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# Numerical Analysis of a Refrigeration System Using Different Nano Fluids by CFD

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***Abstract: Nano refrigerants are special type of nano fluids that are synthesized by mixing or dispersing nano particles in refrigerants. They are relatively new with respect to other nano fluids and have broad range of application in refrigeration, air-conditioning systems and other heat transfer devices due to their enhanced heat transfer characteristics. In present study the coefficient of heat transfer of nano refrigerants is investigated based on different nano fluids Al2O3, CuO and ZnO nano particles are suspended with blended refrigerant R134a+R152a. Correlations from existing studies have been used to determine thermo- physical properties like thermal conduction, viscosity, density and specific heat of nano-refrigerant. Study has been conducted by Numerical Simulation using ANSYS (Fluent14.5) for calculation of heat transfer co-efficient. Results from the current study shows that heat transfer co-efficient is higher in CuO nano particles and the vapour pressure lower which is desirable in refrigeration system.***

***Keywords: Refrigeration, Nano-Fluids, CFD, Thermal Conductivity, Conventional fluids, Heat transfer Coefficient etc.***

## I. INTRODUCTION

Refrigeration is additionally made public as a result of the strategy of achieving and maintaining a temperature below 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.

### *A. Nanofluids*

Nanofluids are a suspension of particles between 0 and 100 nm in a base fluid. They have thermophysical 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 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 behaviour 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 proposed by Choi in are:

*1)* High specific surface area and therefore greater heat transfer surface between particles and fluid.
*2)* High stability of the dispersion where the Brownian motion of particles dominates.
*3)* Reduction of the pumping power in comparison with the base liquid, to achieve an equivalent heat transfer.
*4)* Reduced clogging particles compared to conventional suspensions, promoting miniaturization of the system.

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5) Adjustable properties by varying the concentration of particles. In, the authors describe 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 thermophysical properties with change in temperature.
6) 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 a greater concentration of particles, low specific heat compared to the base fluid, the prediction of thermal conductivity, high costs and production processes.

### *B. Nanofluids Application*

Heat transfer fluids are the most important part of cooling applications in many industries including transport, energy, manufacturing, and electronics. Nanofluids can be used to improve heat transfer and energy efficiency a variety of thermal system, including the important applications of refrigeration vehicles. Some applications of Nanofluids will discuss below-

1) *Nanofluids for Lubrication Applications:* Solid lubricants useful in situations where conventional lubrication is not enough liquid, such as high temperature and excessive contact pressure, their lubricating properties are due to the layer structure at the molecular level with weak bonding between the layers. Graphite and molybdenum disulfide ($MoS_2$) is the main material used as solid lubricants. Other useful solid lubricants include boron nitride, tungsten disulfide, polytetrafluoroethylene (PTFE), etc. to improve the tribological properties of lubricating oils, solid lubricant nanoparticles to disperse. Recent studies have shown that the lubricating oil with additional nanoparticles exhibits improved load carrying capacity, anti-wear and friction reduction property.
2) *Nanofluids for Biomedicine Applications:* Nanofluids have many applications in the biomedical industry. For example, Nanofluids are used to producing effective cooling around the surgical region and thereby enhancing the patient's chance of survival and reducing the risk of organ damage. In a contrasting application to cooling, Nanofluids could be used to produce a higher temperature around tumours to kill cancerous cells without affecting nearby healthy cells
3) *Nanofluids for Cooling Applications:* Developments in new technologies such as highly integrated microelectronic devices, the engine power output are higher, and the reduction of cutting fluids used continuously increasing heat load, which requires the development of cooling capacity. Thus, there is a need for a new heat transfer fluids and innovative ways to achieve better cooling performance. In general, the conventional heat transfer fluid has the characteristics of poor heat transfer compared to the solid, most solids have thermal conductivities orders of magnitude greater than that of conventional heat transfer fluids.Therefore, the liquid containing suspended solid particles are expected to exhibit a significant increase in thermal conductivity compared with conventional heat transfer fluids. In addition, normal coolant operating temperature can be increased since Nanofluids have obtained a higher boiling point, which is desirable for maintaining single phase coolant flow. The results of Nanofluids research are being applied to the cooling of an automatic transmission with variable operating speeds conducted.
4) *Others Application:* There are unending situations where an increase in the heat transfer effectiveness can be beneficial to be the quality, quantity, and cost of product or process. In many of these situations, Nanofluids are good candidates for accomplishing the enhancement in heat transfer performance. For example, Nanofluids have potential application in buildings where increases in energy efficiency could be realized without increases in energy efficiency without increased pumping power. Such an application would save energy in as heating, ventilating and air conditioning system while providing environmental benefits. In the renewable energy industry, Nanofluids could be employed to enhanced heat transfer from solar collectors to storage tanks and increase the energy density. Nanofluids coolants also have potential application in major process industries, such as materials, chemical, food and drink, oil and gas, paper and printing, and textiles.

### *C. Nano-Refrigerents*

Recently nanoparticles have been used to enhance the thermophysical properties of refrigerants in order to achieve greater efficiency and profitability in refrigeration and air conditioning. In the literature, studies have reported rheological and heat transfer mechanisms to different concentrations of CuO nano particles, $Al_2O_3$, $SiO_2$, diamond, CNT (carbon nanotube), $TiO_2$ as refrigerants R11, R113, R123, R134a and R141b. The effect of the size of the nanoparticles on heat transfer in mixtures of refrigerant, oil, and nanoparticles is investigated experimentally with R113, VG68 oil and Cu particles with diameters of 20, 50 and 80 nm. The results show a maximum increase of 23.8 % in the heat transfer coefficient in a pool nucleate boiling with reduced diameter from 80 to 20 nm. One of the main factors in the efficiency of a refrigeration system with nano-refrigerants is the heat transfer in the phase change of the heat exchangers (evaporator and condenser). Heat transfer by flow boiling of nano-refrigerants was studied using a mixture of R113 and CuO particles. Experimental tests show a 29.7 % increase in the heat transfer coefficient due to the addition of CuO nanoparticles.

## II. LITERATURE REVIEW

Coumaressin and Palaniradja (2015) have studied regarding Evaporating heat transfer that is extremely necessary within the refrigeration and air-conditioning systems. HFC 134a is that the largely wide used various refrigerants in refrigeration instrumentality like domestic refrigerators and air conditioners. Tho' the worldwide warming up the potential of HFC134a is comparatively high, it's affirmed that it's a protracted term various refrigerants in numerous countries. By the addition of nanoparticles to the refrigerant leads to enhancements within the thermophysical properties and warmth transfer characteristics of the refrigerant, thereby up the performance of the cooling system. In these experiments, the result of mistreatment CuO-R134a within the vapour compression system on the evaporating heat transfer constant was investigated by CFD heat transfer analysis mistreatment the FLUENT software system. Associate experimental equipment was built in step with the national standards of the Asian nation. The experimental studies indicate that the cooling system with nano-refrigerant works unremarkably. Heat transfer coefficients were evaluated mistreatment FLUENT for warmth flux ranged from 10 to 40 kW/m2, mistreatment nano CuO concentrations ranged from 0.05 to 1 / 4 and particle size from ten to 70 nm. The results indicate that evaporator heat transfer constant will increase with the usage of nanoCuO.

Thangavel et al. (2013) studied the performance of compression cycle is assessed on paper with completely different refrigerants. In compression cooling, organic compound refrigerants like R290 and R600a are thought-about as a refrigerant by combination of those at completely different mass fractions concerning 20%+80%, 25%+75%, 50%+50% and 75%+25% severally. Varied performance measures like mechanical device discharge temperature, pressure quantitative relation, volumetrically cooling capability (VCC), volumetrically potency and mass rate of flow area unit analyzed. The results area unit compared with halogenated refrigerants like R134a, R12 for various condenser and evaporator temperatures. Halogenated compounds are having direct environmental impacts in turns of ODP and GWP. Among the organic compound refrigerants cluster, the mixture of R290 and R600a at concentration of 50 every has optimum performance in terms of upper refrigeration impact, higher heat transfer and COP.

Verma and Chaudhary (2017) have established the Ejector growth refrigeration system achieves the numerous improvements in constant of performance as compared to different system. Use of AN ejector as growth device is one amongst the choice ways that. The performance of a vapour compression system that uses AN ejector as a growth device is investigated. Ejector growth Refrigeration systems square measure analysed during this article exploitation constant pressure and constant space mix ejector as a growth device. This paper provides a comparison between constant pressure and constant space model exploitation R-1270 as a refrigerant. Within the analysis, a two-phase constant space and constant pressure ejector flow model was used. Pressure variation on the length of the ejector is obtained for constant space model. The pressure variation is found to be higher for constant space ejector model compared to constant pressure model.

Rakesh et al. (2017) have studied on the point of Improve the constant of Performance (COP), it's needed to decrease the mechanical device Work and increase the cold result. Experimental analysis on vapour compression refrigeration (VCR) system with R134A (Tetra Fluro Ethane) refrigerant was done and their results were recorded. The consequences of the most parameters of performance analysis square measure mass flow of refrigerant, suction pressure of mechanical device, delivery pressure of mechanical device, temperature of evaporator and condenser. The results from vapour compression refrigerant plant was taken wherever the variables like suction pressure of mechanical device, delivery pressure of mechanical device, temperature of evaporator and condenser were noted and constant of performance (COP) was calculated. The results obtained are going to be valid through CFD simulation. Additional diffuser has been introduced in between mechanical device and condenser in order that power input to the mechanical device has been reduced there by enhancing COP. The improvement is completed through CFD simulation; Modelling and meshing is completed in ICEMCFD, analysis in CFX and post leads to CFD POST.

## III. OBJECTIVES OF THE PRESENT STUDY

Many investigations have been done to deal with the problem of global warming and ozone layer depletion due to the use of alternative refrigerants in the refrigeration system. Therefore it is felt that detailed investigations on the possibility of adding a new alternative refrigerant and Nano additives to the refrigerant and the comparison between the different nano fluids will be analyzed using CFD simulation. Our main objective of the present study is to investigate the heat transfer characteristics of the multiphase refrigeration system; the compound (R134a + R152a) is taking as a major refrigerant and three nano fluids are Al2O3, CuO and

ZnO. The most widely used commercial refrigerant R134a and proven alternate R152A were mixed and new hybrid refrigerant will be prepared and the properties of heat transfer will be examined by the concentration of different quantities. The most commonly used commercial refrigerant R134a and the proven alternative R152a were blended and the new hybrid refrigerant was prepared and the heat transfer characteristics will be investigated with different volume concentration.

Nano additives such as ZnO, CuO and $Al_2O_3$ were blended with R152a refrigerant and their corresponding performance on the same system was investigated. Nano additives of $Al_2O_3$, CuO and ZnO of 0.05%v ,0.1 % v and 0.15%v concentration with particle size of 40-50 nm and 150 gm of R152a was charged investigated by CFD Simulation. Nano particles with refrigerant mixture were used in HFC R152a refrigeration system. The system performance with nano particles was then investigated according to the heat transfer characteristics.

## IV. PROBLEM DEFINITION

The Global Warming Potential (GWP) of currently used R134a is high as 1300.The Ozone Depleting Potential (ODP) of R134a is also relatively high. The Montreal and Kyoto Protocol of United Nations suggests minimizing of Hydro Fluro carbons (HFCs) to use as refrigerants. Researches show HFC 134a not much miscible with lubricant oil in the compressor. European countries have already banned R134a. Blending of R134a with other HFC is a problem. R-22 and R134a will be phased out due to environmental issues. To overcome the above problem, refrigerant R152a is proposed in the present study because R152a has Zero Ozone Depleting Potential and a very less value of 120 as Global Warming Potential (GWP) when compared to other refrigerants. The atmospheric life span for R152a is 1.4 years .Pure substance R152a offers excellent thermodynamic properties non toxic and compatibility with the conventional oil in compressor. R152a has been already approved for use in automobile applications as an alternative to R134a by US Environmental Protection Agency. The refrigerant then enters the condenser as superheated vapour at state 2 and leaves as saturated liquid at state3 as a result of heat rejection to the surroundings. The temperature of the refrigerant at this state is still above the temperature of the surroundings. The saturated liquid refrigerant at state 3 is throttled to the evaporator pressure by passing it through an expansion valve or capillary tube. The temperature of the refrigerant drops below the temperature of the refrigerated space during the process. The refrigerant enters the evaporator at state 4 as a low quality saturated mixture, and it evaporates by absorbing heat from the refrigerated space. The refrigerant leaves the evaporator as saturated vapour and re-enters the compressor, completing the cycle.

## V. METHODOLOGY

### A. *Validation Of The Paper*

In reference paper the results that were obtained after the FLUENT analysis are graphed , Heat flux [q] and concentration were two parameters, which were changed during the process The values obtained for different heat fluxes, q = 10, 20, 30, 40 kW were plotted on a graph. For validation process we have taken same boundary condition as in the reference paper and result is compared to by using fluent which is shown in below figure. In this figure heat transfer coefficient is compared for concentration of CuO is 0.55% and heat flux is 20 Kw . In present case the heat transfer coefficient is 18.03 kW/m2-K.

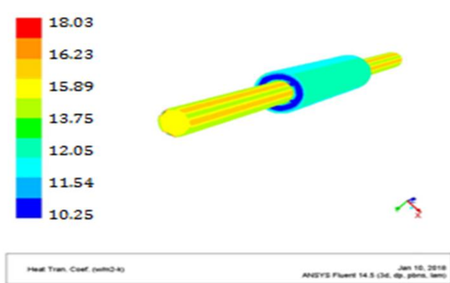


Figure: 1 Heat transfer coefficient in 0.55% CuO and heat flux 20 kW

### B. *blending of r152a and r134a*

This chapter deals with the experimental procedure adopted, relevant parameters during the course of the present investigation. In developing country like India, most of the vapour compression based refrigeration, air conditioning and heat pump systems continue to run on halogenated refrigerants due to its excellent thermodynamic and thermo-physical properties apart from the low cost. However, the halogenated refrigerants have adverse environmental impacts such as ozone depletion potential (ODP) and global warming potential (GWP). Hence it is necessary to look for alternatives refrigerants to full fill the objectives of the international protocols (Montreal and Kyoto) and to satisfy the growing worldwide demand. The mixture composed of R152a and R134a was considered as an alternative to R134a. This mixture is further referred in this work as HCM 50:50 (50% weight of R152a and 50% weight of R134a). Now in this blended refrigerants nano additives are added with the concentration of 0.1%, 0.1% and 0.15%. CFD method is applied for current study and ANSYS (Fluent14.5) tool is used for analysis of different cases.

### C. Basic Steps to perform CFD Analysis:

1) *Pre-processing*

a) *CAD Modelling:* Creation of CAD Model by using CAD modelling tools for creating the geometry of the part/assembly of which we want to perform FEA. CAD model may be 2D or 3d.

b) *Meshing:* Meshing is a critical operation in CFD. In this operation, the CAD geometry is discretized into large numbers of small Element and nodes. The arrangement of nodes and element in space in a proper manner is called mesh. The analysis accuracy and duration depends on the mesh size and orientations. With the increase in mesh size (increasing no. of element), the CFD analysis speed decrease but the accuracy increase.

c) *Type of Solver:* Choose the solver for the problem from Pressure Based and density based solver Choose the required physical model for the problem i.e. laminar, turbulent, energy, multiphase, etc**.**

d) *Material Property:* Choose the Material property of flowing fluid.

e) *Boundary Condition:* Define the desired boundary condition for the problem i.e. velocity, mass flow rate, temperature, heat flux etc.

2) *Solution:*

a) *Solution Method :* Choose the Solution method to solve the problem i.e. First order, second order

b) *Solution Initialization:* Initialized the solution to get the initial solution for the problem.

### D. Post processing.

For viewing and interpretation of Result. The result can be viewed in various formats: graph, value, animation etc.

### E. Mathematical Models

The following equations are used to calculate the thermal properties of nano refrigerant

Specific heat of nano refrigerant

cp = (1-C) cp1+ C cp2 (1)

Thermal conductivity nano refrigerant

k = k1[(k2+2k1- 2C(k1-k2)) / (k2+2k1+C (k1-k2))] (2)

Viscosity of nano refrigerant

$\mu = \mu 1\ [1 / (1- C)^{2.5}]$ (3)

Density of nano refrigerant

$\rho = (1- C)\ \rho 1 + C\ \rho 2$, (4)

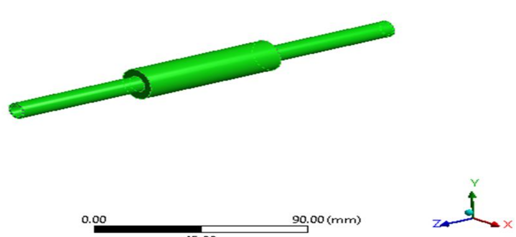


Figure- 2. CAD Model

1) *Mesh:* Generate mesh.

Figure 3. Mesh model

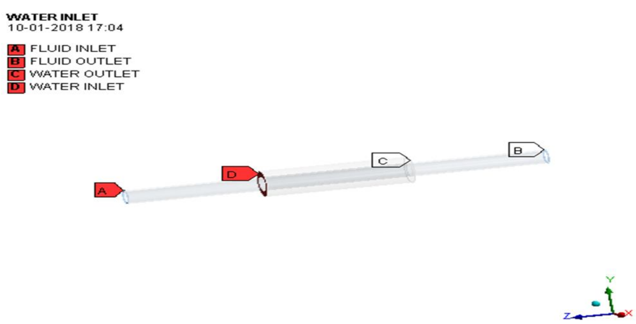


Figure 4 . Boundary regions in model

*F. MESH Dettail*

| MODEL | NODES | ELEMENT | ELEMENT LENGTH |
|---|---|---|---|
| 3D TYPE | 65488 | 40358 | 3e-003m |

1) Fluent setup: After mesh generation define the following setup in the Ansys fluent 14.5.
2) Problem Type : 3D
3) Type of Solver: Pressure-based solver , Absolute and Steady.
4) Physical model: Viscous: K-epsilon two equation turbulence model , Standard wall functions.
5) Material Property: Working fluid is Blended refrigerants with Nano additives-
6) Refrigerants R134a +R152a with concentration percentage is 50:50.
7) Nano additives are $Al_2O_3$, CuO and ZnO with concentration percentages of 0.01, 0.1 and 0.15.
8) In Fluent database these nano additives are available, so the material property is available in data base.

## VI. RESULTS AND DISCUSSION

*A. Numerical Analysis*

The work is conducted to evaluate the heat transfer coefficient of the nano refrigerant with standard volume concentrations of nano-particles in the refrigerant. CFD Simulation results show an excellent stable flow phenomenon which means analysis is done with all dynamics algorithm and values are more accurate. From simulation results shows that temperature drop is higher in case of CuO nano particle as compare to the other and vapour pressure drop is also higher in CuO nano particle. The heat transfer coefficient is quite batter in case of CuO with 0.1 volume concentration as compare to the other nano fluids. The contour images of simulation results are given below.

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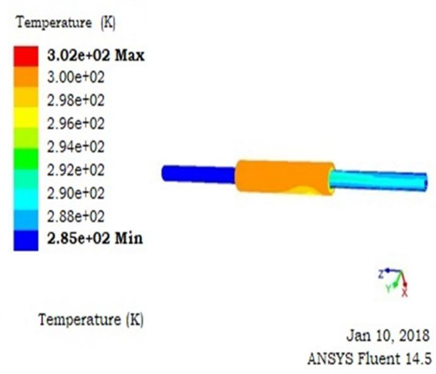


Figure 1. Temperature (˚K) Contour for R132a+R152a+CuO

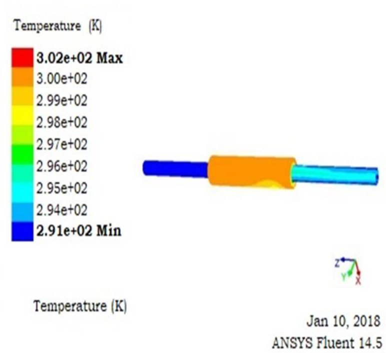


Figure 2. Temperature (˚K) Contour for R132a+R152a+AL2O3

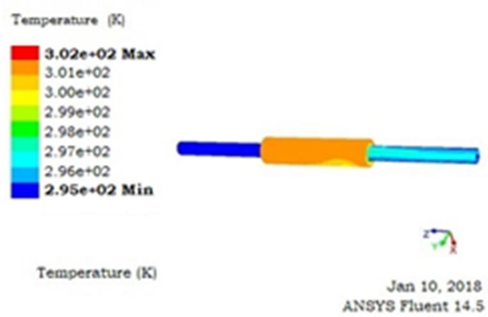


Figure 3. Temperature (˚K) Contour for R132a+R152a+ZnO

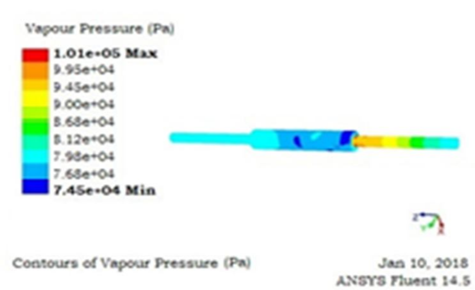


Figure 4. Vapour Pressure (pa) Contour for R132a+R152a+CuO

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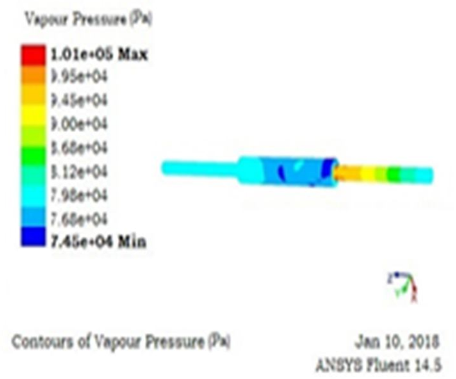


Figure 5. Vapour Pressure (pa) Contour for R132a+R152a+AL2O3

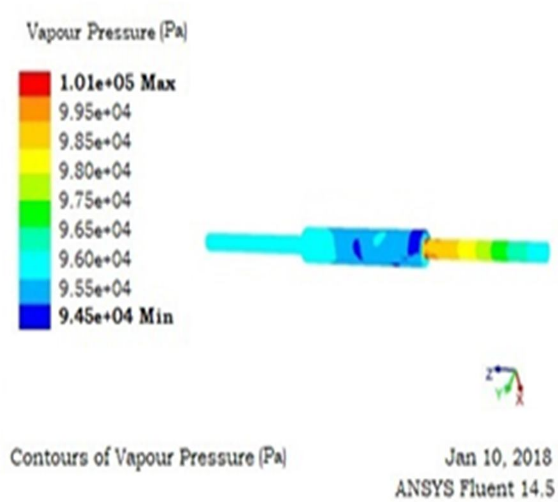


Figure 6. Vapour Pressure (pa) Contour for R132a+R152a+ZnO

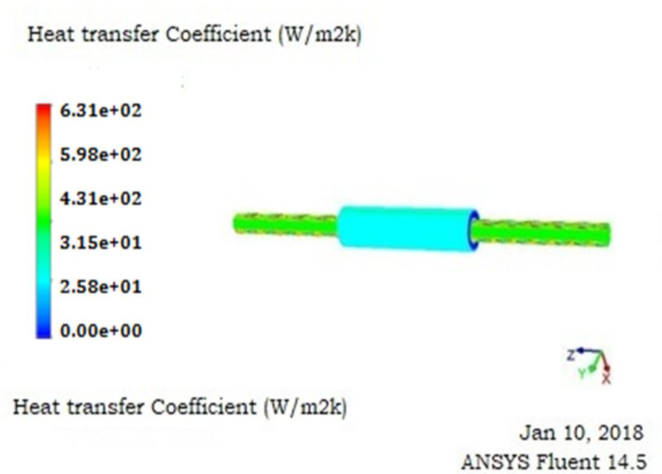


Figure 7. Heat transfer Coefficient (W/m2k) Contour for R132a+R152a+CuO

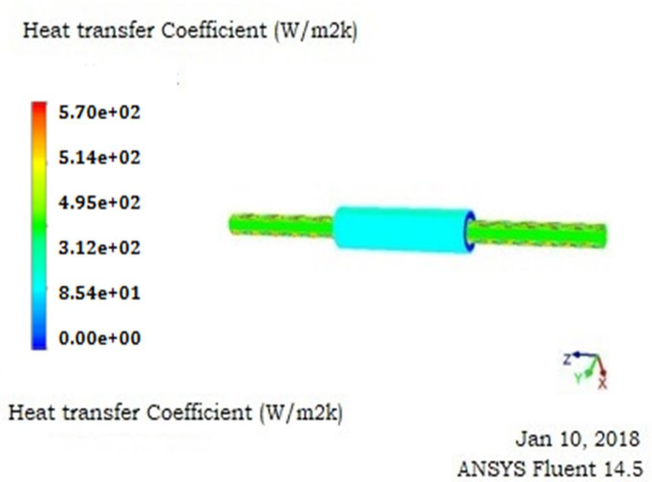


Figure 8. Heat transfer Coefficient (W/m2k) Contour for R132a+R152a+AL2O3

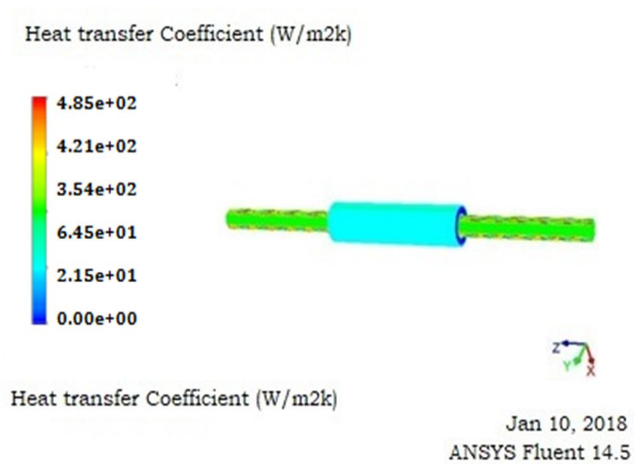


Figure 9. Heat transfer Coefficient (W/m2k) Contour for R132a+R152a+ZnO

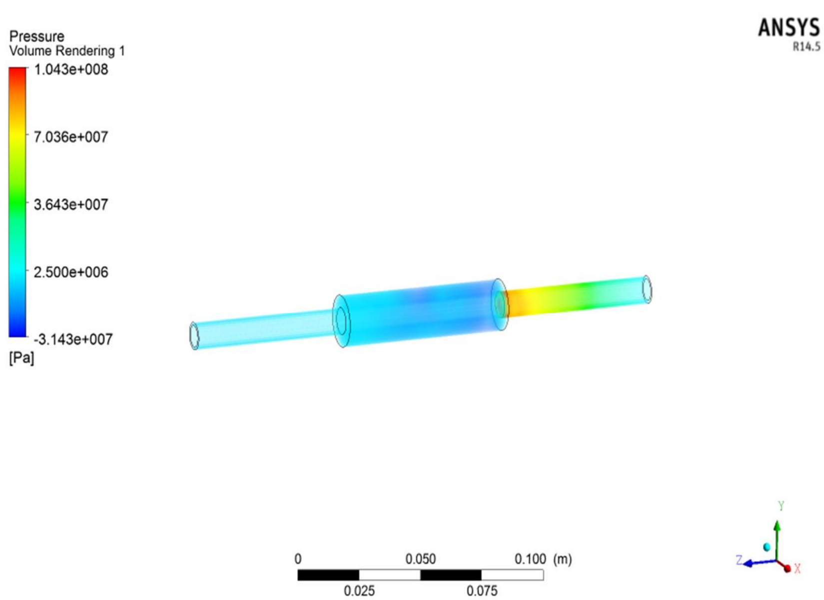


Figure 10 Pressure volume rendering of the system

RESULTS TABLE 1

| Refrigerants With additives | Temperature Drop (˚K) | Vapour Pressure (pa) | | Heat transfer Coefficient (W/m2k) |
|---|---|---|---|---|
| | T2-T1 | MAX | MIN | |
| R132a+R152a+CuO | 17 | 1.01e+05 | 7.45e+04 | 630 |
| R132a+R152a+AL2O3 | 11 | 1.01e+05 | 8.25e+04 | 570 |
| R132a+R152a+ZnO | 07 | 1.01e+05 | 9.45e+04 | 485 |

## VII. CONCLUSION

Heat Transfer characters should be enhanced to get optimal results. By adding nanoparticles to the refrigerant we found out output temperatures to study the heat transfer rate. In the circular section at room temperature of 300 degrees Kelvin. A constant heat flux is applied to study its effect on output temperatures. By analysing the results we concluded that as the nano particle are added to the refrigerants the heat transfer coefficient increases. Refrigerant with low pressure is desirable in the system because higher the vapour pressure, the weight of the equipment parts and accessories increases. Increase in concentration of nano additives reduces the vapour pressure of the refrigerant. The vapour pressure generally increases with the increase in the evaporator temperature. CuO nano additive with R132a+R152a shows a lowest vapour pressure among the other additives. Following CuO nano additive, Al2O3 and ZnO has higher vapour pressure. The vapour pressure of 0.1% of CuO with R132a+R152a was lowest among all the contour and it could be suggested for lighter component of the refrigeration system.

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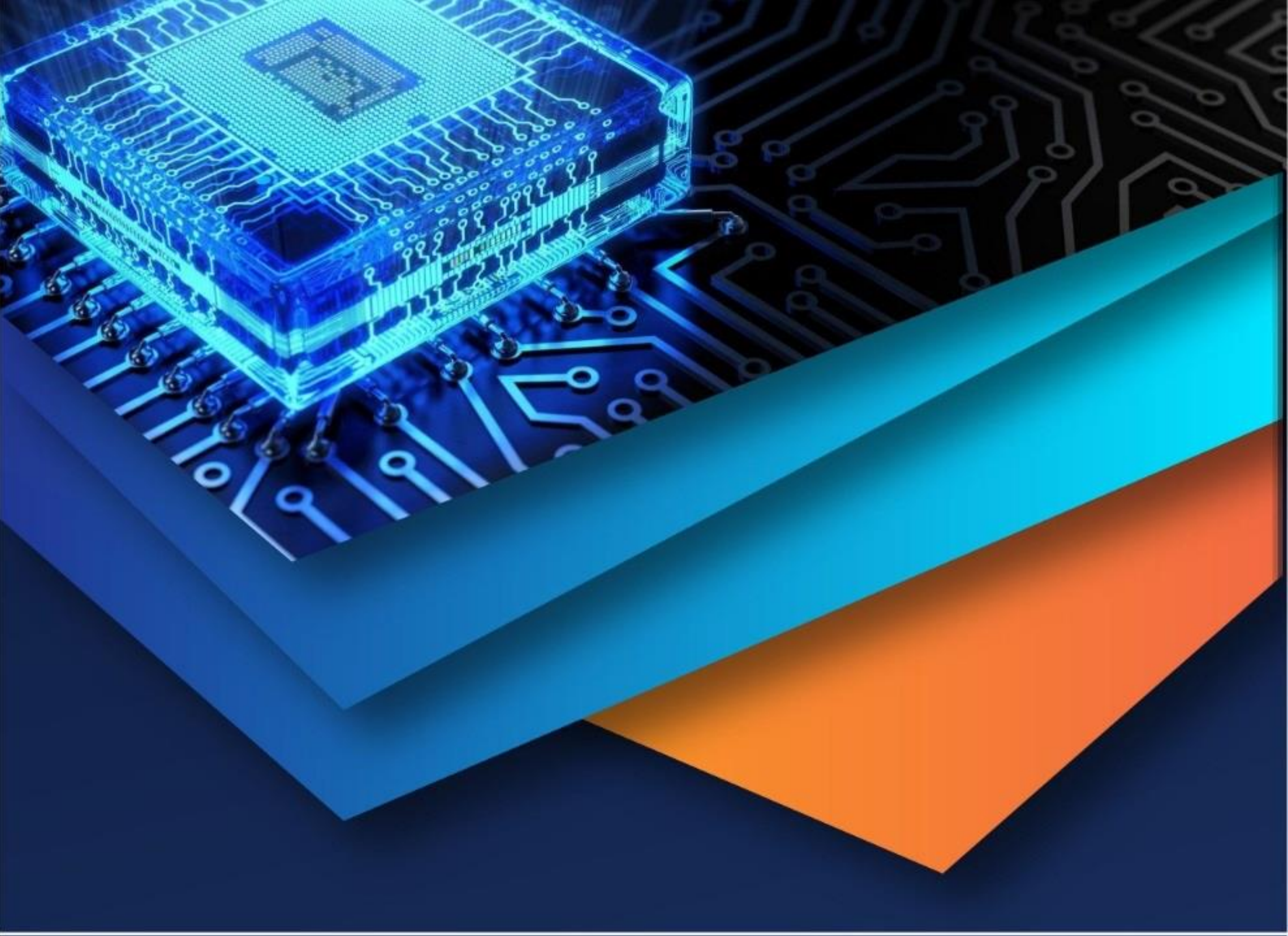


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