IJREI

International Journal of Research in Engineering and Innovation (IJREI)

journal home page: http://www.ijrei.com

ISSN (Online): 2456-6934

Performance improvement using nano materials mixed in R-718 in the secondary circuit of evaporator of vapour compression refrigeration system using ecofriendly refrigerants

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Abstract

Now a day's refrigeration based equipment are most important for industrial and domestic applications. Those systems utilize more energy compare to other appliances. The refrigeration systems have been severely investigated to reduce the energy consumption in many research articles. Hence, nanoparticle based refrigerant has been introduced a superior properties refrigerant that increased the heat transfer performance of base refrigerant of the refrigeration system. Many types of solid and oxide materials could be used as the nanoparticles to be suspended into the conventional refrigerants. In this paper, the effect of the suspended copper oxide (CuO), Titanium Oxide (TiO_2), Aluminum Oxide (Al_2O_3), into secondary circuit of the evaporator and R134a, R1234ze and R1234yf ecofriendly refrigerants were investigated. The use of nano refrigerant/refrigerant as a primary fluid in vapour compression refrigeration systems was studied and computational simulation program was developed to solve the nonlinear equations of the system components and to analyze the effect of these changes to the second law performance of the system in terms of exergetic efficiency and exergy destruction ratio. This investigation includes variation of the thermal conductivity, dynamic viscosity, and heat transfer rate of the nano refrigerants and without nano refrigerant with complete system geometry of VCRS. It is also expected that after implementation of these systems in our existing systems how much cost can be reduced by using optimization techniques. The comparison between nano materials that have been done in the secondary circuit of evaporator, which enhances the evaporator temperature that results in increase in COP. The improvement in the first law efficiency in terms of COP by using copper oxide (CuO),aluminum oxide (Al_2O_3), and Titanium oxide(TiO_2) is about 18.479%, 17.466%, and 15.95%, respectively alongside improvement in the evaporator overall heat transfer coefficient using CuO, Al_2O_3,and$TiO_2$is about 107.656%, 98.6276%,and 86.44%, respectively . Similarly, the improvement in the condenser overall heat transfer coefficient by using CuO, Al_2O_3, and TiO_2 is 11.239%, 10.773%, and 9.942%, respectively. The improvement in the second law (exergetic) performance is using CuO, Al_2O_3, TiO_2, is 13.929 %, 12.9425 %, and 11.492%, respectively.

Keywords: Performance Improvement, ecofriendly refrigerants, Nano Materials,Thermodynamic (Energy-Exergy) Analysis

1. Introduction

Ultrahigh-performance cooling is one of the most vital needs of many industrial technologies. However, inherently low thermal conductivity is a primary limitation in developing energy-efficient heat transfer fluids that are required for ultrahigh-performance cooling. Modern nanotechnology can produce metallic or nonmetallic particles of nanometer dimensions. Nanomaterials have unique mechanical, optical, electrical, magnetic, and thermal properties. Nanofluids are engineered by suspending nanoparticles with average sizes below 100 nm in traditional heat transfer fluids such as water, oil, refrigerant and ethylene glycol. A very small amount of guest nanoparticles, when dispersed uniformly and suspended stably in host fluids, can provide dramatic improvements in the thermal properties of host fluids. Nanofluids (nanoparticle fluid suspensions) is the term coined by Choi [1] to describe this new class of nanotechnology-based heat transfer fluids that exhibit thermal properties superior to those of their host fluids or conventional particle fluids suspensions. Nano fluid technology is a new interdisciplinary field of great importance where nanoscience, nanotechnology, and thermal engineering meet, has developed

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largely over the past decade. The goal of nanofluids is to achieve the highest possible thermal properties at the smallest possible concentrations (preferably <1% by volume) by uniform dispersion and stable suspension of nanoparticles (preferably <10 nm) in host fluids.. Since Choi [1] conceived the novel concept of nanofluids in the spring of 1993, talented and studious thermal scientists and engineers in the rapidly growing nanofluids community have made scientific breakthrough not only in discovering unexpected thermal properties of nanofluids, but also in proposing new mechanisms behind enhanced thermal properties of nanofluids, developing unconventional models of nanofluids, and identifying unusual opportunities to develop next-generation coolants such as smart coolants for computers, Industrial appliances and safe coolants for nuclear reactors. As a result, the research topic of nanofluids has been receiving increased attention worldwide.

1.1 Development of the concept of nanofluid

In the development of energy-efficient heat transfer fluids, the thermal conductivity of the heat transfer fluids plays a vital role. Despite considerable previous research and development efforts on heat transfer enhancement, major improvements in cooling capabilities have been constrained because traditional heat transfer fluids used in today's thermal management systems, such as water, oils, and ethylene glycol, have low thermal conductivities, also pure refrigerant orders-of-magnitude smaller than those of most solids. Due to increasing global competition, a number of industries have a strong need to develop advanced heat transfer fluids with significantly higher thermal conductivities than are presently available. It is well known that at room temperature, metals in solid form have orders of magnitude higher thermal conductivities than those of fluids. For example, the thermal conductivity of copper at room temperature is about 700 times greater than that of water and about 3000 times greater than that of engine oil, as shown in Table 1.. The thermal conductivity of metallic liquids is much greater than that of nonmetallic liquids. Therefore, the thermalConductivities of fluids that contain suspended solid metallic particles could be expected to be significantly higher than those of conventional heat transfer fluids.

Table 1. Thermal Conductivity of Various Materials

All the property of nanoparticle is taken at 300 K unless mentioned.		
Type	Material	Thermal conductivity (W/m.K)
Metallic solids	Silver	429
	Copper	401
	Aluminum	237
Nonmetallic solids	Diamond	3300
	Carbon nanotube	3000
	Silicon	148
	Alumina (Al_2O_3)	40
Metallic liquids	Sodium at 644 K	72.3
Nonmetallic liquids	Water	0.613
	Ethylene glycol	0.253
	Engine oil	0.145

Modern nanotechnology has enabled the production of metallic or nonmetallic nanoparticles with average crystallite sizes below 100 nm. The mechanical, optical, electrical, magnetic, and thermal properties of nanoparticles are superior to those of conventional bulk materials with coarse grain structures. Recognizing an excellent opportunity to apply nanotechnology to thermal engineering, Choi conceived the novel concept of nanofluids by hypothesizing that it is possible to break down these century-old technical barriers by exploiting the unique properties of nanoparticles. Nanofluids are a new class of nanotechnology-based heat transfer fluids engineered by dispersing nanometer-sized particles with typical length scales on the order of 1 to 100 nm (preferably, smaller than 10 nm in diameter) in traditional heat transfer fluids. At the 1995 annual winter meeting of the American Society of Mechanical Engineers (Choi, 1995) Choi presented the remarkable possibility of doubling the convection heat transfer coefficients using ultrahigh-conductivity nanofluids instead of increasing pumping power by a factor of 10.

1.2 Importance of Nano size

As noted above the basic concept of dispersing solids in fluids to enhance thermal conductivity is not new; it can be traced back to Maxwell. Solid particles are added because they conduct heat much better than do liquids. The major problem with the use of large particles is the rapid settling of these particles in fluids. Other problems are abrasion and clogging. These problems are highly undesirable for many practical cooling applications. Nanofluids have pioneered in overcoming these problems by stably suspending in fluids nanometer-sized particles instead of millimeter- or micrometer-sized particles. Compared with microparticles, nanoparticles stay suspended much longer and possess a much higher surface area. The surface/volume ratio of nanoparticles is 1000 times larger than that of microparticles. The high surface area of nanoparticles enhances the heat conduction of nanofluids since heat transfer occurs on the surface of the particle. The number of atoms present on the surface of nanoparticles, as opposed to the interior, is very large. Therefore, these unique properties of nanoparticles can be exploited to develop nanofluids with an unprecedented combination of the two features most highly desired for heat transfer systems: extreme stability and ultrahigh thermal conductivity. Furthermore, because nanoparticles are so small, they may reduce erosion and clogging dramatically. Other benefits envisioned for nanofluids include decreased demand for pumping power, reduced inventory of heat transfer fluid, and significant energy savings.

Because the key building block of nanofluids is nanoparticles (1000 times smaller than microparticles), the development of nanofluids became possible simply because of the advent of nanotechnology in general and the availability of nanoparticles in particular. Researchers in nanofluids exploit the unique properties of these tiny nanoparticles to develop stable and high-thermal-conductivity heat transfer fluids. Stable suspension of small quantities of tiny particles makes conventional heat transfer fluids cool faster and thermal management systems smaller and lighter. It should be noted that in today's science and technology, size matters. Size is also an important physical variable in nanofluids because it can be used to tailor nanofluid thermal properties as well as the suspension stability of nanoparticles. Maxwell's concept is old, but what is new and innovative with the concept of nanofluids is the idea of using nanometer-sized particles (which have become available to investigators as well as commercially only recently) to create stable and highly conductive suspensions, primarily for suspension stability (gravity is negligible) and for dynamic thermal interactions.

1.3 Making of Nanofluid

Materials for base fluids and nanoparticles are diverse. Stable and highly conductive

Nanofluids are produced by one- and two-step production methods. Both approaches to creating nanoparticle suspensions suffer from agglomeration of nanoparticles, which is a key issue in all technology involving nanopowders. Therefore, synthesis and suspension of nearly non agglomerated or mono dispersed nanoparticles in liquids is the key to significant enhancement in the thermal properties of nanofluids.

1.3.1 Material for Nanoparticles and Fluids

Modern fabrication technology provides great opportunities to process materials actively at nanometer scales. Nano structured or nanophase materials are made of nanometer-sized substances engineered on the atomic or molecular scale to produce either new or enhanced physical properties not exhibited by conventional bulk solids. Therefore, particles smaller than 100 nm exhibit properties different from those of conventional solids. The noble properties of nanophase materials come from the relatively high surface area/volume ratio, which is due to the high proportion of constituent atoms residing at the grain boundaries. The thermal, mechanical, optical, magnetic, and electrical properties of nanophase materials are superior to those of conventional materials with coarse grain structures. Consequently, research and development investigation of nanophase materials has drawn considerable attention from both material scientists and engineers.

1.3.2 Nanoparticle material types

Nanoparticles used in nanofluids have been made of various materials, such as oxide ceramics (Al_2O_3, CuO), nitride ceramics (AlN, SiN), carbide ceramics (SiC, TiC), metals (Cu, Ag, Au), semiconductors (TiO_2, SiC), carbon nanotubes, and composite materials such as alloyed nanoparticles $Al_{70}Cu_{30}$ or nanoparticle core–polymer shell composites. In addition to nonmetallic, metallic, and other materials for nanoparticles, completely new materials and structures, such as materials "doped" with molecules in their solid–liquid interface structure, may also have desirable characteristics.

Many types of liquids, such as water, ethylene glycol, refrigerant and oil, have been used as host liquids in nanofluids.

1.3.3 Method of Nanoparticle Manufacture

Fabrication of nanoparticles can be classified into two broad categories: physical

Processes and chemical processes Kimoto [3]. Currently, a number of methods exist for the manufacture of nanoparticles. Typical physical methods include inert-gas condensation (IGC), developed by Granqvist and Buhrman (1976), and mechanical grinding. Chemical methods include chemical vapor deposition (CVD), chemical precipitation, micro emulsions, thermal spray, and spray pyrolysis. The current processes for making metal nanoparticles include IGC, mechanical milling, chemical precipitation, thermal spray, and spray pyrolysis.

1.3.4 Dispersion of Nanoparticles in Liquids

Stable suspensions of nanoparticles in conventional heat transfer fluids are produced by two methods, the two-step technique and the single-step technique. The two-step method first makes nanoparticles using one of the above-described nanoparticle processing techniques and then disperses them into base fluids. The *single-step method* simultaneously makes and disperses nanoparticles directly into base fluids. In either case, a well-mixed and uniformly dispersed nanofluid is needed for successful production or reproduction of enhanced properties and interpretation of experimental data. For nanofluids prepared by the two-step method, dispersion techniques such as high shear and ultrasound can be used to create various particle–fluid combinations.

Most nanofluids containing oxide nanoparticles and carbon nanotubes reported in the open literature are produced by the two-step process. If nanoparticles are produced in dry powder form, some agglomeration of individual nanoparticles may occur due to strong attractive Van Der Waals forces between nanoparticles. This undesirable agglomeration is a key issue in all technology involving making nanofluids using the two-step processes has remained a challenge because individual particles quickly agglomerate before dispersion, and nanoparticle agglomerates settle out in the liquids. Well-dispersed stable nanoparticle suspensions are produced by fully separating nanoparticle agglomerates into individual nanoparticles in a host liquid. In most nanofluids prepared by the two-step process, the agglomerates are not fully separated, so nanoparticles are dispersed only partially. Although nanoparticles are dispersed ultrasonically in liquid using a bath or tip sonicitor with intermittent sonication time to control overheating of nanofluids, this two-step preparation process produces significantly poor dispersion quality. Because the dispersion quality is poor, the conductivity of the nanofluids is low. Therefore, the key to success in achieving significant enhancement in the thermal properties of nanofluids is to produce and suspend nearly mono dispersed or non-agglomerated nano particles in liquids.

A promising technique for producing non agglomerating nano particles involve condensing nano phase powders from the vapor phase directly into a flowing low-vapour-pressure fluid. The direct evaporation–condensation process yielded a uniform distribution of nanoparticles in a host liquid.

1.4 Synthesis of Nanofluid

There are several factors of interest when considering a given synthetic approach such as nanoparticle material, concentration size and shape of nano particle in base fluid, all these parameter play major role in design and synthesis of nanofluid. The complex correlation between all these parameter on the performance of nanofluid in shown in Fig.1. Here we can see that all parameter for example when we increase the concentration of nano particles in base fluid the all four thermo-physical of nanofluid will be changed.

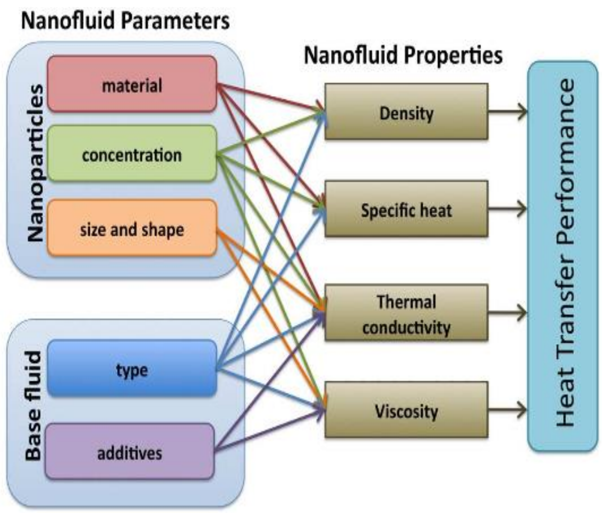

Figure 1. Complexity and multi-variability of nanoparticle suspensions

2. Application of nanofluids

Nanofluids are a new type of heat transfer fluid engineered by uniform and stable suspension of nanometer-sized particles into liquids. Most nanofluids are very dilute suspensions of nanoparticles in liquids and contain a very small quantity, preferably less than 1% by volume, of nanoparticles. The average size of nanoparticles used in nanofluids may vary from 1 to 100 nm (preferably <10 nm). Because nanoparticles are so small, they remain in suspension almost indefinitely and dramatically reduce erosion and clogging compared with the suspension of larger particles. Also, their larger surface area may improve heat transfer. Due to these dramatically thermal properties of nanofluid there are many application of nanofluid have been justified till now. Some of these are given below.

3. Cooling applications of nano fluids

Here few applications of cooling are presented.

3.1 Crystal Silicon Mirror Cooling

One of the first applications of research in the field of nanofluids is for developing an advanced cooling technology to cool crystal silicon mirrors used in high-intensity x-ray. Because an x-ray beam creates tremendous heat as it bounces off a mirror, cooling rates of 2000 to 3000 W/cm^{2}should be achievable with the advanced cooling technology. Lee and Choi [24] carried out analysis to estimate the performance of microchannel heat exchangers with water, liquid nitrogen, and nanofluids as the working fluid. For an optimized channel width that minimizes the thermal resistance of a microchannel heat exchanger, performance of a nanofluid-cooled microchannel heat exchanger has been compared with that of water-cooled and liquid-nitrogen-cooled microchannel heat exchangers. The results show that nanofluids can remarkably reduce the thermal resistances and increase the power densities, so they demonstrated the superiority of a nanofluid-cooled silicon microchannel heat exchanger. The benefits of using nanofluids as a room-temperature coolant are clear, including dramatic enhancement of cooling rates while operating the advanced cooling system at room temperature.

3.2 Electronic cooling

Many of researcher used gold nanofluids as the working fluid for a conventional meshed circular heat pipe. Monodispersed gold nanoparticles of various sizes (2 to 35 and 15 to 75 nm) were synthesized by the reduction of aqueous hydrogen tetrachloroaurate ($HAuCl_4$) with trisodium citrate and tannic acid. The heat pipe was designed as a heat spreader for a CPU in a notebook or desktop PC. A 200-mesh wire screen was used in the heat pipe being tested. They measured the thermal resistance of the meshed heat pipe with nanofluids and DI water. The thermal resistance of the meshed heat pipe with nanofluids is in the range 0.17 to 0.215° C/W, lower than that with DI water. The results show that at the same charge volume, there is a significant reduction (by as much as 37%) in the thermal resistance of heat pipe with nanofluid compared with DI water. The results also show that the thermal resistance of a vertical meshed heat pipe varies with the size of gold nanoparticles and that monodispersed nanoparticles are better than aggregated nanoparticles. The work clearly shows the advantages of a conventional circular heat pipe with nanofluids over that with DI water.

3.3 Vehicle cooling

Many researcher have been studied the suspension of nanoparticle into the radiator of vehicle and found that by using of nanofluid in radiator coolant we can enhance the fluid heat transfer property of and so that efficient cooling of vehicle engine may be possible. Also some experiment has been done for rotary blade coupling (RBC) of a power transmission system of a real time four-wheel-drive vehicle. It adopts advanced RBC, where a high local temperature occurs easily at high rotating speed. RBC design is so precise that if the local temperature is higher than 266°F, excessive thermal stress may damage its rotating components. As a result, the power cannot be transmitted to the rear wheels, affecting vehicle performance severely. Moreover, the damaged RBC is not repairable and should be replaced. Therefore, it is imperative to improve the heat transfer efficiency to contain excessive thermal stress on the components of the power transmission system. Experiment result show the temperature distribution of the RBC exterior at four different rotating speeds (400, 800, 1200, and 1600 rpm), simulating the conditions of a real car at various rotating speeds. The results show that CuO nanofluids have the lowest temperature distribution at both high and low rotating speed and accordingly, the best heat transfer effect.

3.4 Transformer Cooling

The power generation industry is interested in transformer cooling application of nanofluids for reducing transformer size and weight. The ever-growing demand for greater electricity production will require upgrades of most transformers at some point in the near future at a potential cost of millions of dollars in hardware retrofits. The increased thermal transport of transformer oils translates into either a reduction in the size of new transformers at the same level of power transmitted or an increase in the performance of existing transformers. Keeping at the cutting edge of nanotechnology remains a top task for many companies and laboratories. Specifically, nanofluid-based transformer oil is likely to be the next-generation cooling fluid in transformers. The first key element in nanofluid technology is uniform dispersion of non-agglomerated nanoparticles. Homogeneity of the dispersion may be overcome by special mechanical dispersing techniques and the creative use of chemical dispersants. However, this goal is still challenging.

3.5 Space and Nuclear System Cooling

The ability to greatly increase the CHF, the upper heat flux limit in nucleate boiling systems, is of paramount practical importance to ultrahigh-heat-flux devices that use nucleate boiling, such as high-power lasers and nuclear reactor components. Therefore, nanofluids have opened up exciting possibilities for raising chip power in electronic devices or simplifying cooling requirements for space applications. Most of all, leading nuclear researchers are very much interested in the use of nanofluids with dramatically increased CHF values because it could enable very safe operation of commercial or military nuclear reactors.

3.6 Defense Applications

A number of military devices and systems, such as high powered military electronics, military vehicle components, radars, and lasers, require high-heat-flux cooling, to the level of thousands of W/cm^2. At this level, cooling with conventional heat transfer fluids is difficult. Some specific examples of potential military applications include power electronics and directed-energy weapons cooling. Since directed-energy weapons involve heat sources with high heat fluxes (>500 to 1000 W/cm^2), cooling of the direct-energy weapon and associated power electronics is critical and is further complicated by the limited capability of current heat transfer fluids. Nanofluids also provide advanced cooling technology for military vehicles, submarines, and high-power laser diodes. It appears that nanofluid research for defense applications considers multifunctional nanofluids with added thermal energy storage or energy harvesting through chemical reactions.

3.7 Tribological Applications

Nanofluid technology can help develop better oils and lubricants. Recent nanofluid activity involves the use of nanoparticles in lubricants to enhance tribological properties of lubricants, such as load-carrying capacity and anti-wear and friction-reducing properties between moving mechanical components. In lubrication application it has been reported that surface-modified nanoparticles stably dispersed in mineral oils are very effective in reducing wear and enhancing load-carrying capacity.

3.8 Biomedical Applications

Nanofluids was originally developed primarily for thermal management applications such as engine, microelectronics, and photonics. However, nanofluids can be formulated for a variety of other uses for faster cooling. Nanofluids are now being developed for medical applications, including cancer therapy. Traditional cancer treatment methods have significant side effects. Iron-based nanoparticles can be used as delivery vehicles for drugs or radiation without damaging nearby healthy tissue by guiding the particles up the bloodstream to a tumor with magnets. Nanofluids could also be used for safer surgery by cooling around the surgical region, thereby enhancing a patient's chance of survival and reducing the risk of organ damage. Other possible areas for the application of nanofluids technology include cooling a new class of super powerful and small computers and other electronic devices for use in military systems, airplanes, or spacecraft as well as for large-scale cooling. In the future, nanofluids could be used to maintain a high temperature gradient in thermoelectric that would convert waste heat to useful electrical energy. In buildings, nanofluids could increase energy efficiency without the need to use a more powerful pump, so saving energy in a HVAC system and providing major environmental benefits. In the renewable energy industry, nanofluids could be utilized to enhance heat transfer from solar collectors to storage tanks and to increase the energy density. To this must be added cooling for major process industries, including materials, chemical, food and drink, oil and gas, paper and printing, and textiles.

4 Methods for improving thermal performances of vapour compression refrigeration systems

To improve thermal performance of vapour compression refrigeration systems by improving:

- First law efficiency known as thermodynamic energetic efficiency in terms of COP (i.e. coefficient of performance) which is defined as the ratio of net refrigeration effect to the per unit power consumed. The first law analysis restricted to calculate only coefficient of performance of the systems
- Second law efficiency by using the concept of exergy. Second law efficiency is the exergy of the heat abstracted in to the evaporator from the space to be cooled and exergy of fuel is actual compressor work input.
- Exergy destruction ratio (EDR) in terms of exergy destruction ratio which can be defined as the total exergy losses by the system to the exergy of product (EDR_{System}) or the total exergy losses by the system to the exergy of fuel ($EDR\_{Rational}$) by using of nanoparticles in vapour compression refrigeration systems.

Joaquin Navarro et al [1] investigated thermal performance analysis of vapour compression refrigeration cycle (system) using R1234yf as a replacement of R134a. In their work, they the performance of vapour compression refrigeration system using both the refrigerant R1234yf and R134a with presence of internal heat exchanger also without internal heat exchanger under a large range of operating condition. Experimental result is obtained with varying evaporator temperature and condenser temperature and use of internal heat exchanger. From their result C.O.P and cooling capacity decreased 13 and 6 % respectively when R134a is replaced by R1234yf. However the presence of internal heat exchanger can help to control the reduction about 6 and 2 % respectively. The experimental result agreed with the mathematical analysis of the system considering pressure drop negligible. Lee et al.[2]. They measured thermal conductivities of nanofluid at temperatures between 21 and 55°C, and the results were nothing less than miraculous. Over this small 34° C rise in temperature, the thermal conductivity enhancement was more than three times higher. With Al_2O_3, the enhancement increased from 2% to 10.8% at a 1% particle volume fraction and it went from 9.4% to 24.3% at a 4% particle-volume fraction. The same increase for CuO–water nanofluids was 6.5% to 29% for a 1% particle-volume fraction and 14% to 36% for a 4% particle fraction. This puts the entire phenomenological concept regarding nanofluids completely in perspective. In fact, all the theories proclaimed before this work was published crumpled at this observation because none of them could predict such a strong temperature effect. The other important observation from the preceding result is that at elevated temperatures, neither Al_2O_3 nor CuO-based nanofluids comply with the Hamilton–Crosser model. This is because the model is completely insensitive to temperature variations between 21 and 55°C. This clearly indicates that agreement of the Al_2O_3 nanofluids with the Hamilton–Crosser model[16]. Jwo et al. [3] investigated the replacement of polyester lubricant and R-134a refrigerant with mineral lubricant and hydrocarbon refrigerant. The mineral lubricant contains Al_2O_3 nanoparticles to improve the lubrication and performance of heat-transfer. Their studies show that the R-134a at 60% and Al_2O_3 0.1 wt % nanoparticles were optimum .Under these conditions, the consumption of power was reduced by 2.4%, and the C.O.P. was increased by 4.4%.

Peng et al.[4] investigated with an experiment that nucleates boiling heat transfer property of refrigerant/oil mixture containing diamond nano particles. The refrigerant used was R113 and the oil was VG68. They found out that the nucleate pool boiling heat transfer coefficient of R113/oil mixture with diamond nanoparticles is larger than the R113/oil mixture. They also proposed a general correlation for calculating nucleate boiling coefficient heat transfer of mixed refrigerant/oil with nanoparticles, which fully satisfies their experimental results.

Bi et al.[5] conducted an experimental study on the performance of a domestic refrigerator using Ti_2O_3 -R600a nano refrigerant as working fluid. They showed that the Ti_2O_3-R600a system worked normally and efficiently in the refrigerator and an energy saving of 9.6%. They too cited that the freezing velocity of nano refrigerating system was more than that with pure R600a system. The purpose of this article is to report the results obtained from the experimental studies on a vapour compression system. Henderson et al.[6] conducted an experimental analysis on the flow boiling heat transfer coefficient of R134a (refrigerant) based nanofluids in a horizontal tube. They found excellent dispersion of CuO nanoparticle with R134a and POE oil and the heat transfer coefficient increases more than 100% over baseline R134a/POE oil results.

Bobbo et al.[7] conducted a study on the influence of dispersion of single wall carbon nanohorns (SWCNH) and Ti_2O_3 on the tribological properties of POE oil together with the effects on the solubility of R134a at different temperatures. They showed that the tribological behavior of the base lubricant can be either improved or worsen by adding nanoparticles. On the other hand the nanoparticle dispersion did not affect significantly the solubility. Lee et al.[8]investigated the friction coefficient of the mineral oil mixed with 0.1 vol.% fullerene nanoparticles, and the results indicated that the friction coefficient decreased by 90% in comparison with raw lubricant, which lead us to the conclusion that nanoparticles can improve the efficiency and reliability of the compressor. Heriset al.[9] in their experiment they have examined the convective heat transfer coefficient through a circular tube maintaining temperature of tube wall for boundary condition for nanofluids consisting containing Al_2O_3 and CuO oxide nanoparticles in water considering water as a base fluid. In the experiment they have chosen a tube having 6 mm diameter and length 1meter copper tube. Thickness of copper tube is taken 0.5 mm and another outer stainless steel tube having 32 mm diameter. In their experiment nanofluid flow inside the copper tube and saturated steam in the annuli section of the steel tube makes constant wall temp. The fluid after then goes to a heat exchanger where water was used for cooling the test chamber. The experimental result concluded that homogeneous model (single phase correlation of nanofluid) was not able to calculate enhancement of coefficient of heat transfer of nanofluid. The experimental result shows that the heat transfer coefficient predicted for CuO/water and Al_2O_3 /water of homogeneous model were very close to each other but when they increase the vol. % concentration of nanoparticle much higher coefficient of heat transfer observed for Al_2O_3 /water. They have concluded that the coefficient of heat transfer of nanofluid depend upon many factor such as nanoparticle diameter and thermal conductivity of nanoparticle, movement of nanoparticle suspension process of nano particle etc. Wang and Xie[10]found that TiO_2 nanoparticles could be used as additives to enhance the solubility between mineral oil and hydrofluorocarbon (HFC) refrigerant. The refrigeration systems using the mixture of R134a and mineral oil appended with nanoparticles Ti_2O_2, possess to give best performance by returning more vol of lubricant oil return to the compressor, and had the similar performance compared to the systems using polyol-ester (POE) and R134a. In the present study the refrigerant selected is R600a and the nanoparticle is alumina. Isobutane (R600a) is more widely adopted in domestic refrigerator because of its better environmental and energy performances. In this paper, a new refrigerator test system was built up according to the National Standard of India. A domestic R600a refrigerator was selected. Al_2O_3-R600a nano-refrigerant was prepared and used as working fluid. The energy consumption test and freeze capacity test were conducted to compare the performance of the refrigerator with nano-refrigerant and pure refrigerant so as to provide the basic data for the application of the nanoparticles in the refrigeration system.

Y. He et al. [11] conducted an experiment to find out the behavior of nanofluid under laminar and turbulent flow. Their experiment consist a heating and cooling unit, a flow loop and a measurement unit. The test section consist a straight vertically oriented copper tube having 1834 mm length and 6.35 outer 3.97 mm inner diameter. In the experiment they heated the tube with help of 2 silicon rubber flexible heater. For the constant heat flux condition in the test section they provided a thermally insulated layer. For measurement the pressure drop 2 pressure transducer ware used. They have experimented the effect of Reynolds number nanoparticle size, concentration of nanopraticle in the base fluid. They concluded that suspension of nanoparticle into the host fluid the enhancement of thermal conductivity of base fluid may achieved and as well we go for decreasing particle size and increasing concentration the enhancement increases. Thus the nanoparticle concentration and particle size paly major role in enhancement of thermal conductivity of base fluid in both turbulent and laminator flow. They have also concluded that the pressure drop by using nanofluid were close to the base fluid. Hwang et al.,[12] investigated the convective heat transfer coefficient of Al_2O_3 /water based nanofluid. In their experiment nanofluid considered flowing through circular tube having 1.812 mm inside diameter and maintaining constant heat flux for fully developed laminar regime. Al_2O_3 /water based nanofluids with various volume % concentration 0.01% to 0.3% are manufactured with two-step method. They have also obtained the thermo physical property of nanofluid such as density, viscosity, heat capacity and thermal conductivity. They have concluded that the convective heat transfer coefficient enhancement occurs with 0.01 and 0.3 vol % concentration of nanoparticle in fully developed laminar regime and heat transfer enhancement about 8 % obtained under the same Reynolds number of base fluid. They also concluded that enhancement in heat transfer coefficient were much higher that the thermal conductivity enhancement at the same vol % concentration of nanoparticle. Mahbubul and Saadah [13] investigated the thermal performance of Al_2O_3/R134a nano refrigerant C.O.P. of nano refrigerant increased about 15% and thermal conductivity about 28.8 %, dynamic viscosity about 13.68 % and density of nano refrigerant about 11 % compare to the pure refrigerant . in their study they have considered uniformly mass flux of nano refrigerant in a horizontal smooth tube.

Xuan and Li [14] were first to show a significant increase in the turbulent heat transfer coefficient. They found that at fixed velocities, the heat transfer coefficient of nanofluids containing Cu nanoparticles at 2.0 vol% was improved by as high as 40% compared to the host water. The Dittus–Boelter correlation failed to obtain the improved experimented heat transfer behavior of nanofluids. Recent unpublished work shows that the effect of particle size and shape and dispersion becomes predominant in enhancing heat transfer in nanofluids. Even greater heat transfer effects are expected for nanofluids produced by the one-step process. Therefore, there is great potential to "engineer" ultra-energy-efficient heat transfer fluids by choosing the nanoparticle material as well as by controlling particle size, shape, and dispersion. Murshedet al.[15] carried out experiments with spherical and rod-shaped TiO_2nanoparticles. The spherical particles were 15 nm in diameter and the rod-shaped particles were 10 nm in diameter and 40 nm in length. The base fluid was deionized water. The measurement method was transient hot wire. It should be mentioned here that they used oleic acid and cetyltrimethyl ammonium bromide (CTAB) surfactants (0.01 to 0.02 vol %). They maintained a nearly neutral (pH 6.2 to 6.8) suspension. For the first time, a nonlinear correlation between the volume fraction and conductivity enhancement was observed here at lower concentrations. This is interesting with respect to the temperature effect and pure metallic particles. They found that the conductivity enhancement was higher for rod-shaped particles than for spherical particles. Enhancement up to 29.7% was found with 5% spherical particles and up to 32.8% with rod-shaped particles. They attributed this to the higher shape factor (n =6) of the rods than of the spheres (n =3) in the Hamilton–Crosser model [16]. Kulkarni et al., [17] investigated the heat transfer performance also fluid dynamics performance of nanofluids using SiO_2 nanoparticle suspended in the ration of 60:40 weight % in to the EG/water mixture. A test section they have taken for this experiment having copper tube 3.14 mm inside and 4.76 mm outer diameter and 1m length. To measure the wall temperature they fitted 6 no. of thermocouple on surface of the copper tube along the length, the outlet and inlet temperature measurement they used 2 thermocouple at the outlet and inlet section respectively. To isolate the thermal heat transfer two plastic fitting ware provided at the inlet and outlet section respectively. To obtain the constant heat flux four strip heater were used. The whole test section was insulated with 10 cm fiber glass to reduce the heat loss from the test section to the ambient. To maintain the constant inlet temperature of fluid four shell and tube type heat exchanger with counter flow were used. In their experiment they have investigated the effect of enhancement of convective heat transfer of nanofluid with diameter of nanoparticle 20nm, 50nm and 100nm in the turbulent region by increasing volume concentration of nanoparticle and pressure drop recorded when they increase the concentration of nanoparticle in the nanofluid. Sharma et al.,[18] investigated to evaluate friction factor and heat transfer coefficient with a inserted twisted tape in the flow region of tube with Al_2O_3 nanpfluid they have consider a test section of L/D ration 160 and 1.5m length. For uniform heating test section were wrapped with 1 Kw .The aluminum strip having 0.018mm width and 1mm thick are used. Test section is subjected to 180° twist br holding both end of test section in lathe machine obtaining 5, 10 and 15 twist ratio. The result show enhancement in heat transfer coefficient with Al_2O_3 nanoparticle into the base fluid compare to the base water. The heat transfer coefficient was 23.7 % higher that the water at Reynolds number 9000.

Yu et al., [19] investigated the heat transfer coefficient of silicon carbide nanoparticle having diameter 170nm and 3.7 vol % suspended into the pure water and found that an increment in heat transfer coefficient about 50-60 % compared to host fluid.their test section was stainless steel tube with 4.76 mm outside diameter and 2.27 inside diameter. Their test rig have heat exchanger flow meter horizontal tube. Pre heater as a closed loop system. They concluded that enhancement is 14-32 % higher that the predicted value for single phase turbulent correlation of heat transfer. Also they found that the pressure loss is little lower than the Al_2O_3 water nanofluid. Torii and Yang [20] investigated the heat transfer coefficient of suspended diamond nanoparticle into the host fluid by maintaining constant heat flux. Their test section contain a flow loop, a digital flow meter, a pump, a reservoir and a tank. The test is prepared stainless steel tube having 4.3 mm outer diameter 4.0 mm inner diameter and 1000 mm length. The whole is heated with a dc electrode heater considering joule heating. They reported that (i) the heat transfer performance of nanofluid increases with the suspension of diamond nano particle into the water compared to pure water. (ii) Reynols number variation influence the enhancement occurs in heat transfer coefficient.

Rea et al., [21] investigated the heat transfer coefficient and viscous pressure loss for Al_2O_3 /water and zirconia-water nanoparticle based nanofluid flowing loop. The stainless steel vertical heated test section considered having outer diameter of 6.4 mm, an inner diameter of 4.5 mm and 1.01 m length. The test section 8 T type thermocouples sheathed and insulated electrically and soldered onto the outside wall of the tube along axial direction 5, 16, 30,44, 58, 89 and 100 cm from heated inlet section of the test facility. To measure the fluid temperatures Two same T-type thermocouples were inserted into the flowing passage of the channel after and before of the test section. They observed that the heat transfer coefficients increased 17% and 27%, in fully developed region compare to base water. The heat transfer of zirconia–water nanofluid increases by approx 2% at 1.32 vol.% in the inlet region and 3% at 1.32 vol % in the fully developed region.

The observed pressure loss for nanofluids was higher than the base water having good agreement with predicted model for laminar flow. Faulkner et al. [22] conducted fully developed laminar convection heat transfer tests and made the startling discovery that water-based nanofluids containing CNTs provide significant enhancements to the overall heat transfer. First, the heat transfer coefficient of the nanofluids increase with Reynolds number. The heat transfer coefficient of the nanofluid were roughly twice those of plain water at the upper end of the Reynolds number range tested, and it appears that this enhancement will continue to increase with larger Reynolds numbers. Second, nanofluids outperform water, but nanofluids with low particle concentrations (1.1 vol%) perform better than those with higher concentrations (2.2 and 4.4 vol%). This is an unexpected and, indeed, counterintuitive result. This negative concentration dependence of the heat transfer enhancement could be due partially to the interaction between particles. Faulkner et al. [22] also proposed that the pseudo turbulence induced by rolling and tumbling CNT agglomerates in a microchannel results in micro scale mixing, which enhances the laminar heat transfer coefficient. Since heat transfer applications operate over a wide range of Reynolds numbers and heat fluxes, additional work is needed to develop nanofluids that can provide the most significant benefit to specific heat transfer applications.

Wen and Ding [24] were first to study the laminar entry flow of nanofluids and showed a substantial increase in the heat transfer coefficient of water-based nanofluids containing γ-Al_2O_3 nanoparticles in the entry region and a longer entrance length for the nanofluids than water. Also in 2006 they have studied the laminar entry flow of water-based nanofluids containing multiwall carbon nanotubes (CNT nanofluids). For nanofluids containing only 0.5 wt% Carbon nano tubes, the maximum convective heat transfer coefficient enhancement reaches above 350% at Re equal to 800. Such a higher enhancement could not be considered purely for thermal conductivity enhancement. They proposed possible mechanisms such as thickness of thermal boundary layer, particle rearrangement, due to the presence of carbon nanotubes, and very high aspect ratio of Carbon nano tubes. Eastman et al. [25] investigated the pool boiling heat transfer characteristics of R11 refrigerant with TiO2 nanoparticles and showed that the heat transfer enhancement reached 20% at a particle loading of 0.01 g/L. Mishra et al**.** [26] experimentally evaluated the performance of a vapour compression refrigeration system by using Cu, Al_2O_3, CuO and TiO_2 based nano refrigerants in the primary circuit. The experimental results showed that the C.O.P of the system using Al_2O_3/R134a nano refrigerant was enhanced by 35% which was highest among all other nano refrigerants. Sabareesh et al. [12] experimentally investigated 17% increase in COP by using 0.01% by volume concentration TiO2 nano fluid in VCRS as a lubricant additive.

Sabareesh et al. [27] experimentally investigated 17% increase in COP by using 0.01% by volume concentration TiO_2 nano fluid in VCRS as a lubricant additive.

Sajadi A.R. et.al.[28], experimentally investigated turbulent convective heat transfer coefficient and pressure drop of TiO_2 dispersed in water nano fluid in the circular tube and also compared experimental results with correlation of Nusselt number and not concluded that how much (%) convective heat transfer coefficient increased.

Huang Dan , et.al. [29], observed the effect of hybrid nano fluid mixture Al_2O_3 in the plate heat exchanger and found that convective heat transfer coefficient is increased as compared without nano fluid. Lots of researches have been done and going on based on the performance evaluation of various metallic/ nonmetallic nanoparticle suspended into the conventional fluid to enhance the heat transfer property of base fluid. Also some theoretical analysis of suspension of nanoparticle Al_2O_3 in conventional refrigerant. On the other hand the performance of vapour compression cycle based chiller facility using nano refrigerant yet to be analyzed with different type, concentration and diameter of nanoparticle. Such as TiO_2, CuO nanoparticle suspension into conventional refrigerant with different concentration and diameter are yet to be analyzed and also effect of variation of concentration and nanoparticle diameter on the performance of vapour compression refrigeration system is yet to be analyzed. The effect of changing input parameter of VCRS using nano refrigerant also required. The idea of Suspension nanoparticle into conventional refrigerant and theoretical analysis of VCRS using nano refrigerant is proposed after going through the research work and literature review.

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Thermodynamic analysis of different refrigeration systems have been carried out using various combinations of condensers and evaporators. Performance analysis to be done also employing different refrigerants and its combination/mixture.

It has been concluded that different kinds of nanoparticles are used or mixed with the coolant fluid already in use and gives positive out-come. But almost none of the literature represents use of nanoparticle suspended into the pure refrigerant for use in the vapour compression refrigeration based chiller facility with direct suspension of nanoparticle. Also none of the literature shows the theoretical analysis of 1st law and 2nd law of thermo dynamics by using nano refrigerant in VCRS based chiller facility. Based on the literature it was observed that investigators have gone through detailed first law analysis in terms of coefficient of performance and second law analysis in term of exergetic efficiency of simple vapour compression refrigeration system with single evaporator. Investigators also analyzed the effect of nanofluids on simple vapour compression cycle in the term of pool boiling, thermal conductivity improvement etc. However the investigators did not go through the irreversibility analysis in terms of exergy destruction ratio using energy generation concept (i.e. second law analysis of vapour compression refrigeration systems.

5 Results and Discussions

The following input values have been taken for numerical computations

(i) Mass flow rate of brine flow in the secondary circuit of evaporator is ranging from 0.006 (kg/sec) to 0.01 (Kg/sec)
(ii) Mass flow rate of water flow in the secondary circuit of condenser is ranging from 0.006 (kg/sec) to 0.01 (Kg/sec)
(iii) Inlet brine flow temperature in the secondary circuit of evaporator is 27°C
(iv) Inlet water flow temperature in the secondary circuit of evaporator is 27°C
(v) Inlet pressure of brine evaporator temperature=2 (bar)
(vi) Inlet pressure of water flow in condenser temperature=2 (bar)
(vii) Length of evaporator heat exchanger= 0.72 m
(viii) Length of condenser heat exchanger= 1.2 m
(ix) Air pressure= 1.05 (bar)

The properties of nano fluid is computed as shown in table-2.

Table 2: Properties of nanomixed fluid obtained in vapour compression refrigeration systems

Performance Parameters	Copper Oxide	Al_2O_3	TiO_2
Effective mixture Density (kg/m^3)	13.93	1145	1155
Effective mixture specific heat (J/KgK)	2965	3590	3558
Effective mixture thermal conductivity (W/mK)	31.33	16.62	9.727
Effective mixture viscosity	0.003653	0.003653	0.003653
Prandtl Number of nano Mixture	0.3457	0.7795	1.336
Effective mixture Density (Kg/m^3)	1393	1145	1155

Table-3 shows the variation of Reynold number in the capillary tube using different nanomaterials mixed in R718 fluid flowing in the secondary circuit of evaporator and it is found that higher Reynold number was observed using copper oxide and lowest by using TiO_2 . It is also found that the improvements in Reynold number by using copper oxide is 47.998%, 45.671% by using $Al_2O_3$and 42.263% by using TiO_2. Similarly, Reynold number improvement in the condenser tube is 3.222%. Using copper oxide, 3.107% using Al_2O_3 and 2.963% using TiO_2.

Table-3: Variation of Reynold numbers with nanomaterials in vapour compression refrigeration systems

Reynold numbers	Copper Oxide	Al_2O_3	TiO_2	Without nano
Reynold number in Capillary Tube	27097	26671	26047	18309
Reynold number in Condenser Tube	206819	206601	206312	200375
Reynold number of brine flow	104.3	104.3	104.3	104.3

Table 4: First law efficiency in terms of coefficient (COP), second law efficiency (exergetic efficiency), and other performance parameters of vapour compression refrigeration systems using R134a ecofriendly refrigerant

Performance Parameters	Copper Oxide	Al_2O_3	TiO_2	Without Nano
First Law efficiency $(COP)_{\_Actual}$	3.507	3.477	3.432	2.960
Exergetic Efficiency	0.3923	0.3892	0.3842	0.3436
Over All evaporator heat transfer coefficient $U_{\_Eva}$ (W/m^2K)	1380.01	1320.01	1239.0	664.62
Over All Condenser heat transfer coefficient $U_{\_Cond}$ (W/m^2K)	717.61	714.01	708.64	644.56

Table-4 shows the variation of first law performance in terms of coefficient of performance using different nanomaterials mixed in R718 fluid flowing in the secondary circuit of evaporator and it is found that higher COP was observed using copper oxide and lowest by using TiO_2 . It is also found that the improvements in COP by using copper oxide is 18.4797 %, 17.4662% by using Al_2O_3 and 15.946% by using TiO_2. Similarly second law improvement in the condenser tube is 13.9292% using Copper oxide, 12.9425% using Al_2O_3 and 11.492% using TiO_2. Similarly the variation in evaporator heat transfer is also shown in Table-5 and percentage improvement using copper oxide is , Al_2O_3 and TiO_2 is also shown in Table-5 respectively.

Table 5: Improvement in performance parameters Vapour compression refrigeration systems using R-134a ecofriendly refrigerants

% Improvement in the Performance Parameters	CuO	Al_2O_3	TiO_2
First law Efficiency	18.479	17.466	15.95
Second law Efficiency	13.9292	12.9425	11.492
Exergy Destruction Ratio	(-) 6.071	(-) 6.83	(-) 6.058
Evaporator Overall heat transfer coefficient (W/m^2K)	107.656	98.6276	86.44
Condenser Overall heat transfer coefficient (W/m^2K)	11.239	10.7732	9.942
Isentropic Efficiency of compressor	0.8169	0.8131	0.8094
Volumetric Efficiency of compressor	0.6299	0.6289	0.6275

6 Conclusions

The following conclusions were taken from present investigation

(i) Improvement in the first law efficiency in terms of coefficient of performance using copper oxide (CuO) is18.479%

(ii) Improvement in the first law efficiency in terms of coefficient of performance using Al_2O_3 is17.466%

(iii) Improvement in the first law efficiency in terms of coefficient of performance using TiO_2 is15.95%

(iv) Improvement in the evaporator overall heat transfer coefficient using copper oxide (CuO) is107.656%

(v) Improvement in the evaporator overall heat transfer coefficient using Al_2O_3 is98.6276%

(vi) Improvement in the evaporator overall heat transfer coefficient using TiO_2 is86.44%

(vii) Improvement in the condenser overall heat transfer coefficient using copper oxide (CuO) is11.239%

(viii) Improvement in the condenser overall heat transfer coefficient using Al_2O_3 is10.773%

(ix) Improvement in the condenser overall heat transfer coefficient using TiO_2 is9.942%

(x) Improvement in the second law (exergetic)efficiency using copper oxide (CuO) is13.929 %

(xi) Improvement in the second law (exergetic)efficiency using Al_2O_3 is12.9425 %

(xii) Improvement in the second law (exergetic)efficiency in terms of coefficient of performance using TiO_2 is11.492%

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Cite this article as: R.S. Mishra, Performance improvement using nano materials mixed in R-718 in the secondary circuit of evaporator of vapour compression refrigeration system using ecofriendly refrigerants, International Journal of Research in Engineering and Innovation Vol-3, Issue-4 (2019), 265-275.