EVALUATION OF NANO REFRIGERANT THROUGH CAPILLARY TUBE IN VCRS BY USING CFD

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Abstract

A refrigeration applications using nano-refrigerants has been presented. Over the decay,the researchers have contributed to achieve new ideas in the field of refrigeration systems. The refrigerants R-134a, R- 22,R-12,R600,R600a and R-22 are most widely used for heat transfer enhancements purpose with nano particles like copper oxide, alumina oxide, TiO2 and carbon CNT tube in vapour compression cycle. The applications of refrigeration systems are microelectronics cooling, double tube gas cooler, double pipe heat exchanger, domestic deep freezer, cylindrical horizontal annuli, evaporator and air conditions etc.Nanorefrigerants are framed when nanoparticles are scattered in refrigerant-based. The utilization of nano refrigerants is one of the procedures in improved heat transfer. This research includes the CFD analysis of nano-refrigerant through a capillary tube. The CFD studies showed that addition of aluminium nanoparticles increased the total heat transfer rate of the refrigerants which is predominant in the capillary tube when compared to the helical coil for the same operating conditions.

Key words: *Refrigerants, Nano Fluid, CFD, thermal performance.*

Introduction:

Refrigeration Systems:

Refrigeration is a thermal process in which heat transfer is promoted between a system and a refrigerating fluid to remove heat and maintain a low temperature. Refrigeration systems are used for domestic, commercial and industrial applications. Additionally, they are used for food preservation, air conditioners and in the transportation industry. Refrigerants are those kinds of fluids that have the ability to absorb heat at low temperatures and pressures, and yield to higher temperatures and pressures. They can be classified into five groups:

- Halocarbon: CFC-11 or R-11, CFC-12 or R-12, CFC-113or R-113, CFC-114 or R-114 and CFC-115 or R-115.
- Hydrocarbons (HC): Methane (R-50), ethane (R.170),propane (R-290), n-butane (R-600), and isobutane (R-600a).
- Inorganic compounds: ammonia (R-717), water (H_2O),air (R-729), carbon dioxide (R-744) and sulfur dioxide(SO_2).
- Azeotropic mixtures: R-502 (48.8% R-22 and R-11551.2%), R-500 (73.8% R-12 and R-152a 26.2%), R-503(59.95% R-13 and R-23 40.1%), and R-504 (48.2% R-32and R-115 51.8%).
- Zeotropic Mixtures: R-401A and R-401B.

Vapour compression refrigeration system :

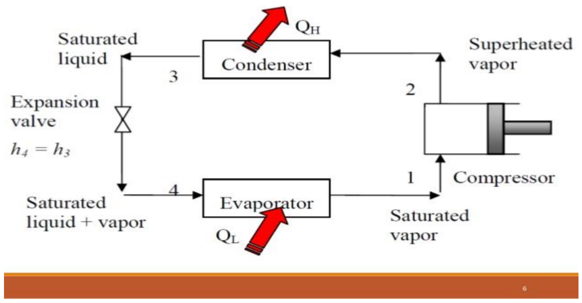


Fig. Schematic representation of vapour compression refrigeration system

Several authors have studied and identified the optimal parameters for optimal performance of the compression refrigeration cycle. No fluid is ideal in all aspects; each refrigerant can have negative properties such as toxicity, chemical instability, flammability, high operating pressures or poor thermodynamic properties. Currently, the most widely used fluid in refrigeration and air conditioners is limited to HFCs refrigerants R134a, R32, R125, R143a and mixtures of these, as well as some hydrocarbons (propane and isobutane), ammonia and dioxide carbon.
Historically inorganic natural refrigerants such as R717, R744, R764, R11 or R12 have been used as CFCs and HCFCs such as R22, and R502 mixture [3]. Currently HFCs like R32 and R134a are used as replacement refrigerants, as well as zeotropic as mixtures of HFCs R404A, R407C, R410A, R507 azeotropic mixtures of HFCs and natural hydrocarbons such as R600a and R290. The CFC refrigerants R11 and R12 have been substituted by R123 (HCHC) and R134a (HFC) refrigerants with a reduction in impact on the deterioration of the ozone layer [3]. R134a is still a greenhouse gas, so in the future must be replaced. R152a, CO2 and R1234yf have been considered as possible replacements of this. However, R152a is a flammable fluid, making it difficult to use and CO2 requires higher working pressure than R134a, which is not practical for a refrigeration system.
Many studies have been undertaken on the impact of refrigerants in the deterioration of the ozone layer and global warming**.** Efforts have focused on finding an alternative fluid as an ideal substitute. However, the probability of finding an ideal refrigerant is practically zero, due to the number of factors that are involved in the performance of refrigeration systems**.** R123 has replaced R11 in centrifugal chillers. It is a low pressure, high efficiency refrigerant, and miscible with mineral lubricants. R123 is safer than R11, but a long term alternative to replace it (R245fa or R245ca) must be found. HCHC are less reactive than CFCs, because of their hydrogen content. R123 has a lifetime in the atmosphere and a lower ODP (Ozone Depletion Potential) than CFCs. However, the Montreal Protocol has limited its use since
Refrigeration is additionally made public as a result of the strategy of achieving and maintaining a temperaturebelow that of the surroundings, the aim being too cool some Product or space to the specified temperature. One in every of the foremost very important applications of refrigeration has been the Preservation of spoilable nutrient by storing them at low temperatures. Refrigeration systems are also used extensively for providing thermal comfort to groups of people by implies that of air conditioning. The refrigeration and air conditioning sector in India contains a protracted history from the first years of last century. India is presently producing R134a, R22, R717 and hydrocarbon-based refrigeration and air conditioning units in large quantities. the Utilization of CFC refrigerants in new systems was stopped since the year 2002. The factors that Dictate the adoption of a specific refrigerant apart from its quality for the precise application are its accessibility and worth. The halogenated refrigerants like R12, R22, R134a and natural refrigerant like R717 are promptly on the market at low prices. The compound (HC) and Hydro Fluro Carbon (HFC) mixtures (such as R404a, R407, and R410A) do not appear to be presently ready-made indigenously and therefore ought to be foreign at a stronger worth. this will be on the face of it to possess an impression on the growth in refrigeration and air conditioning sector in India and in addition the total conversion to environmentally friendly alternatives at intervals the near future.

1.2. Nanofluids

Nanofluids are a suspension of particles between 0 and 100 nm in a base fluid. They have thermo-physical properties different to the base fluid due to the addition of metal or metal oxide particles to increase the coefficients of thermal conduction and convection [8,9]. The main characteristic of nanofluids is the ability to enhance heat transfer without altering the base fluid Newtonian behaviour with the addition of small concentrations of solid particles.

Experimental and numeric tests have been performed in order to better understand the behavior of these fluids and their characteristics. Studies have focused on thermal conductivity, convective heat transfer coefficient, viscosity, evaporation phenomenon, the influence of particle size and optimal concentration of particles. Some of the advantages to using nano fluids are:

- High specific surface area and therefore greater heat transfer surface between particles and fluid.
- High stability of the dispersion where the Brownian motion of particles dominates.
- Reduction of the pumping power in comparison with thebase liquid, to achieve an equivalent heat transfer.
- Reduced clogging particles compared to conventional suspensions, promoting miniaturization of the system.
- Adjustable properties by varying the concentration of particles.
- The challenges faced in studying nanofluids and its characteristics such as thermal conductivity, the Brownian motion of particles, migration of these and the variation of thermo-physical properties with change in temperature.
- The long-term stability of the dispersion of nanoparticles is a technical challenge to prevent the accumulation and sedimentation of particles. The pressure drop and higher pumping power should also be considered to determine the efficiency of nanofluids. Other challenges include an increase in viscosity with greater concentration of particles, low specific heat compared to the base fluid, the prediction of thermal conductivity, high costs and production processes.

Computational Fluid Dynamics:

CFD is useful for studying fluid flow, heat transfer; chemical reactions etc by solving mathematical equations with the help of numerical analysis.CFD resolve the entire system in small cells and apply governing equations on these discrete elements to find numerical solutions regarding pressure distribution, temperature gradients. This software can also build a virtual prototype of the system or device before can be apply to real-world physics to the model, and the software will provide with images and data, which predict the performance of that design. More recently the methods have been applied to the design of internal combustion engine, combustion chambers of gas turbine and furnaces, also fluid flows and heat transfer in heat exchanger. The development in the CFD field provides a capability comparable to other Computer Aided Engineering (CAE) tools such as stress analysis codes. Basic Approach to using CFD .

(1). Pre-processor : Establishing the model

(a) Defining the problem (Computational Domain)

(b) Mesh generation

- Identify the process or equipment to be evaluated.
- Represent the geometry of interest using CAD tools.
- Use the CAD representation to create a volume flow domain around the equipment containing the critical flow phenomena.
- Create a computational mesh in the flow domain.

2) Solver :

Specifying the fluid and flow properties

Choosing the discretization scheme

Setting boundary conditions

- Identify and apply conditions at the domain boundary.
- Solve the governing equations on the computational mesh using analysis software.

(3) Post processor : Interpreting the results

(a) Examine the results

(b) Vector plots

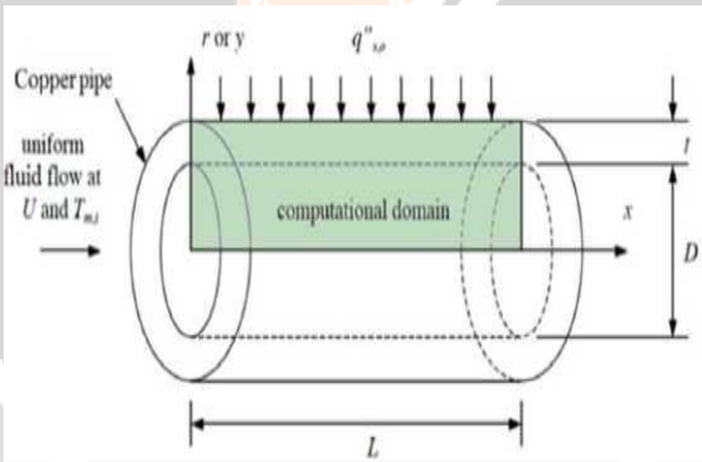
(c) Contour plots

(d) 2D and 3D Surface plots

- Post-process the completed solutions to highlight findings.
- Interpret the prediction to determine design iterations or possible solutions, if needed

Modelling and Simulation:

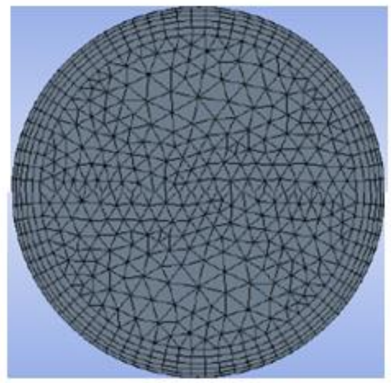
The modelling and simulation consist of designing geometry, pre-processing and CFD analysis. The geometric modelling consists of designing helical coil and capillary tube. The helical coil and capillary tube are designed in ANSYS. Preprocessing consists of defining materials for the helical coil and the capillary tube, defining properties of nano refrigerants and meshing of bodies, i.e., capillary tube and a helical coil. The CFD analysis is done to find the solution (like temperature, heat flux, etc.).
The designing of geometry is done by using various tools like sketches, extrude and revolve. The capillary tube dimensions are shown in figure. Figure gives the front and top views of the capillary tube with dimensions.



RESULT & DISCUSSION :

A mesh is a representation of a larger geometric domain by smaller discrete cells. Meshes are commonly used to compute solutions of partial differential equations and render computer graphics, and to analyze geographical and cartographic data. A mesh partitions space into elements (or cells or zones) over which the equations can be solved, which then approximates the solution over the larger domain. Element boundaries may be constrained to lie on internal or external boundaries within a model. Higher-quality (better-shaped) elements have better numerical properties, where what constitutes a "better" element depends on the general governing equations and the particular solution to the model instance.

In two dimensions, flipping and smoothing are powerful tools for adapting a poor mesh into a good mesh. Flipping involves combining two triangles to form a quadrilateral, then splitting the quadrilateral in the other direction to produce two new triangles. Flipping is used to improve quality measures of a triangle such as skewness. Mesh smoothing enhances element shapes and overall mesh quality by adjusting the location of mesh vertices. In mesh smoothing, core features such as non-zero pattern of the linear system are preserved as the topology of the mesh remains invariant. Laplacian smoothing is the most commonly used smoothing technique.



Mesh distribution of the duct

Governing Theory :

The numeric and different equations that administer the fluid flow and are utilized as a part of CFD analysis. The N-S portrays how the pressure, density, and temperature are identified with a moving fluid. The Navier – Strokes (N-S) conditions which are details of momentum, mass, and energy conservations laws are utilized by the CFD programming to solve the problems related to the fluid flows. The two-equation turbulence model, $k - \varepsilon$, turbulent kinetic energy (k) – turbulent energy dissipation rate (ε) is used in predicting turbulence.
The overseeing conditions which are momentum, mass, and energy conservation laws are given as takes after:

A. Conservation of mass (Continuity equation):
The conservation of mass rule expresses that without mass sources and sinks, a region will conserve its mass on a local level. It is given as:

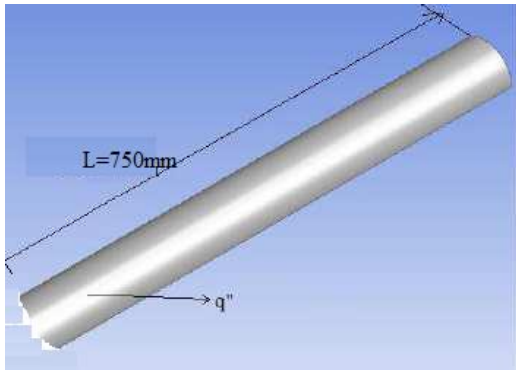
$$\frac{\partial \rho}{\partial t} + \nabla . [\rho \vec{v}] = 0$$

where ρ is the density and v is the velocity of the fluid.
B. Conservation of momentum:
The conservation of momentum expresses that in the absence of any external force acting on a body, the body retains its total momentum (product of its mass and velocity). It is given as:

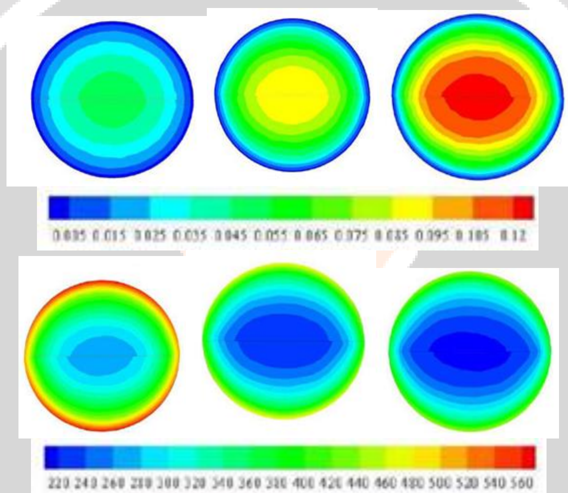
$$\rho \left[\frac{\partial \vec{v}}{\partial t} + (\vec{v}.\nabla)\vec{v} \right] = f$$

wheref is the external force per unit volume acting on the material volume.
C. Conservation of energy:
It is represented by the First law of thermodynamics which expresses that states that energy can be neither created nor destroyed during a process; it can change from one form into another. It is given as:

$$\frac{\partial}{\partial t}(\rho e) + \nabla . [\rho \vec{v} e] = -\nabla . \left(\sum_j h_i J_j \right) + S_h$$



In their study, a general purpose finite-volume based commercial CFD software package Ansys Fluent 14.5 has been used to carry out the numerical study.
The software provides mesh flexibility by structured and unstructured meshes as shown in Fig.



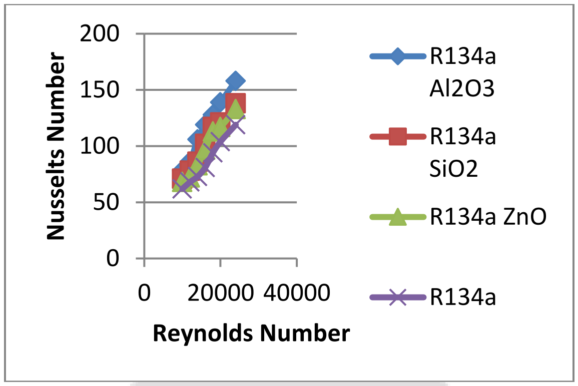
In the present paper the most of the studies about using nanoreffrigerants according to the recent literature are summarized. Due to air conditioning systems which are used nanorefrigerants, obviously, it is expected using nanorefrigerant instead of common refrigerants increase in near future.

The maximum outcome of Nusselts Number by using Nano Refrigerants

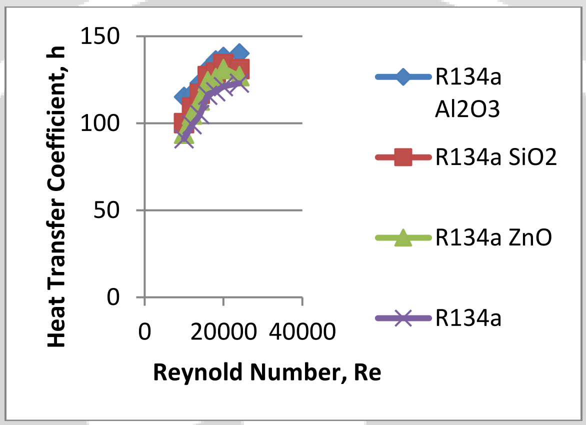
Value	**Refrigerants**			
	R134a	**R134a Al_2O_3**	**R134a SiO_2**	**R134a ZnO**
Nu	119	158	138	133
h	125	140	131	128
ReX10^3	24	24	24	24

The obtained numerical results for water are compared with the available Nusselt number correlations in the estimated Reynolds number range. The Nusselt number correlations are used for comparison purpose. The CFD resultsareplottedand compared with analytical results. The numerical Nusselt number values are in very good agreement when compared with the correlated values.

Result of Nusselts Number vs Reynolds Number



Result of Heat Transfer coefficientvs Reynolds Number



The results of numerical computations were presented in terms of average heat transfer coefficient and average friction factors in Figure. On the other hand, average friction factor decreases with increasing Reynolds number, also average heat transfer coefficient increases with increasing particle volume fractions.

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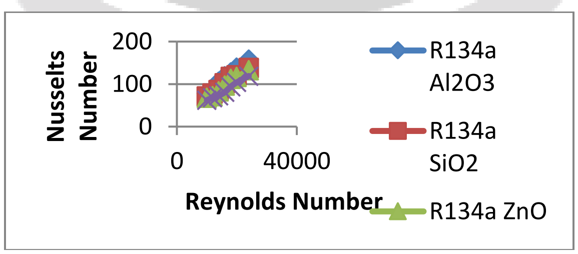
Table: Result of Nusselts Number vs Reynolds Number



Result of Heat Transfer coefficientvs Reynolds Number

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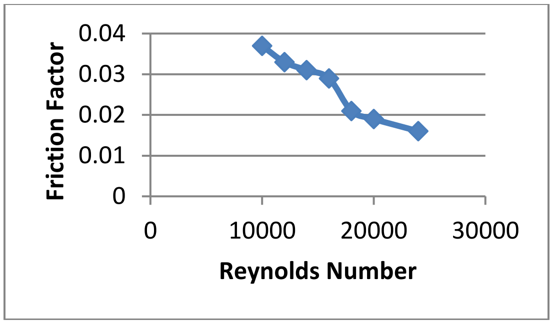

Conclusion:

In this the three dimensional model is investigated for the nano refrigerant andCFD analysis is carried out for the refrigerant with different designs of cross sections.

This research investigated to show the effect of refrigerant and nano particles on the overall performance of system under the conditions. From the simulation results, the following remarks can be concluded:

1- Nanoparticle with R134a refrigerant can be used as an excellent refrigerant to improve the heat transfer characteristics in a refrigeration system.

2- The obtained evaporating heat transfer coefficient result with increases with the usage of nano particles.

3- The heat transfer characteristics have been increased while using Nano refrigerant compare to purerefrigerant.

4- The capillary tube and helical coils are modeled using different modules of ANSYS are analyzed at real operatingconditions using ANSYS software.

5- It can be observed that addition of nanoparticles increased the total heat transferrate of the refrigerants.

6- The addition of nanoparticles has better heat transfer rates.

7- Results show that adding nanoparticles to refrigerantfluids improves the thermal characteristics such as thermalconductivity and the heat transfer coefficient.

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