

A Study of Refrigeration Applications Using Nanofluids

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ABSTRACT : A Critical review of refrigeration applications using nanorefrigerants 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. Using nanorefrigerants the freezing capacity was higher and reduces the power input by 11.5% in one of the case study. It has been shown with 0.5% wt concentration alumina oxide nanoparticle size range 15-70nm, the coefficient of performance was found to be increased by 8.5%. 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.

KEYWORDS: refrigeration, nanofluid, refrigerants etc.

I. INTRODUCTION

Allison Massao Hirata and Flávio Augusto Sanzovo Fiorelli [1] presented in their technical paper the results of a numerical analysis on the use of nanoparticle in refrigerant-based fluids and its effects on the performance of capillary tubes. Using R-134a as the refrigerant and CuO as the nanoparticle, some parameters that affect refrigerant mass flow have been simulated in order to evaluate their relevance and effect on the system component. The numerical study indicated that nanofluids have an impact on capillary tube performance that cannot be neglected, and further numerical and experimental research must be developed to better quantify such impact, as well as the impact in the whole refrigeration cycle performance.

S. Vandaarkuzhali and R. Elansezhian [2] presented in their technical paper thermal modeling of air conditioning system using various

nanofluids. The performance of the heat pipe greatly depends on the filling ratio of the working fluids. The model uses information of the fluid input conditions, geometric characteristics of the system, size of nanoparticles and the compressor speed to forecast the fluids output temperatures, the operating pressures, the compressor power consumption and the system overall energy performance. Such an

analysis can be conveniently useful to compare the thermal performance of different nano particles. The use of nanofluids as a fluid in air conditioning system was studied and the computer simulation program was developed to solve the nonlinear equations of the system model. The advantages of nanofluids are higher thermal conductivity than that predicted by currently available macroscopic models, excellent stability and little penalty due to an enhancement in pressure drop and pipe wall erosion experienced by suspensions of micrometer or millimeter particles. Simulation results have shown that for the same geometric characteristics of the system performance increased from 12% to 18% by application of nanofluid as a fluid in VCS. In this paper the performance of refrigeration system with R22 and 0.1%v of three types of nanofluids namely (CuO, ZnO, Al₂O₃) has been analysed, compared and the results have been discussed.

ailong Li Wenyan Yang, Zhixin Yu, Li Zhao [3] presented in their technical paper that the nano-particles, including metals, oxides,

carbides, or carbon nanotubes, can increase the conduction and convection coefficients and consequently, enhance the heat transfer. Using nanofluids as working fluids in the refrigeration, air-conditioning and heat pump systems has attracted much attention. This work set-up a test rig to experimentally study the system performance of a heat pump with nanofluid as refrigerant, which was prepared by mixing 5wt% TiO₂ with R22. Results show that adding the nano

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particle TiO₂ didn't changed the heat absorbed in the evaporator clearly but increase the heat released in the condenser. As a results, compared to using pure R22, when using R22 + TiO₂, the COP of the cooling cycle was decreased slightly, however, the COP of the heating cycle was increased significantly increased power consumption of compression.

,R. Reji Kumar , ,K. Sridhar , ,M.Narasimha [4] presented in their technical paper the performance of the refrigeration system depends upon the heat transfer capacity of the refrigerant. Normally R12, R22, R600, R600a and 134a are used as a refrigerant. This refrigerant heat transfer capacity was not so good and increase power consumption. Due to these limitation nanofluids are enhanced with the normal lubricant and increases the heat transfer capacity and reduces the power consumption. Aluminium oxide nanofluid was used for enhancing the heat transfer capacity of the refrigerant in the refrigeration System. In this experiment heat transfer enhancement was investigated numerically on the surface of a refrigerator by using Al₂O₃ nano-refrigerants, where nanofluids could be a significant factor in maintaining the surface temperature within a required range. The addition of nanoparticles to the refrigerant results in improvements in the thermophysical properties and heat transfer characteristics of the refrigerant, thereby improving the performance of the refrigeration system. Stable nanolubricant has been prepared for the study. The experimental studies indicate that the refrigeration system with nano-refrigerant works normally. It is found that the freezing capacity is higher and the power consumption reduces by 11.5 % when POE oil is replaced by a mixture of mineral oil and Aluminium oxide nanoparticles. Thus using Aluminium oxide nanolubricant in refrigeration system is feasible.

Eed Abdel-Hafez Abdel-Hadi, Sherif Hady TaherAbdel Hamid Mohamed Torki and Samar Sabry Hamad Shobra[5] presented in their technical paper the effect of using nano CuO-R134a in the vapour compression system on the evaporating heat transfer coefficient was experimentally investigated. An experimental test rig was designed and constructed here for this purpose. The test section was a horizontal tube in tube heat exchanger made from copper. The refrigerant was evaporated inside an inner copper tube and the heatload was provided from hot water that passing in an annulus surrounding the inner tube. Measurements were performed for heat flux ranged from 10 to 40 kW/m², using nano CuO concentrations ranged from 0.05 to 1% and particle size from 15 to 70 nm. The measurements indicated that for a certain nano concentration as heatflux or mass flux increases the evaporating heat transfer coefficient increases. The measurements indicated also that the evaporating heat transfer coefficient increases with increasing nano CuO concentrations up to certain value then decreases.

Subramani.N1, Aswin Mohan2, Dr.Jose Prakash.M3[6] presented in their technical paper the investigation on a vapour compression refrigeration system with mineral oil and mineral oil with different nanoparticles added to it. The results indicate that refrigeration system with nanolubricant works normally and safely. It is found that power consumption reduces by 15.4% and the coefficient of performance increases by 20% when TiO₂ nanolubricant is used instead of SUNISO 3GS

Kuljeet Singh, 2Kundan Lal [7] presented in their technical paper alumina (Al₂O₃) nanoparticles of 20 nmdiameter are dispersed in refrigerant R134a to improve its heat transfer performance. After conducting experimental study, it has been found out that performance of the system has been improved. The improvement in coefficient of performance (COP) was maximum (7.2 to 8.5%) with 0.5% Al₂O₃ (% wt.) nanoparticles. When the mass fraction of nanoparticles increased to 1% in refrigerant COP was found to be lower than even from pure R134a. Further,increased mass fraction of Al₂O₃ (1%), lowers down the pressure and temperature after expansion of the nanorefrigerant in the expansion valve. In addition to this the specific heat of refrigerant gets decreased.

home Bekele Kotu & R. Reji Kumar [8] Convective heat transfer is very important in the HVAC, refrigeration and microelectronics

cooling applications. R134a is most widely adopted alternate refrigerant in refrigeration equipment, such as domestic refrigerators and

air conditioners. Though the global warming up potential of R134a was relatively high, it is affirmed that it was a long term alternate

refrigerants in lots of countries. The addition of nanoparticles to the refrigerant results in improvements in the thermophysical

properties and heat transfer characteristics of the refrigerant, there by improving the performance of the refrigeration system. The performance of the domestic refrigeration system with HFC134a/mineral oil system was compared with mineral oil/nanorefrigerant and HFC134a/mineral oil/double pipe heat exchanger. The result indicates that the system

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performance has improved when HFC134a/mineral oil/DPHE system was used instead of HFC134a/mineral oil and mineral oil/nano refrigerant system. The mineral oil/nano refrigerant and HFC134a/mineral oil/DPHE works normally and safely in the refrigeration system. The HFC 134a/mineral oil/DPHE system reduced the energy consumption by 30% and mineral oil/nano refrigerant system reduced the energy consumption by 26 % when compared with the HFC134a/mineral oil system. There was also an enhancement in coefficient of performance (COP) when DPHE was introduced in the normal system.

Muhammad Abbas, Rashmi G. Walvekar, Mohammad Taghi Hajibeigy, Farhood S. javadi [9] presented in their technical paper that CNT Nanoparticles was introduced into the system through lubricant to improve its heat transfer performance. A concentration of 0.01-0.1wt% of CNT Polyester Oil was tested along with suitability and environmental friendly refrigerant R134a. Results show that CNT nanoparticle concentration of 0.1wt% was optimal and gives highest heat transfer enhancement and improve the coefficient of performance (COP) by 4.2%.

Sarkar, J [10] presented in their technical paper the theoretical analyses of the double-tube gas cooler in transcritical carbon dioxiderefrigeration cycle have been performed for improvement of gas cooler as well as CO₂ cycle using Al₂O₃, TiO₂, CuO, and Cu nanofluids as coolants. Effects of various operating parameters (nanofluid inlet temperature and mass flow rate, CO₂ pressure and particle volume fraction) are studied as well. Use of nanofluid as coolant in double-tube gas cooler of CO₂ cycle improves the gas cooler effectiveness, cooling capacity, and COP without penalty of pumping power. The CO₂ cycle yields best performance using Al₂O₃-H₂O as a coolant in double-tube gas cooler followed by TiO₂-H₂O, CuO-H₂O, and Cu-H₂O. The maximum cooling COP improvement of transcritical CO₂ cycle for Al₂O₃-H₂O was 25.4%, whereas that for TiO₂-H₂O was 23.8%, for CuOH₂O – 20.2%, and for Cu-H₂O – 16.2% for the given ranges of study. Study shows that the nanofluid may effectively use as coolant in double-tube gas cooler to improve the performance of transcritical CO₂ refrigeration cycle.

Omer A. Alawi, Nor Azwadi Che Sidik, Rizalman Mamat [11] presented in their technical paper the Control Volume based Finite Element Method (CVFEM) was used to simulate the natural convection heat transfer of nanorefrigerant in cylindrical horizontal annuli with imposed temperatures in both surfaces. The Maxwell–Garnetts (MG) and Brinkman models are also employed to estimate the effect of thermal conductivity and viscosity of nanorefrigerant. The governing parameters are nanoparticles types, nanoparticles

concentration and size, effect of Rayleigh numbers (Ra), eccentricity and rotation of inner cylinder. Results are presented in the form of isotherms and streamlines of nanorefrigerant temperature and velocity. The results indicate that Al₂O₃/R141b with concentration (2%) and nanoparticles size (20 nm) has the best heat transfer performances. Moreover, the heat transfer and fluid flow enhance by increasing the Rayleigh numbers (Ra). Eccentricity and rotation of inner cylinder also have effects on heat transfer characteristics. S. A. Fadhilah, R. S. Marhamah, and A. H. M. Izzat[12] presented in their technical paper the effect of the suspended copper oxide (CuO) nanoparticles into the 1,1,1,2-tetrafluoroethane, R-134a was investigated by using mathematical modeling. The investigation includes the thermal conductivity, dynamic viscosity, and heat transfer rate of the nanorefrigerant in a tube of evaporator. The results show enhanced thermophysical properties of nanorefrigerant compared to the conventional refrigerant. These advanced

ermophysical properties increased the heat transfer rate in the tube. The nanorefrigerant could be a potential working fluid to be used in the refrigeration system to increase the heat transfer characteristics and save the energy usage. C. V.

Papade, R. S. Wale [13] presented in their technical paper the performance of an air conditioning system with and without a nanorefrigerant. R134a was most

dely adopted alternate refrigerant in refrigeration equipment, such as domestic refrigerators and air conditioners. This refrigerant heat

transfer capacity was not so good and increase power consumption. Due to these limitation nanofluids are enhanced with the normal lubricant and increases the heat transfer capacity and reduces the power consumption. The experimental studies indicate that the air conditioning system with nanorefrigerant works normally. It was found that the coefficient of performance was increased by 14% and the power consumption reduces nearly by 20% when POE oil was replaced by a mixture of POE oil and Al₂O₃ nanoparticles. Juan

Carlos Valdez Loaiza [14] presented in their technical paper a simulation model for a liquid-to-water heat pump, with reciprocating compressor and double-tube condenser and evaporator was studied. The multi-zone method was employed in the modeling of the heat exchangers. The water based nanofluid was supposed to flow through the inner

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circular section of the evaporator, while the refrigerant was left to the annular passage. A computational program was developed to solve the resulting non-linear system of algebraic equations. Different nanoparticles (Cu, Al₂O₃, CuO and TiO₂) were studied for different volume fraction and particle diameters. Simulation results have shown that, for a given refrigerating capacity, evaporator area and refrigerant-side pressure drop are reduced when: (i) the volume fraction of nanoparticles increase; (ii) the diameter of nanoparticles decrease. Also, nanofluid-side pressure drop and, consequently, pumping power, increase with nanoparticle volume fraction and decrease with nanoparticle size. Results from a typical case-study indicated an evaporator area reduction, with the use of nanofluids as secondary coolant, if compared to the conventional basefluid (H₂O). Nilesch S. Desai and P.R. Patil [15] presented in their technical paper the SiO₂ nano-oil was proposed as a promising lubricant to enhance the performance of vapour compression refrigerator compressor. The stability of SiO₂ nanoparticles in the oil was investigated experimentally. It was confirmed that the nanoparticles steadily suspended in the mineral oil at a stationary condition for long period of time. The application of the nano-oil with specific concentrations of 1%, 2% and 2.5% (by mass fraction) were added in the compressor oil. The VCRS performance with the nanoparticles was then investigated using energy consumption tests. The result shows the COP of system were improved by 7.61%, 14.05% & 11.90%, respectively, when the nano-oil was used instead of pure oil.

Mohd Hazwan Syafiq Bin Harun [16] presented in their technical paper Alumina and Carbon Nanotubes nanoparticles have been used in experiment. This two types of nanoparticles are selected based on study conducted by previous researchers who showed encouraging results. The nanolubricant was prepared by using 'two steps' technique which was alumina and CNT particles diluted with 'poly-ester lubricant' with concentration of 0.2%. There are three types of experiment have been conducted in this project. The first experiment was using normal lubricant which was 'poly-ester' lubricant, followed by experiments using CNT lubricant and 'Alumina lubricant'. The result shows that, with addition of nano particle into 'poly-ester lubricant' it increases the rate of refrigeration system performance. The maximum rate of performance improvement by adopting CNT into lubricant was 8.29%, while by using Alumina lubricant the maximum rate of performance improvement was 13.8%. As a calculation, Alumina was more suitable compared to CNT to be mixed with Ploy-ester lubricant for refrigeration system.

Gupta H.K, Agrawal G.D, Mathur J [17] presented in their technical paper the broad range of nanofluid based current and future applications. Some barriers and challenges are also focused for implementing these new class of working fluids. At last future opportunities in nanofluid research are identified and directions are given so that the vision of nanofluid can be completed.

Mr. Sajjan Kawade, P.T. Kharat [18] presented in their technical paper the performance of refrigerator was evaluated in term of COP which was the ratio of refrigeration effect to the net work input given to the system. The COP of vapour compression refrigeration system was improved either by (i) increasing the refrigeration effect in terms of cooling load capacity or (ii) by reducing compressor work input given to the vapour compression refrigeration system, Work input can be reduced by multistage compression or compound compression instead of single stage compression. Refrigeration effect can be increased by passing the refrigerant through sub cooler after condenser to evaporator. These methods have their own advantages and limitations. The use of additives in the lubricant to improve the performance of the compressor and, at the same time, enhance the heat transfer performance of the condenser and

evaporator, represents a new type of energy saving technology. Comparing the use of nanoparticles to modify the organic surface with

ditional lubricant additives, the former was more environmentally friendly and gives better heat transfer performance. This work aims to concentrate on experimental study on the effect of nanoparticles in vapour compression refrigeration system. Initial step is develop the vapour compression system. In this study the nanoparticles of SiO₂ (15-20nm) are to be used as additive in refrigerant and lubricating oil. Nanoparticles of SiO₂ are to be added in the refrigerant and in lubricant to prepare the nanorefrigerant and mineral oil

with volume fraction 0.1, 0.2 and 0.3% by mass. Experimentation results shows that COP of experimental system for 0.1 %, 0.2% and 0.3% of refrigerant are increased by 3.77%, 6.70% and 9.86% respectively. Results shows that COP of experimental system for 0.1 %, 0.2% and 0.3% of lubricant are increased by 6.97%, 9.90% and 12.68% respectively.

T. Coumaressin and K. Palaniradja [19] presented in their technical paper experiments which effect the use of CuO-R134a in the vapour compression system on the evaporating heat transfer coefficient was investigated by CFD heat

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transfer analysis using the FLUENT software. An experimental apparatus was build according to the national standards of India. The experimental studies indicate that the refrigeration system with nanorefrigerant works normally. Heat transfer coefficients were evaluated using FLUENT for heat flux ranged from 10 to 40 kW/m², using nano CuO concentrations ranged from 0.05 to 1% and particle size from 10 to 70 nm. The results indicate that evaporator heat transfer coefficient increases with the usage of nanoCuO.

R. S. Mishra [20] presented in their technical paper thermal modeling of Vapor Compression Refrigeration System using R134a in primary circuit and AL₂O₃-Water based nanofluids in secondary circuit. The model uses information of the secondary fluids input conditions geometric characteristics of the system, size of nanoparticles and the compressor speed to predict the secondary fluids output temperatures, the operating pressures, the compressor power consumption and the system overall energy performance. Such an analysis can be conveniently useful to compare the thermal performance of different nano particles (Cu, Al₂O₃, TiO₂ and CuO) based nano fluid as a secondary fluid in a Vapor Compression Refrigeration System. The influence of input variables on the output of the system is presented. Such a model can also be used to design various Components viz. Evaporator, Compressor, Condenser and Throttle Valve for Vapor Compression Refrigeration Systems for any desired cooling capacity. The use of nanofluids as a secondary fluid in vapour compression refrigeration systems was studied and computational simulation program was developed to solve the non linear equations of the system model. Simulation results have shown that for the same geometric characteristics of the system performance increased from 17% to 20% by application of nanofluid as a secondary fluid in VCS.

D.Sendil Kumar, Dr.R.Elansezhian [21] presented in their technical paper experimental investigation was made to reduce the usage of HFC 134a with the Hydrocarbon Refrigerant mixtures (HCM) of R134a and R152a refrigerants in the proportion of 30:70, 50:50, and 70:30 by mass. Experiments were conducted by continuous running tests under an ambient temperature of 32°C. The overall performance of the system proved that the HCM could be a long term alternative for R134a.

N. Subramani , M. J. Prakash [22] presented in their technical paper experimental studies indicate that the refrigeration system with nanorefrigerant works normally. It was found that the freezing capacity was higher and the power consumption reduces by 25 % when POE oil was replaced by a mixture of mineral oil and alumina nanoparticles. Calculations show that the enhancement factor in the evaporator was 1.53 when nanorefrigerants are used instead of pure refrigerant

Satnam Singh, Kapil Sharma, Kundan Lal, Naveen Mani Tripathi [23] presented in their technical paper the performance of the nanorefrigerant in vapour compression cycle and the challenges of using nanorefrigerants in vapour compression cycle.

Kiran Kumar K, Ramesh Babu Bejjam, Atul Najan [24] presented in their technical paper A thermosyphon system was a heat transfer loop which operates on the basis of gravity and buoyancy forces. It guarantees a good reliability and low maintenance cost as it does not involve any mechanical pump. Therefore, it can be used in many industrial applications such as refrigeration and air conditioning, electronic cooling, nuclear reactors, geothermal heat extraction, etc. But flow instabilities and loop configuration are the major problems in this system. Several previous researchers studied that stabilities can be suppressed by using nanofluids as loop fluid. In the present study arectangular thermosyphon loop with end heat exchangers areconsidered for the study. This configuration is more appropriate for many practical applications such as solar water heater, geothermal heat extraction, etc. In the present work, steady-

te analysis is carried out on thermosyphon loop with parallel flow coaxial heatexchangers at heat source and heat sink. In this loop nanofluid isconsidered as the loop fluid and water is considered as the external fluid in both hot and cold heat exchangers. For this analysis onedimensional homogeneous model is developed. In this model,conservation equations like conservation of mass, momentum, energyare discretized using finite difference method. A computer code is written in MATLAB to simulate the flow in thermosyphon loop. A comparison in terms of heat transfer is made between water and nanofluid as working fluids in the loop

Bhagat UK, More PV and Khanna PK [25] presented in their technical paperr describes preparation of zinc oxide (ZnO) based

nanofluids in polymer matrix. The rheological properties of nanofluid were studied and were applied in heat transfer application. Heat transfer application of aqueous based ZnO nanofluid was tested and it was observed that, the presence of ZnO nanofluid effectively reduces the temperature propagation in a sono-chemically heated system. It was observed

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that the heat absorption capacity was increased by about 30-40% for the ZnO containing nanofluid. For the preparation of nanofluids, as synthesized ZnO nanoparticles were utilized after characterization by various modern tools such as UV-visible, Raman spectroscopy, XRD, SEM, Particle size analysis, and TGA studies. The average particle size of as prepared ZnO nanoparticle was in the range of 19 to 30 nm and XRD analysis revealed hexagonal crystal structure.

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