ISSN No:-2456 – 2165

A Review on the Performance Analysis of VCR System Using Nanorefrigerants

Dr.N. Gunasekar, T. Manikandan, P. Pon prasanth, N. Ponvinoth.
Department of Mechanical Engineering
Sri Ramakrishna Engineering College, Coimbatore.

Abstract:-The heat transfer performance of thermal devices may be enhanced by active and passive techniques. One of the passive techniques is the mixing of nanoparticles to the common heat transfer fluids so that the thermal properties of the prepared solution will be enhanced as compared to the base fluid. Nanorefrigerants are a special type of nanofluids which are mixtures of nanoparticles and refrigerants and have a wide range of applications in various fields for example in refrigeration systems, air conditioning systems, and heat exchangers. This review is performed to explain the effect of nanorefrigerant properties on heat transfer and pressure drop compared to pure refrigerant.

Keywords:- Nanorefrigerants, Base Fluid, Refrigeration System, Pressure Drop, Heat Transfer.

I. INTRODUCTION

Nanotechnology is a branch of science and technology regarding the modification and use of particles in the atomic and molecular order. These particles can be distinguished, based on their diameter, into three groups, including coarse particles (10,000–2500 nm), fine particles (2500–100 nm), and ultra-fine particles or nanoparticles (1–100 nm). Especially in heat transfer applications, the use of nanoparticles is required because using the particles with a higher size may cause some problems like fouling, sedimentation, erosion and higher pressure drop.

In the past few decades, advances in nanotechnology have led to the emergence of new generation heat transfer fluids called ''nanofluids''. Nanofluids are defined as suspension of nanoparticles in a host fluid. Some nanofluids are ethylene glycol based copper nanofluids, water based copper oxide nanofluids, etc. Nanofluids are developed with the specific aim of increasing the thermal conductivity of heat transfer fluids, which have now evolved into a promising nanotechnological area.

Nanorefrigerant is one kind of nanofluids, in which the base fluid is conventional pure refrigerant. Experimental studies showed that the nanorefrigerant has higher thermal conductivity than the base refrigerant [8,9] and the refrigeration system using nanorefrigerant has better performance than that of using conventional pure refrigerant. However, the accumulation and sedimentation of nanoparticles in the nanorefrigerants will minimise the stability of nanorefrigerant and restrict the application of nanorefrigerant in refrigeration system.

Nanorefrigerant was anticipated on the premise of the idea of the nanofluids, which was set up by mixing the nanoparticles and customary refrigerant. There were three principle focal points for the nanoparticle utilized as a part of the refrigerators [3].

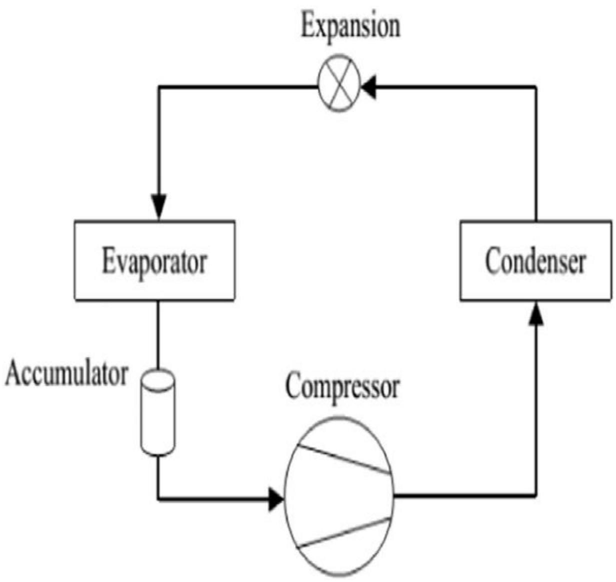
Firstly, nanoparticles can improve the solubility between the lubricant and the refrigerant. Wang et al [18]found that TiO_2nanoparticles could be used as additives to improve the solubility between mineral oil and hydrofluorocarbon (HFC) refrigerant. The refrigeration systems operating with mixture of R123a and mineral oil mixed with the nanoparticle TiO_2 gives better results by giving back more lubrication oil to the compressors. They had similar performance in comparison with the systems using polyolester and R123a.

Secondly, the thermal conductivity and the heat transfer characteristics of the refrigerants should be increased, which have been agreed by a lot of investigations. Jiang et al.[9,10] measured the thermal conductivities of CNT–R113 nanorefrigerant and found that the measured thermal conductivities of four kinds of 1.0 vol.% CNT-R113nanorefrigerants increase to 82%, 104%, 43% and 50%, respectively.

Finally, nanoparticles dispersed in lubricant should reduce the friction coefficient and wear rate. Lee et al. [13]investigated the friction coefficient of the mineral oil blended with 0.1 vol.% fullerene nanoparticles, and the results indicated that the friction coefficient decreased by 90% in evaluation with raw lubricant, which leads us to the conclusion that nanoparticles can enhance the efficiency and dependability of the compressor. Jwo et al. [10] carried out the performance analysis of a domestic refrigerator using hydrocarbon refrigerant and 0.1 wt.%Al_2O_3–mineral oil as working fluid, the results indicated that the consumption of power was lessened by around 2.4%, and the coefficient of performance was expanded by 4.4%.

II. REFRIGERATION SYSTEM

The refrigeration system consists of four main components: a compressor, a condenser, a capillary tube and an evaporator. The four components of the system are suitable for the application of refrigerators and air conditioners. In sequence of its order, the compressor will compress the refrigerant in vapour form to high pressure and high temperature, then this refrigerant is fed into the condenser. In the condenser, high pressure and high temperature refrigerant will be cooled by means of free convection heat transfer and then fed into a capillary tube. A capillary tube is a throttling device which reduces condenser pressure to evaporator pressure. At the meanwhile, the temperature of the refrigerant also decreases and it will alter the phase of refrigerant from sub-cooled liquid into mixture. Then the refrigerant is fed into the evaporator (heat exchanger). Evaporators are heat exchanging devices that can absorb available heat in a refrigerated space and the heat is then carried by the refrigerant into the compressor.



A. Types of Refrigerants

The working fluid in the refrigerator is called refrigerant which is working as the heat absorber or cooling agent. The refrigerant absorbs heat by evaporating at low temperature and low pressure and removes the heat by condensing at high temperature and high pressure. The most common refrigerant used at the early stages of refrigerator system was familiar solvents and volatile fluids. Almost all these refrigerants were flammable, toxic, or both, and some were also highly reactive. In developing the refrigerant for refrigeration system, propane (R-290) was marketed in replacing ammonia (R-717) as refrigerant [19]. Propane is considered to be a neutral chemical, therefore no corrosion occurred and neither harmful nor insufferable. The engineer can work in its vapour with convenience. Carbon dioxide (R-744) has been used in the 1920s in the field of positive-displacement and centrifugal compressors operating in air conditioning system. In addition, they used ammonia and water (R-718), sulphur dioxide (R-764), carbon tetrachloride (R-10) and dielene (1,2-dichloroethene, R-1130). From these refrigerants, only dielene can work with the centrifugal machine. The rest did not perform well because of several findings such as low performance, safety reason and incompatible with metals [19, 20].

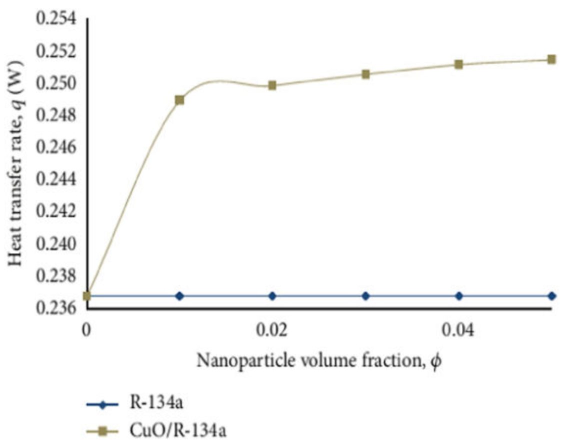
Development of a new refrigerant becomes vital as the effect of the end product of CFCs and HCFCs refrigerant. Rader maker and Kim [20] reported that the effort to explore new refrigeration started since the 1960s with two objectives: (1) achieving a low operating temperature with a moderate pressure ratio during single stage compression and (2) saving energy when the refrigeration process consists of cooling a fluid stream through a large temperature range. The most ideal refrigerant was HFC134a and expected to be used for long term. However, the observation found that HFC134a systems can withstand fewer contaminants than CFC12 systems, thus, expected to be used for long term. Therefore, another possible refrigerant was identified to replace CFC12. It was HFC152a.

However, because of the awareness of ozone layer depleting effects of chlorine, people slowly moved on to another alternative which is the hydrofluorocarbon (HFC) and hydrochlorofluorocarbon (HCFC) refrigerants. HCFC and HFC refrigerants are not miscible with mineral oil, this will disturb the performance of the refrigeration system. Synthetic lubricants like Polyalkylene glycol (PAG), polyol ester (POE), alkyl benzene (AB) are normally used together with HFC and HCFC refrigerants [21]. PAGs are extensively used in automotive applications using HCFC-based refrigerants. In HFC refrigerants like R-134a and HFC-based refrigerants, ester based oils like POE are normally used. Polyol ester (POE) oil, another type of lubricant oil used in refrigeration systems, is favoured over mineral oil for use in oil applications because of its solid chemical polarity and solubility with refrigerant. Similarly, the utilization of nanoparticles in the lubricants for compressors increases the system's efficiency and performance, causing no choking in the system [22].

III. PROPERTIES OF NANOREFRIGERANTS

Different concentrations of nanoparticles of CuO, Al_2O_3, SiO_2, diamond, CNT, TiO_2were used in base refrigerants such as R11, R113, R123, R134a, and 141b as found in the available literatures [24,25]. The nanofluid is a new type of heat transfer fluid by suspending nano-scale materials in a conventional host fluid and has higher thermal conductivity than the conventional host fluid. The nanorefrigerant is a kind of nanofluid and its host fluid is a refrigerant. The nanorefrigerant has greater heat transfer coefficient than that of the host refrigerant and thus it useful in improving the performance of the refrigeration system. The heat transfer coefficient of the fluid with lower thermal conductivity is lesser than that of the fluid with high thermal conductivity if their Nusselt number are same. Therefore, researches on improving thermal conductivities of nanorefrigerants are necessary. There are two methods to improve the thermal conductivity of a nanorefrigerant. The first one is to increase the volume fraction of nano-scale materials in the nanorefrigerant, and the second one is to use nanoscale materials with high thermal conductivity [24].

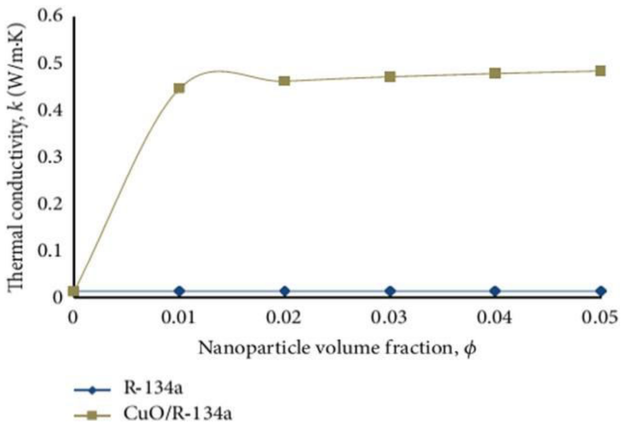
The experimental results by Jiang et al. showed that the thermal conductivities of carbon nanotube (CNT) nanorefrigerants are much higher than those of CNT–water nanofluids or spherical nanoparticle R113 nanorefrigerants. Authors reported that the smaller the diameter of CNT is or the larger the aspect ratio of CNT is, the larger the thermal conductivity enhancement of CNT nanorefrigerant.



A. *Thermal Conductivities of Nanofluids*

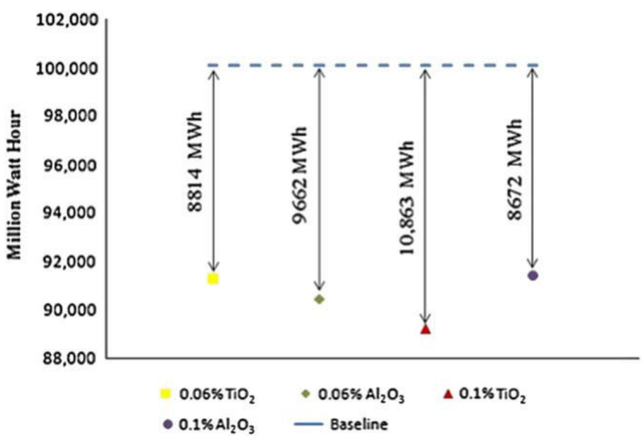
Thermal conductivity of nanofluids found to be an attracting characteristic for many applications including refrigeration and air conditioning. It represents the ability of material to conduct or transmit heat. Considerable researches have been carried out on this topic. It may be mentioned that it is a driving factor that leads to an idea of considering nanofluids as refrigerant. Eastman et al [26].found that thermal conductivity of 0.3% copper nanoparticles of ethylene glycol nanofluids is increased up to 40% compared to base fluid. Authors stressed that, this property plays an important role in construction of energy efficient heat transfer equipment. Hwang et al. suggested that thermal conductivity enhancement of nanofluids is greatly influenced by thermal conductivity of nanoparticles and base fluid. However, Yoo et al [28].argued that surface to volume ratio of nanoparticles is a dominant factor that influences the nanofluids thermal conductivity rather than nanoparticles thermal conductivity. Surface to volume ratio is increased with smaller sizes of nanoparticles.

The enhanced thermal conductivity of nanofluids offer several benefits such as higher cooling rates, decreased pumping power needs, smaller and lighter cooling systems, reduced inventory of heat transfer fluids, reduced friction coefficients, and improved wear resistance. Those benefits make nanofluids promising for applications like refrigerants, coolants, lubricants, hydraulic fluids, and metal cutting fluids.



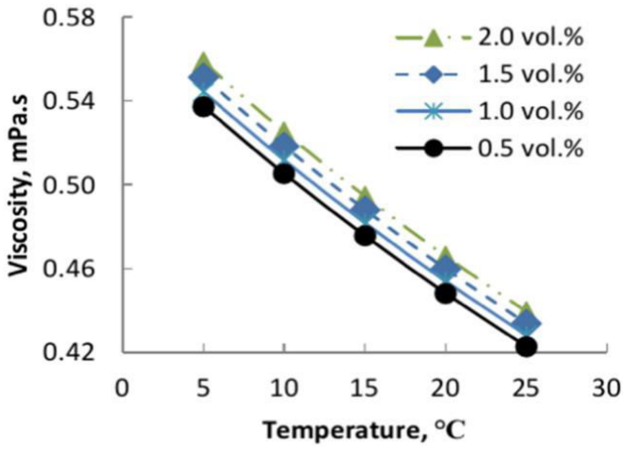
B. *Energy Performance*

The refrigerator performance with the nanoparticles was investigated using energy consumption tests and freezer capacity tests [32]. Authors reported that refrigerator's performance was better with 26.1% less energy consumption with 0.1% mass fraction of TiO_2nanoparticles compared to the HFC134a and POE oil system. Similar testswith Al_2O_3nanoparticles demonstrated that the distinctive nanoparticles properties have little impact on the refrigerator energy performance. In this manner, nanoparticles can be utilized as a part of local refrigerators to significantly lessen energy utilization. Authors revealed that there are two conceivable components by which the nanoparticles influence the refrigerator performance. One is that some nanoparticles remain in the compressor to improve the compressor friction characteristic. The other reason is that some nanoparticles flow into the heat exchanger with the refrigerant to enhance the refrigerant heat transfer characteristics. However, details of the mechanism have not been investigated.



C. *Viscosity of Nano Oil*

The kinematic viscosity of nano-oils as a function of volume fraction of fullerene nanoparticles in suspension for temperature ranging from 40° to 80°C. There was no considerable change in the kinematic viscosity of nano-oil at the various volume fractions of nanoparticles, indicating that the kinematic viscosity of nano-oils is a weak function of oil temperature [33]. At the point when particles are included, the rate of viscosity of the nano-oil is increased within 1%. In the temperature go for a compressor with time, the viscosity of the nano-oil is about the same concerning the mineral oil, however the consistency of the nano-oil increases by 7% at 20C in comparison with the mineral oil.



D. Pressure Drop Performance of Nanorefrigerant

In the bleeding edge street of research, refrigerant-based nanofluids moulded by suspension of nanoparticles in unadulterated refrigerants have been used as another kind of working fluid to upgrade the performance of refrigeration systems [31,32,34]. Presence of nanoparticles fit as a fiddle may change the pressure drop traits of the fluid, so this trademark ought to have been grasped in picking the refrigerant. Liquid solid phase pressure drops characteristics and liquid solid and vapor phase (phase change) pressure drop characteristics of nanofluids are studied by different researchers.

Pressure drop developed during the flow of coolant is one of the important parameters determining the efficiency of nanofluids application. Pressure drop and coolant pumping power are closely associated with each other. There are few properties which could influence the coolant pressure drop: density and viscosity. It is normal that coolants with higher density and viscosity encounter higher pressure drop. This has added to the disservices of nanofluids application as coolant fluids. Yu et al [29,30].and Lee et al [29]. examined viscosity of water based Al_2O_3nanofluids and ethylene glycol based ZnO nanofluids. Results unmistakably appear, viscosity of nanofluids is higher than base liquid. Praveen et al [36] in their numerical study reviewed that density of nanofluids is greater than base fluid. Both properties are found proportional with nanoparticles volume fraction. Several literatures have indicated that there is significant increase of nanofluids pressure drop compared to base fluid. Peng et al [37]. concluded that the frictional pressure drops of pure refrigerants flow boiling inside the horizontal tube is lesser than that of nanorefrigerants, and increases with the increasing mass fraction of the nanoparticles. It is found that the maximum increase of frictional pressure drop was 20.8%.

IV. STUDIES ON NANOREFRIGERANT APPLICATIONS

Jwo et al [10] discoursed the replacement of the polyester lubricant and R-134a refrigerant with a mineral lubricant and hydrocarbon refrigerant. The mineral lubricant added with Al_2O_3nanoparticles (0.05, 0.1, and 0.2 wt.%) improves the lubrication and heat-transfer rate. Experimental results indicated that the 60% R-134a and 0.1 wt.% Al_2O_3nanoparticles were optimal. Under these conditions, the power consumption was reduced by about 2.4%, and the coefficient of performance was increased by 4.4%. These outcomes exhibited that replacement of R-134a refrigerant with hydrocarbon refrigerant and addition of Al_2O_3nanoparticles to the lubricant successfully lowered the power utilization.

Bi et al. investigated experimentally the work on the nanorefrigerant [5]. TiO_2–R600a nanorefrigerant was used as a working fluid of domestic refrigerator. The results indicated that TiO_2–R600a worked normally and efficiently in a refrigerator. Compared with a refrigerator using pure R600a as working fluids, 0.1 and 0.5 g/L concentrations of TiO_2–R600a can save 5.94% and 9.60% energy consumption respectively and the freezing velocity of a nanorefrigerant system was quicker than the pure R600a system. In addition, the results were similar to the author's early research of using TiO_2–R134a as working fluids. So, the above works have demonstrated that nanoparticles can improve the performance of the domestic refrigerator.

Abdel-Hadi [1] et al. experimentally investigated the effect of using nanoCuO–R134a in the vapor compression system on the evaporating heat transfer coefficient. An experimental test rig was designed and constructed for this purpose. The test section was a horizontal tube in tube heat exchanger made from copper. The refrigerant evaporated inside an inner copper tube and the heat load provided from hot water passed in an annulus surrounding the inner tube. Measurements performed for heat flux ranged from 10 to 40 kW/m, using nanoCuO concentrations that ranged from 0.05 to 1% and particle size from 15 to 70 nm. The measurements showed that for a specific nano concentration as heat flux or mass flux increases with respect to the increase in the evaporating heat transfer coefficient. The measurements showed that the evaporating heat transfer coefficient is increased with increasing nanoCuO concentrations up to certain point and then decreased. Comparison with the available published data showed good agreement.

Convective heat transfer is very important in the HVAC, refrigeration and microelectronics cooling applications. R134a is the most widely adopted alternate refrigerant in refrigeration equipment, such as domestic refrigerators and air conditioners. Though the global warming up potential of R134a is relatively high, it is affirmed that it is a long term alternate refrigerant in lots of countries. The addition of nanoparticles to the refrigerant results in improvements in the thermophysical properties and heat transfer characteristics of the refrigerant, thereby improving the performance of the refrigeration system.

The irreversibility at the process of a vapor-compression refrigeration system (VCRS) with nanoparticles in the working fluid was investigated experimentally by Padmanabhan and Palanisamy [15] Mineral oil (MO) with 0.1 g/L TiO_2nanoparticles mixture was used as the lubricant instead of Polyolester (POE) oil in the R134a, R436A (R290/R600a-56/44-wt.%) and R436B (R290/R600a-52/48 wt.%) VCRSs. The VCRS irreversibility at the process with the nanoparticles was investigated using the second law of thermodynamics. The results indicated that R134a, R436A and R436B and MO with TiO_2nanoparticles worked normally and safely in the VCRS. The VCRS total irreversibility (529, 588 and 570 W) at a different process was better than the R134a, R436A and R436B and POE oil system (777, 697 and 683 W). The same tests with Al_2O_3nanoparticles showed that the different nanoparticle properties have little effect on the VCRS irreversibility. Thus, TiO_2nanoparticles can be used in VCRS with a reciprocating compressor to considerably reduce irreversibility at the process.

Kumar and Elansezhian[12] investigated an experimental work on nanorefrigerant. Nano Al_2O_3-PAG oil was used as nanorefrigerant in a R134a vapor compression refrigeration system. An experimental setup was designed and fabricated in the lab. Energy consumption test and freeze capacity test were done to find the system performance. The outcomes shown that Al_2O_3nanorefrigerant works usually and securely in the refrigeration system. The refrigeration framework execution was superior to anything pure lubricant with R134a working fluid with 10.32% less energy utilized with 0.2 vol. % of the concentration utilized. The outcomes demonstrated that heat transfer coefficient increments with the use of nanoAl_2O_3. Along these lines, utilizing Al_2O_3nanorefrigerant in a refrigeration framework was observed to be doable.

R134a is the most extensively accepted alternate refrigerant in refrigeration equipment, for instance domestic refrigerators and air conditioners. By virtue of the strong chemical polarity of R134a, the conventional mineral oil can be utilized as oil in refrigeration system with R134a as working fluid. The present work managed the examination on a vapor compression refrigeration framework with mineral oil and mineral oil with various nanoparticles mixed to it. The outcomes showed that the refrigeration framework with Nano oil worked regularly and securely. It was discovered that power utilization lessened by 15.4% and the coefficient of performance got increments by 20% when TiO_2Nanolubricant is utilized rather than SUNISO 3GS [14].

Aktas et al [2] concentrated on five different nanorefrigerants with Al_2O_3nanoparticles and their pure refrigerants: R12, R134a, R430a, R436a, and R600a. The coefficient of performance (COP) and compressor worked for various evaporation and condensation temperatures are investigated. Results obtained using theoretical analysis compared with the results available in the literature, and deviations were 22.5% and 28.6% for pure R134a and R134a/Al_2O_3mixtures (when the density of particles is 3690 kg/m^3), respectively. The deviation was 20.8% for the R134a/Al_2O_3mixture when the nanoparticle density was 2200 kg/m^3. The results indicated that COP was enhanced by adding nanoparticles to the pure refrigerant and maximum values obtained using the R600a/Al_2O_3mixture.

Singh and Lal [16] Conducted an experimental study on Alumina (Al_2O_3) nanoparticles of 20 nm diameter dispersed in refrigerant R134a to improve its heat transfer performance. It has been found out that performance of the system has been improved. The improvement in coefficient of performance (COP) was maximum (7.2 to 8.5%) with 0.5% Al_2O_3 (wt.%) nanoparticles. When the mass fraction of nanoparticles gets increased to 1% in refrigerant, COP is found to be lesser than even from pure R134a. Further, enlarged mass fraction of Al_2O_3(1%), lowers the temperature and pressure after expansion of the nanorefrigerant in the capillary tube. Hence, the specific heat of refrigerant is decreased. So, these two factors will decrease the refrigeration effect, thus COP. Furthermore, system worked normally using nanorefrigerant.

Fadhilah et al. [7] examined precisely the effect of the suspended copper oxide (CuO) nanoparticles into R-134a. The study includes the heat transfer rate, thermal conductivity, and dynamic viscosity of the nanorefrigerant in evaporator. The results showed improved thermophysical properties of nanorefrigerant in comparison with the conventional refrigerant. These advanced thermophysical properties increased the heat transfer rate in the tube. The nanorefrigerant could be a suitable working fluid to be used in the refrigeration framework to enhance the heat transfer properties and save the energy consumption.

Coumaressin and Palaniradja[6] studied the effect of using CuO–R134a in the VCR system on the evaporating heat transfer coefficient by CFD analysis using the FLUENT software. An experimental device was built according to the national standards of India. The investigational studies specified that the refrigeration system with nanorefrigerant will work normally. FLUENT software is used to assess the heat transfer coefficient for heat flux from 10 to 40 kW/m^2, using nano CuO concentrations ranging 0.05 to1.0% and particle size ranging 10.0 to 70.0 nm. The results showed that evaporator heat transfer coefficient enhances the usage of nanoCuO.

Kumar and Elansezhian [11]investigated experimentally the reliability and performance of vapor compression refrigeration system with ZnO nanoparticles in the working fluid. Nanorefrigerant was synthesized on the basis of the concept of the nanofluids, which was prepared by mixing ZnO nanoparticles with R152a refrigerant. The conventional refrigerant R134a has a global warming potential of 1300 whereas R152a has a significant low value of global warming potential of 140 only. An investigational test rig

ISSN No:-2456 – 2165

was designed and made-up indigenously in the laboratory to carry out the experiments. ZnO nanoparticles mixed with refrigerant were used in a HFC R152a refrigeration system. The concentration of nano ZnO ranged in the order of 0.1 vol.%, 0.3 vol.% and 0.5 vol.% with particle size of 50 nm and 150 g of R152a was charged and tests were conducted. The compressor suction pressure, discharge pressure and evaporator temperature were measured. The results indicated that ZnO nano refrigerant worked normally and safely in the system. The zinc oxide concentration was a vital factor considered for heat transfer augmentation in the Refrigeration system. The performance of the system was significantly enhanced with 21% less energy utilization when 0.5 vol.% ZnO–R152a refrigerant. Both discharge and suction pressureshas been dropped by 10.5% with the usage of nanorefrigerants. There was a 6% decrement in the evaporator temperature with the usage of nanorefrigerant. So, ZnO nanoparticles with pure refrigerant could be used in a refrigeration system to substantially reduce energy consumption. The usage of R152a with zero ozone depleting potentialand very less global warming potential provides a clean and green environment.

Studies related to refrigeration systems.

Researcher	Refrigerant	Nanoparticle	Lubricant	Nanoparticle mass fraction	Evaluation
Bi et al.	HFC134a	TiO_2–Al_2O_3	POE	0.06%–0.1%	The nanoparticles can be used in domestic refrigerators to considerably reduce energy consumption
Jwo et al.	R-134a	Al_2O_3	Polyester	0.05, 0.1, and 0.2 wt.%	The power consumption was reduced by about 2.4%, and the coefficient of performance was increased by 4.4%
Bi et al.	R600a	TiO_2	–	0.1 and 0.5 g/L	TiO_2–R600a can save 5.94% and 9.60% energy consumption respectively and the freezing velocity of nanorefrigerant system was more quickly than the pure R600a
Abdel-Hadi et al.	R134a	CuO	–	0.05 to 1%	For a certain nano concentration as heat flux or mass flux increases the evaporating heat transfer coefficient increases
Subramani and Prakash	R134a	Al_2O_3	POE	–	The freezing capacity is higher and the power consumption reduces by 25%
Padmanabhan and Palanisamy	R134a, R436A and R436B	TiO_2	Mineral oil	0.1 g/L	Nanoparticles work normally and safely in the VCRS. The VCRS total ir-reversibility (529, 588 and 570 W)
Kumar and Elansezhian	R134a	Al_2O_3	PAG	0.2%	The refrigeration system performance was better than pure lubricant with R134a working fluid with 10.32% less energy
Javadi and Saidur	R-134a	TiO_2–Al_2O_3	Mineral oil	0.06%–0.1%	The energy saving using nanorefrigerant (0.1% TiO_2 nanoparticle/mineral oil) would be greater than normal refrigerant, with 10,863 MW h reduction in energy consumption
Kumar et al.	R12, R22, R600, R600a and R134a	Al_2O_3	POE	0.06%	The freezing capacity is higher and the power consumption reduces by 11.5%
Subramani et al.	R134a	TiO_2	Mineral oil	300 g	Power consumption reduces by 15.4% and the coefficient of performance increases by 20%
Kotu and Kumar	R-134a	Al_2O_3	Mineral oil	–	The results showed that the COP of HFC134a/ mineral oil/DPHE system increases by 10% and HFC134a/mineral oil/alumina nanoparticle system was increased by 6% when compared with the conventional system
Aktas et al.	R12, R134a, R430a, R436a, and R600a	Al_2O_3	–	–	COP is enhanced by adding nanoparticles to the pure refrigerant and maximum values obtained using the R600a/Al_2O_3 mixture
Singh and Lal	R134a	Al_2O_3	–	0.5%–1%	The improvement in coefficient of performance (COP) was maximum (7.2 to 8.5%)
Fadhilah et al.	R-134a	CuO	–	1%–5%	The nanorefrigerant could be a potential working fluid to be used in the refrigeration system to increase the heat transfer characteristics and save the energy usage
Coumaressin and Palaniradja	R134a	CuO–R134a	0.55%		The results indicated that evaporator heat transfer coefficient increases with the usage of nano CuO
Kumar and Elansezhian	R134a	ZnO	–	0.1 vol.%, 0.3 vol.% and 0.5 vol.%	The performance of the system was significantly improved with 21% less energy consumption

ISSN No:-2456 – 2165

V. CONCLUSION

- Based on the literatures, it has been found that the thermal conductivities of nanorefrigerants are higher than traditional refrigerants. It was also observed that increased thermal conductivity of nanorefrigerants is comparable with the increased thermal conductivities of other nanofluids.
- Thermal conductivities of refrigerant with carbon CNT is found to be higher than refrigerant without CNT. The maximum thermal conductivity enhancement was found to be about 46% and the thermal conductivities of nanorefrigerants depend on concentrations and aspect ratio of CNT.
- It has been found out that heat transfer enhancement can be.
- achieved from a minimum value of 21% to a maximum value of 275% using nanorefrigerants compared to traditional refrigerants. The refrigerator's performance was found 26.1% better with 0.1% mass fraction of TiO_2nanoparticles compared to a refrigerator's performance with the HFC134a and POE oil system.
- The mineral lubricant with Al_2O_3nanoparticles (0.05, 0.1, and 0.2 wt%) was used to investigate the lubrication and heat transfer performance. Results indicated that the 60% R134a and 0.1 wt% Al_2O_3nanoparticles provided optimal performance. Under these conditions, the power consumption was reduced by about 2.4%, and the coefficient of performancewas increased by 4.4%.
- There is a significant increase in nanofluids pressure drop compared to base fluid. It has been studied the thermal design of compact heat exchanger using nanofluids and found that pressure drop of 4% Al_2O_3+ H_2O nanofluids is almost double of the base fluid. The maximum increase of frictional pressure drop was found to be about 20.8% under the experimental conditions.
- The stability and production cost of nanofluids are the major hinderance factors for the commercialization of nanofluids.By resolving these challenges, it is likely that nanofluids can make considerable impact in heat exchanging devices.

REFERENCES

[1]. E.A.H. Abdel-Hadi, S.H. Taher, A.H.M. Torki, S.S. Hamad, Heat transfer analysis of vapor compression system using nano CuO-R134a, Int. Conf. Adv. Mater Eng, IPCSIT 2011.

[2]. M. Aktas, A.S. Dalkilic, A. Celen, A. Cebi, O.Mahian, S.Wongwises, A theoretical comparative study on nanorefrigerant performance in a single-stage vapor-compressionrefrigeration cycle, Ad. Mech. Eng. (2014).

[3]. O.A. Alawi, N.A.C. Sidik, H.A.Mohammed, A comprehensive review of fundamentals, preparation and applications of nanorefrigerants, Int. Commun. Heat Mass Transfer (2014).

[4]. S.S. Bi, L. Shi, L.L. Zhang, Application of nanoparticles in domestic refrigerators, Appl. Therm. Eng.(2008).

[5]. S. Bi, K. Guo, Z. Liu, J. Wu, Performance of a domestic refrigerator using TiO2-R600a nano-refrigerant as working fluid, Energy Convers. Manag.(2011).

[6]. T. Coumaressin, K. Palaniradja, Performance analysis of a refrigeration system using nano fluid, Int. J. Adv. Mech. Eng.(2014).

[7]. S. Fadhilah, R. Marhamah, A. Izzat, Copper oxide nanoparticles for advanced refrigerant thermophysical properties: mathematical modeling, J. Nanopart. (2014).

[8]. W. Jiang, G. Ding, H. Peng, Measurement and model on thermal conductivities of carbon nanotube nanorefrigerants, Int. J. Therm. Sci.(2009).

[9]. W. Jiang, G. Ding, H. Peng, Y. Gao, K. Wang, Experimental and model research on nanorefrigerant thermal conductivity, HVAC&R Res.(2009).

[10]. C.S. Jwo, L.Y. Jeng, T.P. Teng, H. Chang, Effects of nanolubricant on performance of hydrocarbon refrigerant system, J. Vac. Sci. Technol., B: Microelectron. Nanometer Struct.Process., Meas., Phenom.(2009).

[11]. D.S. Kumar, R. Elansezhian, ZnO nanorefrigerant in R152a refrigeration system for energy conservation and green environment, Front. Mech. Eng.(2014).

[12]. D. Kumar, R. Elansezhian, Experimental study on Al2O3-R134a nano refrigerant in refrigeration system, Int. J. Modern Eng. Res. (IJMER)(2012).

[13]. K. Lee, Y. Hwang, S. Cheong, L. Kwon, S. Kim, J. Lee, Performance evaluation of nano- lubricants of fullerene nanoparticles in refrigeration mineral oil, Curr. Appl. Phys.(2009).

[14]. N.Subramani, Aswin Mohan, M. Jose Prakash, Performance studies on a vapour compression refrigeration systemusingnano-lubricant, Proc. Int. Conf. Energy Environ, (2013).

[15]. V.M.V. Padmanabhan, S. Palanisamy, The use of TiO2 nanoparticles to reduce refrigerator ir-reversibility, Energy Convers. Manag,(2012).

[16]. K. Singh, K. Lal, An investigation into the performance of a nanorefrigerant (R134a Al2O3) based refrigeration system, Int. J. Res.Mech. Eng. Technol,(2014).

[17]. K.J.Wang, K. Shiromoto, T. Mizogami, Experiment study on the effect of nano-scale particle on the condensation process, Proceedings of the 22nd International Con- gress of Refrigeration, Beijing, China, 2007.

[18]. B1–B1005. R.X. Wang, B. Hao, G.Z. Xie, H.Q. Li, A refrigerating system using HFC134a and mineral lubricant appended with n-TiO2 (R) as working fluids, Proceedings of the 4th International Symposium on HAVC, Tsinghua University Press, Beijing, China 2003.

[19]. Calm JM. The next generation of refrigerants historical review, considerations, and outlook. Int J Refrig 2008.

[20]. Radermacher R, Kim K. Domestic refrigerators: recent developments. Int J Refrig 1996.

[21]. Bock W. Refrigeration oils. In: Encyclopedia of lubricants and lubrication. Springer; 2014.

[22]. Celen A, Çebi A, Aktas M, Mahian O, Dalkilic AS, Wongwises S. A review of nanorefrigerants: flow characteristics and applications. Int J Refrig 2014.

[23]. Choi SUS. Development and applications of Non-Newtonian flows'. In: Singer DA, Wang HP, editors. Development and application of non-Newtonian flows. Vol. FED,New York ASME; 1995.

[24]. Jiang W, Ding G, Peng H. Measurement and model on thermal conductivities of carbon nanotube nanorefrigerants. International Journal of Thermal Sciences 2009.

[25]. Wen DS, Ding YL. Experimental investigation into the pool boiling heat transfer of aqueous based g-alumina nanofluids. Journal of Nanoparticle Research 2005.

[26]. Eastman JA, Choi SUS, Li S, Yu W, Thompson LJ. Anomalously increased effective thermal conductivities of ethylene glycol-based nanofluids containing copper nanoparticles. Applied Physics Letters 2001.

[27]. Hwang YJ, Ahn YC, Shin HS, Lee CG, Kim GT, Park HS, et al. Investigation on characteristics of thermal conductivity enhancement of nanofluids. Current Applied Physics 2006.

[28]. Yoo D-H, Hong KS, Yang H-S. Study of thermal conductivity of nanofluids for the application of heat transfer fluids. Thermochimica Acta 2007.

[29]. Lee J-H, Hwang KS, Jang SP, Lee BH, Kim JH, Choi SUS, et al. Effective viscosities and thermal conductivities of aqueous nanofluids containing low volume concentrations of Al2O3 nanoparticles. International Journal of Heat and Mass Transfer 2008.

[30]. Yu W, France DM, Choi SUS, Routbort JL. Argonne National Laboratory review and assessment of nanofluid technology for transportation and other applications. Energy Systems Division; 2007.

[31]. Wang RX, Xie HB. A refrigerating system using HFC134a and mineral lubricant appended with n-TiO2(R) as working fluids. In: Proceedings of the 4th International Symposium on HAVC; 2003.

[32]. Bi SS, Shi L, Zhang LL. Application of nanoparticles in domestic refrigerators. Applied Thermal Engineering 2008.

[33]. Jaekeun L, Sangwon C, Yujin H, Changgun L, Soo HK. Enhancement of lubrication properties of nano-oil by controlling the amount of fullerene nanoparticle additives. Tribology Letters 2007.

[34]. Wang KJ, Shiromoto K, Mizogami T. Experimental study on the effect of nanoscale particle on the condensation process. In: Proceedings of the 22nd international congress of refrigeration; 2007.

[35]. Li J, Kleinstreuer C. Thermal performance of nanofluid flow in microchannels. International Journal of Heat and Fluid Flow 2008.

[36]. Praveen K, Namburu DK, Das KM, Tanguturi, Ravikanth SV. Numerical study of turbulent flow and heat transfer characteristics of nanofluids considering variable properties. International Journal of Thermal Sciences 2009.

[37]. Peng H, Ding G, Jiang W, Hu H, Gao Y. Measurement and correlation of frictional pressure drop of refrigerant-based nanofluid flow boiling inside a horizontal smooth tube. International Journal of Refrigeration 2009.