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Method for improving thermodynamic performance of vapour compression refrigeration system using nanofluids- A Review

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Abstract

In this paper, nanoparticle based refrigerant has been used to increase the heat transfer performance of base refrigerant in the vapour compression refrigeration system. Many types of solid and oxide materials could be used as the nanoparticles to be suspended into the conventional/non-conventional refrigerants. In this project work, the effect of the suspended copper oxide (CuO), Titanium Oxide (TiO_2), Aluminum Oxide (Al_2O_3) into the ecofriendly refrigerant (i.e. R134a, R407c and R404A) is used for enhancing the thermal performance of vapour compression refrigeration system. Comparison was made between utility of ecofriendly refrigerant mixed with nanoparticle and used in the primary circuit of VCRS. That ecofriendly nano refrigerant is used in primary circuit of VCRS along with mixing of nanoparticle with R718 in the secondary evaporator circuit. The performance of VCRS is evaluated using pure refrigerant (w/o nano particle) in the primary circuit and R718 in the secondary circuit, Eco friendly refrigerant in primary circuit and nanofluid (nanoparticle mixed with R718 in the evaporator secondary circuit, Nano refrigerant (nanoparticle mixed into pure refrigerant) in primary circuit and R718 in secondary circuit of VCRS. Experiment was conducted to verify theoretically computed value and it was observed that the experimental value matches well with theoretical calculated value of VCRS for case as mentioned above. Computational simulation was also carried out to compare for above mentioned three cases and it was observed that the performance enhancement is ranging between 8 to 19 % for case with different types of nanoparticle, while for case the enhancement value ranges between 2.6 to 35 % with different types of nanoparticle.
Keywords: Thermodynamic Performances, Vapour compression refrigeration system, Nanofluids

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.

1.1 Nanofluid technology

A new interdisciplinary field of great importance where nanoscience, nanotechnology, and thermal engineering meet, has developed 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. To achieve this goal it is vital to understand how nanoparticles enhance energy transport in liquids. 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

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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. The recent growth of work in this rapidly Emerging area of nanofluids is most evident from the exponentially increasing number of publications.

1.2 Utility of nanofluid

Heat transfer is one of the most important processes in many industrial and consumer products. The inherently poor thermal conductivity of conventional fluids puts a fundamental limit on heat transfer. Therefore, for more than a century since Maxwell [2], scientists and engineers have made great efforts to break this fundamental limit by dispersing millimeter- or micrometer-sized particles in liquids. However, the major problem with the use of such large particles is the rapid settling of these particles in fluids. Because extended surface technology has already been adapted to its limits in the designs of thermal management systems, technologies with the potential to improve a fluid's thermal properties are of great interest once again. The concept and emergence of nanofluids is related directly to trends in miniaturization and nanotechnology. Maxwell's concept is old, but what is new and innovative in the concept of nanofluids is the idea that particle size is of primary importance in developing stable and highly conductive nanofluids.

1.3 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 1.1. 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 at 300K [40]

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.

1.4 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. 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.

1.5 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.

1.5.1 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. All physical mechanisms have a critical length scale below which the physical properties of materials are changed. 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.

1.5.2 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 Al70Cu30 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.

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1.5.3 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.

1.5.4 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 sonicator 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 nonagglomerated nanoparticles in liquids.

A promising technique for producing nonagglomerating nanoparticles involves condensing nanophase powders from the vapor phase directly into a flowing low-vapor-pressure fluid. . The direct evaporation–condensation process yielded a uniform distribution of nanoparticles in a host liquid.

1.6 Synthesis of Nanofluid

There are several factors of interest when considering a given synthetic approach such as nanoparticle material, concentration size and shape of nanoparticle 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 nanoparticle in base fluid the all 4 thermo physical of nanofluid will be change.

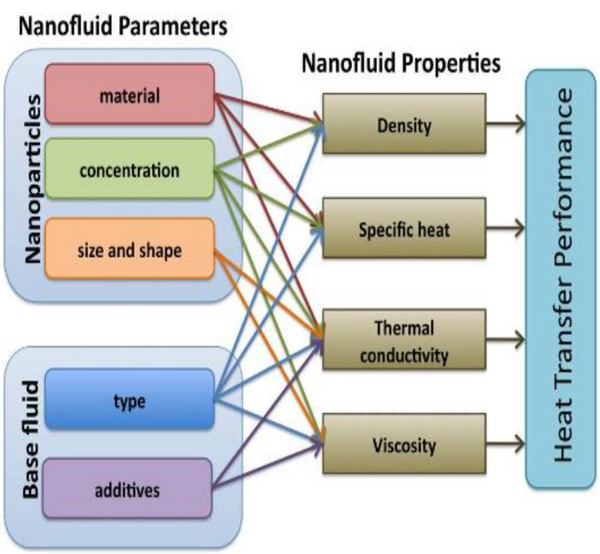

Figure 1: Complexity and multi-variability of nanoparticle suspensions

1.7 Application of nanofluid

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.

1.7.1 Cooling applications

1.7.1.1 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/cm2 should be achievable with the advanced cooling technology. Lee and Choi 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.

1.7.1.2 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 tetra chloroaurate ($HAuCl_4$) with tri sodium 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.

1.7.1.3 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.

1.7.1.4 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. If the heat transfer capability of existing transformers can be increased, many of the upgrades may not be necessary the heat transfer properties of transformer oils can be improved by using nanoparticle additives 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 no 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.

1.7.1.5 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.

1.7.1.6 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/cm2. 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/cm2), 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.

1.7.2 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.

1.7.3 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.

2. Literature Review

A few studies have been illustrated as a part of literature review related to theoretical study and experimental investigation of refrigeration systems based on first law and second law analysis with different pairs of refrigerants, nanoparticle behaviour and application of nanofluid in vapour compression refrigeration system. Jwo et al. [4] 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. [5] 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. 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 Ti2O3 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. Bi et al. [8] conducted an experimental study on the performance of a domestic refrigerator using Ti2O3 -R600a nano-refrigerant as working fluid. They showed that the Ti2O3-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. Lee et al. [9] 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. Wang and Xie [10] found that Ti2O3 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 Ti2O3, 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. Heris et al.[11] 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.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. Y. He et al. [12] conduct an experiment to find out the behavior of nanofluid under laminar and turbulent flow. Their experiment consist a 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. Kulkarni et al., [13] investigated the heat transfer performance also fluid dynamics performance of nanofluids using SiO2 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 fraction of nanoparticle and pressure drop recorded when they increase the concentration of nanoparticle in the nanofluid. Hwang et al., [14] 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. Sharma et al.,[15] investigated to evaluate friction factor and heat transfer coefficient with a inserted twisted tape in the flow region of tube with Al_2O_3 nanofluid 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 holding both end of test section in lathe machine obtaining 5, 10 and 15 twist ratio. Their 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., [16] 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 [17] 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., [18] 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. Murshed et al.[19] carried out experiments with spherical and rod-shaped TiO_2 nanoparticles. 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 [20] model. Xuan and Li [21] 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. Mahbubul and Saadah [22] investigated the thermal performance of Al_2O_3 /R134a nanorefrigerant 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. Faulkner et al. [23] 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. 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 multiwalled 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.

Lee et al. [25]. 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. Joaquin Navarro et al [26] in his investigation 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.

2.1 Conclusion from Literature Review and research gap Identified

The study of above literatures and many others not mentioned in the description Concluded that Lots of researches have been done and going on based on the performance evaluation of various metallic/ nonmetallic nanoparticle suspended into the conventional fluid (w/o refrigerant) to enhance the heat transfer property of base fluid. Also some theoretical analysis of suspension of nanoparticle Al_2O_3 in conventional refrigerant has been done. 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. Thermal performance of nano refrigerant (nanoparticle mixed into pure refrigerant) with different type, concentration and diameter of nanoparticle are yet to be analyzed and also performance enhancement of vapour compression refrigeration system using nanofluid (nanoparticle mixed in water) in secondary circuit and eco friendly refrigerant in primary circuit is yet to be analyzed. Also find out the various parameter witch effect the performance enhancement of VCRS.

3. Results and Discussion

Mishra [38-39] carried out the theoretical and experimental analysis of vapour compression refrigeration system using five ecofriendly refrigerants and found that R134a have highest C.O.P. than other refrigerants such as R407c, R404a and R410a for the same geometry and input parameter of the VCRS. it is because compressor work reduces about 20-30 % than other refrigerant by using R134a in VCRS. Also working pressure ratio is little lower than the other refrigerant. So that R134a is most commonly used in HVAC and automobile AC system. Similarly C.O.P. value of R134a and R290 is quite similar but R404A and R407C have very less value of C.O.P than R134a and R290. Thus the R134 and R290 are more efficient considering first st law performances. It can be seen that compressor work is also high of R407C and R404A than the R134a and R290 so that its first st law performance reduces.

Similarly the refrigeration effect of R134a is less than the R290 but due to higher compressor work of R290 than R134a the C.O.P. value of R290 is lower than the R134. Also that refrigeration effect of R404A is higher than the R407C.

When brine mass flow rate 0.004 to 0.008 kg/s (100%) then change in COP for R134a is 14.10 %, R404a is 13.94%, R407c is 14.39% and R290 is 17.06%. When water mass flow rate 0.006 to 0.008 kg/s (33.3%) then change in COP for R134a is 5.54%, R404a is 5.65%, R407c is 3.58% and R290 is 5%.

When condensing water inlet temperature 18 to 30 oC (66.67%) then change in COP for R134a is 20.27%, R404a is 16.13%, R407c is 12.50% and R290 is 16.32%. When brine inlet temperature 18 to 30 oC (66.67%) then change in COP for R134a is 20.46%, R404a is 17.15%, R407c is 18.47% and R290 is 20.54%. Similarly the compressor speed is from 2400 to 3000 rpm (25%) then change in COP for R134a is 5.55%, R404a is 7.38%, R407c is 5.08% and R290 is 6.98%.

The enhancement in thermal conductivity of nano-refrigerant when different kind of nanoparticle is suspended into the host refrigerant. The enhancement factor varies from 0.06 to 2 for different nanoparticle. It was observed that copper nanoparticle have more enhancement factor (EF) at higher temperature .The conductivity ratio of pure refrigerant to nano refrigerant increases with increasing concentration of nanoparticle into the host refrigerant. Cu nanoparticle based nano refrigerant have higher cond. Ratio than other nanoparticle and have around two times higher than base refrigerant at 5 vol % concentration . The convective heat transfer coefficient ratio increases by increasing the concentration of nanoparticle and copper nanoparticle based nano refrigerant have highest convective heat transfer coefficient ratio than other particle its value ranges from 1 to 1.7. The heat transfer enhancement factor of nano-refrigerant with different nanoparticle its value ranges from 1.2 to 3.2. It is found that R134 a with cu nanoparticle have highest EF around 3.2 at 5 vol % of concentration. Similarly enhancement factor (EF) increases with increasing vol % .the maximum enhancement theoretically achieved about 35 % with combination of R134a with Al_2O_3 nanoparticle at 5 vol % based nanorefrigerant. The exergetic efficiency (i.e. 2nd Law efficiency) of vapour compression refrigeration systems will increase by using nanorefrigerant. It is found that the 2nd law efficiency of vapour compression refrigeration system using nano refrigerant R134a/CuO is much higher than the other nanorefrigerant having value approx 12% .as shown in Table-2

Table 2: Enhancement in C.O.P using Al_2O_3 at 5 vol % nanofluid in secondary circuit

For Al_2O_3 at 5 vol %		
Refrigerant	C.O.P.	Improvement C.O.P.
R134a	3.406	17.98%
R404A	3.0635	16.00%
R407c	3.110488	17.20%
R-152a	3.4102	18.00%
R-600	3.3402	17.20%
R-600a	3.466	19.90%
R-125	3.033016	14.80%
R-290	3.54312	19.70%

4. Conclusion

The research work presented in this paper, following conclusions have been drawn.

1. Use of nanoparticles enhances thermal performance of vapour compression refrigeration system from 8 to 35 % using nano refrigerant in primary circuit
2. Use of nanoparticles enhances the thermal performance of vapour compression refrigeration system from 7 to 19 % using nanofluid in secondary circuit.

3. Maximum enhancement in performance was observed using R134a/ Al_2O_3 nano refrigerant in primary circuit and water in secondary circuit of VCRS.
4. Lowest enhancement in performance was observed using R404Aa/TiO_2 nano refrigerant in primary circuit and water in secondary circuit of VCRS

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