0.9}})]^2$

$$\Delta P g_s = Co/2\rho u^2$$

f -Friction coefficient
D -Pipe diameter
k - Roughness factor
R_e-Reynolds number
Co -Loss coefficient for the bends(1.47)
P-Density of refrigerant (kg/m^3)
L_s-Length of the coil

V.INTRODUCTION TO CFD PACKAGES

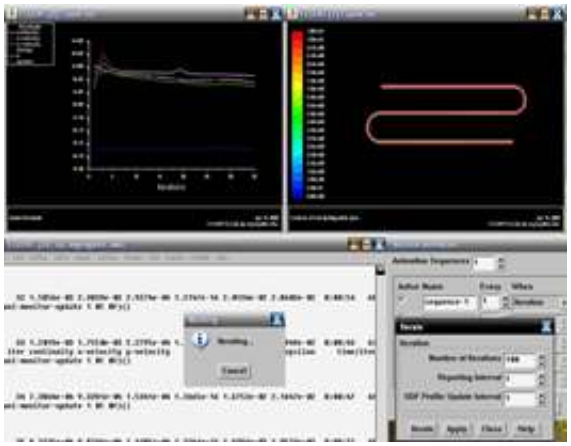
Computer aided fluid dynamics is a sophisticated analysis technique. It is the analysis of two systems involving fluid flow, heat transfer and associated phenomena such as chemical reaction by means of computer based simulation.It applies the fluid flow physics to the virtual prototype and the software outputs a prediction of the fluid dynamics. It also predicts the transfer of heat, mass phase change etc. In order to provide easy access to their solving power all codes contain three main elements.1.A preprocessor, 2.A solver, 3.A post processor.

CFD packages used for the simulation were the gambit 2.2.30 and fluent 6.2.16. Gambit has a single interface for geometry creation and meshing that brings together all of fluent preprocessing technologies in one environment. It can import geometry from virtually any CATIA, CAD/CAE software in Para solid ACIS, STEP, or IGES format and Pro-E integrations is also made available. Using Gambit software the fluid domain can be extracted from imported geometry and further decomposition can be performed using simple Boolean operations. Fluent is another software used for simulation visualization and analysis of fluid flow heat and mass transfer and chemical reactions. Using fluent software product development design and research Engineers build virtual prototypes and improve design quality while reducing cost and spending much time to market.

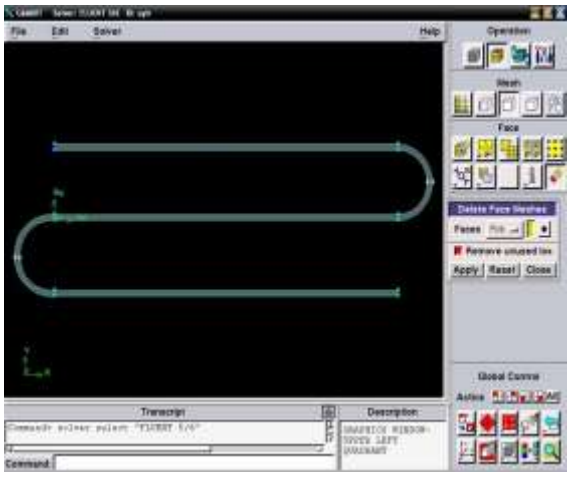
VI.SIMULATION AND WORK

The study of pressure drop in the 'S' shaped coil include the following procedure to compute and simulate

- Gambit 2.2.30 software is used to design the 2D 'S' shaped coil.
- The coil design is meshed with caution to obtain the proper simulation taking bend wall into consideration.
- The meshed 2D is then defined for its boundary condition.
- At last the 2D meshed model is exported to fluent as file.msh



- The 2D meshed model is checked for the mesh
- The model is standardized for its units.



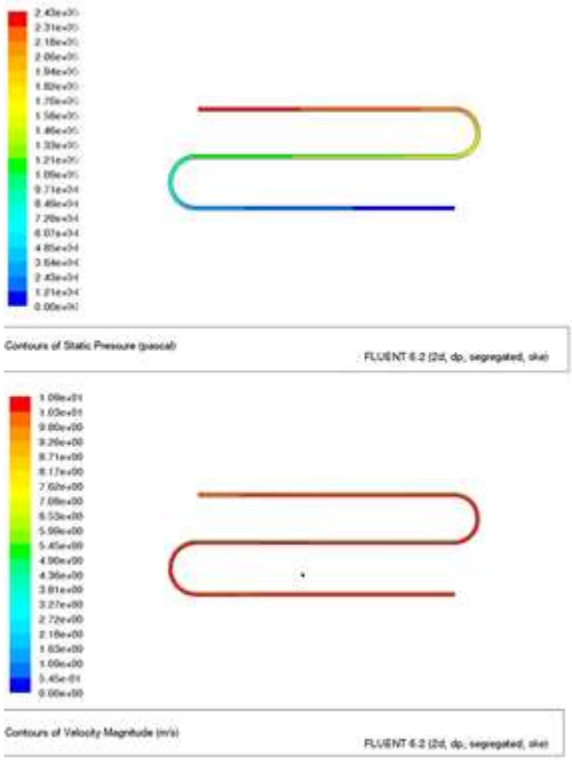
- The various parameters which has been defined in the fluent is given as

  Solver: Segregated
  Viscosity: Epsilon model
  Energy equation: On

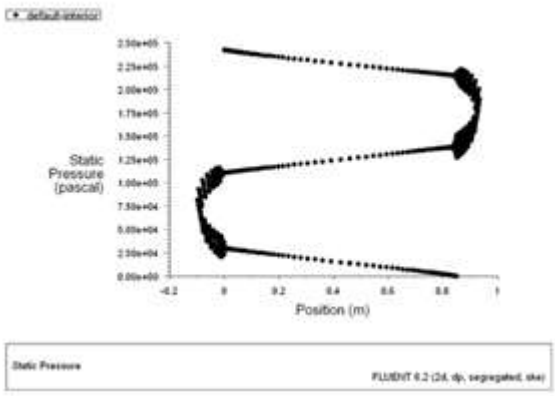
REFRIGERANTS/PROPERTIES (LIQUID)	R134a	R744	R12
DENSITY (kg/m^3)	1.237	1.164	1.437
VISCOSCITY (m^2/s)	2.08E-07	2.07E-07	3.13E-07
SPECIFIC HEAT (J/kg-k)	1408	1017	938.8
THERMAL CONDUCTIVITY (W/m-k)	0.1009	0.11	0.07591
ODP	0	0	3.1
GWP (100 years)	1320	1	1

- The model is initialized and the residual is monitored to check for the convergence.
- Thus the model is solved.

PRESSURE AND VELOCITY SIMULATION OF R12 LIQUID



RELATIVE GRAPH OF R12 LIQUID



VII.MODEL CALCULATION

REFREGIRANTS	DENSITY (kg/m^3)	VISCOSITY (m^2/s)	GEOMETRIC PRESSURE DROP ΔPgs (Pa)	REYNOLDS NUMBER (Re)	FRICTION COEFFICIENT (f)	TOTAL PRESSURE DROP ΔP (Pa)
R12 liquid	1.437	3.13E-07	105.6195	6.09E+05	1.48 E^{02}	247
R134a LIQUID	1.237	2.08E-07	90.9195	962645.91	7.23E-02	403
R744 LIQUID	1.164	2.07E-07	85.55	965975.1	7.23E-02	380

VIII.RESULT AND CONCLUSION

Table shows that the relationship between theoretical pressure drop and predicted pressure-drop using CFD when considering the liquid flow. The comparison of the pressure loss of the refrigerants that were taken for the study is tabulated. The results prove that CFD is viable tool in predicting the flow characteristics of any fluid.

REFREGIRANTS	PRESSURE LOSS (Pa)		
	R134a	R744	R 12
CFD LIQUID	406	383	243
THEORY LIQUID	403	380	247

The results has shown that the performance of the new eco-friendly refrigerants such as R744, R134a to be better than of R12 refrigerant.

Richie Allen Vaz:

"The refrigerating effect of R134a and R 744 per pound of its weight is more when compare to R12 .The greater weight of refrigerants helps controlling the refrigeration system. It also avoids a compressor displacement require per ton of

refrigeration since the higher vapour density is an advantage. More over R12 is a CFC and hence replacement is required by other refrigerants like R134a and R744"

Thamilazhagan:

"The proved refrigerants are eco friendly substances are created from normally sourced substances thus they do not have adverse effect on environment. Perhaps the conventional substances do not use all the compound during the process where hydrocarbons don't remain .The main advantage is that it won't have effect on ozone layer depletion differing from CFC or HCFC refrigerants. Also they won't affect human health which is portrayed through some advanced experiments".

Samuel Praveen kumar:

"We found it helpful tool to solve basic equations using CFD that model the flow movement. Majority of these equations did not have analytical solution hence we resort to numerical analysis with CFD. Comparatively the pressure loss is simulated were R134a and R744 shows up more than that of R12 refrigerants. The difference peeked up about 3 % from theoretical values which means the CFD analysis and values are considerable and accurate to commence on practical experiments".

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