Available online at www.sciencedirect.com

ScienceDirect

Materials Today: Proceedings 5 (2018) 20518–20527

www.materialstoday.com/proceedings

ICMPC_2018

Employing magnetic field to a liquid channel of nano lubricant equipped VCR system by using R134a refrigerant

Gudlavalleti V V S Vara Prasad[a,]*, K Dilip kumar[b]

[a,b]*Mechanical Engineering Department , Lakireddy Bali reddy College of Engineering Mylavaram, A.P, India-521230.*

Abstract

This article represents an experimental investigation accomplished to examine the impact of magnetic field on liquid channel of nano lubricant (CuO& PAG oil) equipped VCR system. This effects on energy economics in VCR system. By employing magnetic field to fluid flow, atomization of the fluid will takes place and reduces the specific volume of the fluid molecules. This drop in specific volume of fluid molecules results to loses it's viscosity that decreases the input compressing power required by compressor, also increases heat changing rates in evaporator and condenser in behalf of raised mass flow rates of the refrigerant. Addition of nano particles to the lubricating oil of compressor enhances heat changing rates in ejector (i.e. condenser) and evaporator & by reducing frictional power leads to rise in mechanical efficiency. By this experimental study, an improvement in the performance of VCR system was noticed and the occupancy of best level of magnetic field in the presence of different volumetric compositions (0.01%, 0.015%, 0.02%, and 0.025%) of CuO nano particles to PAG oil observed. Finally by combining both magnetic and lubrication effects, the coefficient of performance of system enhanced up to 25.14% for refrigerant R134a at fourth magnetic pair among all five magnetic pairs (each 11,800 Gauss), by the application of magnetic field to liquid channel with 0.025% volumetric addition of copper-oxide nano particles (APS: 40-80 nm) to the compressor lubricating oil (PAG oil), when compared to simple VCR.

Keywords:Magneticfield;Hydroflurocarbon refrigerant (R134a);Refrigerating effect; Compressor input power; COP

* Corresponding author.
*E-mail address:*varaprasadgudlavalleti@gmail.com

Nomenclature

R.E.	Refrigerating effect
VCR	Vapour compression refrigeration system

1. Introduction

Refrigeration is a process of absorbing heat from low temperature sink and transfers it to the high temperature source. Refrigerator is a device, which maintains system temperature below the surroundings temperature. Now a days due to global warming human beings were most interested in thermal comfort devices like refrigerator, air conditioning devices. By getting little improvement in performance of VCR system (i.e. COP), enormous changes will come in energy savings. In simple VCR system, refrigerant flows through pipes in entire circuit. While passing in circuit it changes it's phase (liquid to vapour&vapour to liquid) due to heat interactions. Mainly four components involved in simple VCR system are compressor, condenser, expansion device, and evaporator. In this circuit two components (compressor, expansion device) were meant for pressure variations and remaining two other components (condenser, evaporator) were designedfor temperature variations. In this circuit to maintain evaporator (heat absorbing device) at low temperature level, lower temperature lesser pressure liquid refrigerant absorbs heat from evaporator and it becomes low pressure high temperature vapour. This low pressure high temperature vapour refrigerant moves to compressor by getting compression it converts into high pressure high temperature (superheated) vapour afterwards it becomes high pressure low temperature liquid refrigerant by rejecting heat to atmosphere while passing through the condenser (heat rejecting device),Finally this higher pressure lower temperature liquid refrigerant changes into lesser pressure lower temperature liquid state when it passes through expansion device (Capillary tube).To get improvement in COP of VCR system, either by enhancing heat transfer rates at condenser and evaporator (refrigerating effect) or by decreasing input compressing power required by compressor. Based on Fourier- law of heat conduction and convection analysis, concludes lower viscous fluids contains more chance to do greater heat interactions when compared to higher viscous fluids with in a prescribed short duration. In macroscopic view, a higher viscous fluid contains higher specific volume molecules when compared to lower viscous fluids. Based on the specific volume of molecules present in the fluid decides that particular fluid viscosity. By doing atomization, reduction in the specific volume of molecules takes place. Magnetic refrigeration is extraordinary compared to other strategies of eco-accommodating refrigeration systems. To do atomization of fluid molecules, provision of magnetic field is needed by procuring suitable magnets. It has been studied that frictional coefficient of compressor reduces with decreasing viscosity of lubricant oil. In general, if the viscosity of the lubricant oil decreases, wear action increases. Due to increment in wear action frictional power generation was more. It has been introduced that addition of copper-oxide nano particles to lubricating oil (PAG oil), decreases both frictional coefficient and wear action of compressor. By reducing frictional power it leads to enhancement in mechanical efficiency a little bit. And also, whenever refrigerant comes into compressor it pickss some of the lubricant molecules which were present in the casing of compressor. In this way, some of the nano lubricant (CuO + PAG oil) particles were also moves into entire circuit.(i.e. moves through all components which were present in the circuit.) So heat transfer rates enhances in condenser &evaporator, based on thermo physical properties of nano particles which were used in the lubricant oil (PAG oil). Several techniques have beentried out for enhancing the COP of the VCR system, as reported in the literature. Pralhad.Tipole et.al (2012) have done experimental research on employment of magnetic field to liquid channel of VCR system for different refrigerants R600a and R134a and talked about the restricted magnetic field.[1] Khovaylo VVet.al (2014)has announced the part of magnetic materials for the change in VCR system. Magnetic materials influence the fluid molecules changes into atoms and sub-atoms also, while fluid passing through magnetic field.MCE (Magneto-Caloric Effect) is nothing but applying heating or cooling to the magnetic materials for different magnetic field variations.[2,3] Bansal Pradeep et.al, Tagliafico LA et.al, Pecharsky KV et.al, Christensen DV et.al, Trevizoli PV et.al (2005)have summarized and noticed the use of magnetic components for the enhancement in the VCR system. The magnetic field impacts on thermal properties of fluids like specific heat, entropy, and thermal conductivity. [4–10].Bi et.al (2007) has done experiments on a nano refrigerant equipped household refrigerator. In that, they used (mineral oil + TiO_2) mixture as a lubricant oil and R134a as a refrigerant. They reported that for nano refrigeration system, there is a 21.2% decrement in energy input to compressor noticed when compare with R134a/POE lubricant oil.[11]Bi et.al (2008)watched diminishment in the input energy requirement and extensive change in cooling capacity. They summarized that enhancement of performance of system (i.e. COP) is a result of great (thermal+ physical) nature of lubricating mineral oil and edibility nature of nanopowder particles in refrigerant. [12]Jwo et.al (2009) examined on VCR system with polyester as lubricant and R134a as refrigerant and also hydrocarbon refrigerant with mineral oil as lubricant. The mineral oil lubricant is embedded with nanoparticles to enhance heat exchange rates. Their report represents that at 60% of R134a plus Al_2O_3 nanoparticles with 0.1 weight% were showed fruitful performance. [13]Shengshan et.al (2011) identified that the performance of household refrigerator withR134a as a refrigerant and (mineral oil + TiO2) as a lubricant. The addition of nano Copper–Oxide (APS: 15nm-70nm) in the R134a refrigerant improves the heat changing rate at evaporator. The conclusions showed that decrement in 26.1% of input power consumption. [14].Ching-Song Jwo et.al (2010) examined the addition of aluminum-oxide (Al2O3) nano particles in R134a refrigeration system. The output results showed that the thermal conductivity increased up to somewhat, when the temperatures were maintained at 20°C to 40°C. [15]. Henderson et.al (2010) has researched on heat exchanging phenomena by boiling process and fluid flow behavior with R134a refrigerant within the sight of nanofluids in a horizontal pipe. They distinguished that incredible diffusion of Copper-Oxide nanoparticles with refrigerant R134a and lubricant POE oil leads to increase heat exchanging rates above 100% when compare with hybrid (R134a+POE) VCR system. [16]. Bobbo et.al (2010) directed an examination because of impact of separation of nanohorns with single wall carbon and TiO_2 nanoparticles in view of the thermo-physical nature of lubricant oil consolidated with the dissolving idea for R134a at various temperatures. They abridged that the lubricant tribological nature can be enhanced by the rate of inclusion of nanoparticles. [17].Bi et.al (2008) [30] have done performance analysis on household refrigerator using nanorefrigerant mixture (R600a +TiO_2nano particles) as working fluid. [18]

2. Experimental study

This present experimental investigation examined the followings:

I. Identified variation in performance (i.e. COP), of simple VCR system in the absence and presence of procurement of magnetic power to liquid channel for R134arefrigerant.

II. Identified variation in performance (i.e. COP), of simple VCR system with and without inclusion ofdifferent volumetric compositions (i.e. 0.01%, 0.015%, 0.02%, 0.025%) of copper-oxide (CuO) nano particles tocompressor lubricant oil (PAG oil) for R134a refrigerant as shown in below Fig (1-7).

III. Identified variation in performance (i.e. COP), of simpleVCR system with and without Procurement of magnetic field to liquid channel for R134a refrigerant in the presence ofdifferent concentrations of CuO nano particles to lubricant oil (PAG oil) of compressor.

IV. Observed limiting magnetic field strength concerning number of magnetic sets in the presence of different volumetric compositions (i.e. 0.01%, 0.015%, 0.02%, 0.025%) of copper-oxide (CuO) nano particles to compressor lubricant oil (PAG oil) for R134arefrigerant, further which system performance (COP) diminishes.

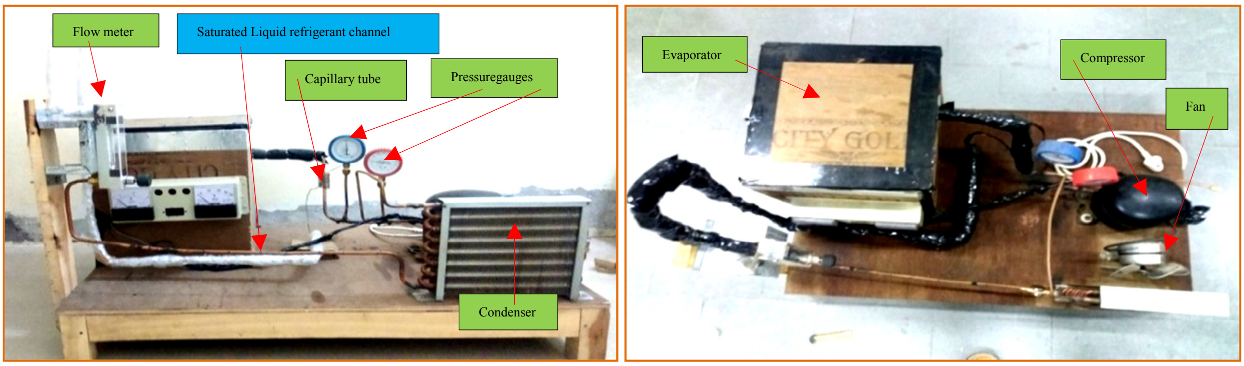

Fig 1. Simple VCR experimental setup test rig

An investigational setup of VCR system was made to examine the performance with R134a refrigerant. A test setup rig was appeared in Fig.1. It abides of circuit which comprises of a pressurizing device (compressor), heat rejecting device (condenser), pressure reducing device (i.e. capillary tube) and heat absorbing device (evaporator). In this set up hermetically closed reciprocating type compressor used. The evaporator and condenser were made by copper tubes having diameter ¼ inches. In this used condenser, the saturated vapour refrigerant passes inside the copper pipe and over the tubes, air flows by fan. Next this cooled liquid refrigerant sent to the evaporator after capillary action. Low flow glass tube flow meter (0-10 LPH) was utilized to control the mass stream rate and to discover change in mass stream rate of the refrigerant due to magnetic effect on copper tube, which is in between condenser and flow meter In the single tube evaporator, the low pressure saturated liquid refrigerant flows inside of copper tube and water is outer surface of thecopper tubes. To minimize the heat wastage proper insulation provided.

2.1. Procuring Magnetic field to liquid channel of VCR system

Fig2.Procuring no magnetic pair to liquid channel

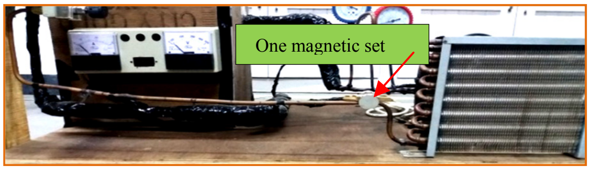

Fig 3. Procuring one magnetic pair to liquid channel

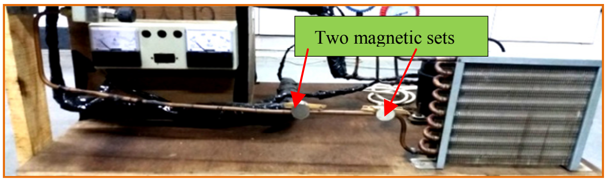

Fig4. Procuring two magnetic pairs to liquid channel

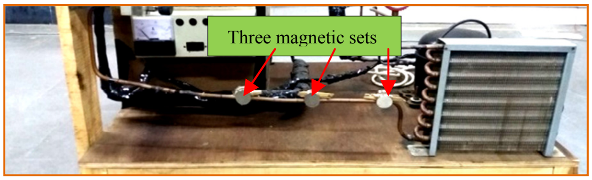

Fig5. Procuring three magnetic pairs to liquid channel

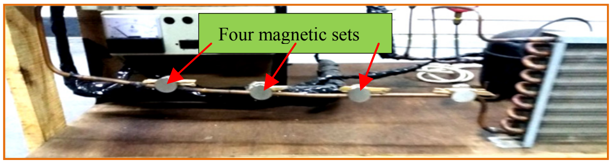

Fig6. Procuring four magnetic pairs to liquid channel

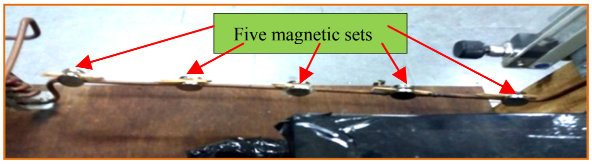

Fig7. Procuring five magnetic pairs to liquid channel

Five (rare earth neodymium disc type) magnetic sets with a Gaussian power of 11,800 each were employed in this experiment and located on the saturated liquid refrigerant passing channel. The readings were attained by adding number of magnetic sets. With the help of 4-channel k-type digital thermometer thermocouple sensors includes: 1 x Meter and 4 Probe sensor (length ~ 95cm each, -30°C to 300°C), At different points, (Entry and exit of evaporator, inlet and outlet of condenser, refrigerated water and ambient air).Temperatures of the refrigeration circuit were observed with the help of six sensor probes. By using voltmeter and ammeter power supply to the system was noted. To find suction and discharge pressures, two suitable pressure gauges at the entry and exit of the compressor were placed. The magnets used in this study were neodymium rare earth disc type magnets (N35) with dimensions [3/8"*1/16"]. The Copper oxide (CuO) nano particles used in this experiment, having APS: 40-80 nm were purchased from Sigma- ald-rich Company. In this present research, at first the temperature of the water in evaporator is at 32^0C maintained by using electrical heater. The readings were noted down at duration of 20 min. Each test was conducted for 3 hours. At first, experiment was organized in the absence of magnetic power on the liquid channel of simple VCR system. Next tests were operated by employing magnetic power on liquid refrigerant channel of the simple VCR system. Employment of magnetic power was boosted by the addition of digit of magnetic sets on liquid refrigerant channel to observe the impact of strength of magnetic poweron system performance. Following operations were governed by employing magnetic field to liquid refrigerant channel of the VCR system. The imposition of digit of magnetic sets on the liquid refrigerant channel is raised from one set to five sets (11,800 Gauss each) to examine its impact on the compressor input power requirement and performance of the VCR system. The gap provided in between two successive magnetic sets was maintained fixed, i.e. 13 cm as shown in below Fig (8-13).

2.2 Inclusion of various concentrations of CuO nano particles to compressor lubricating oil (PAG oil)

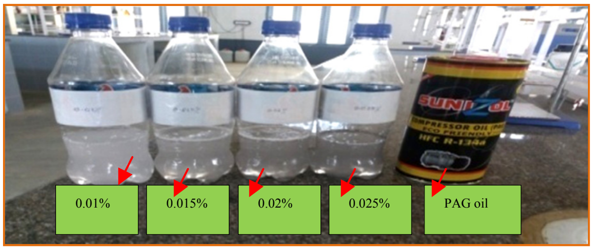

Fig 8.Nano lubricants of different compositions before mixing

Fig 9. Mixing of nano lubricant with Electronic Magnetic Stirrer

Poly alkaline glycol oil in the compressor is mainly for heat transfer from the refrigerant and minimizing the friction. Amount of PAG oil is poured in to the compressor is 240 ml. A nano lubricant is nothing but proportionate mixing of nano particles to lubricant oil. In this experiment different volume fraction (0.01%, 0.015%, 0.02%, 0.025%) of CuO nano particles are added to the PAG oil lubricant with the help of magnetic stirrer for 72 hours.

Fig 10. Charging of nano lubricant for various concentrations

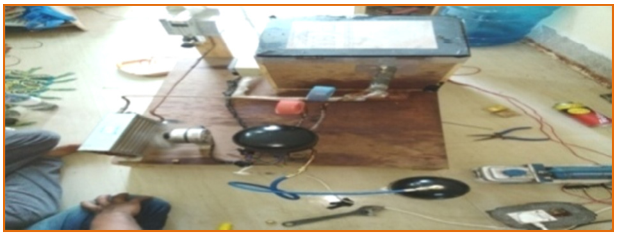

Fig 11. Charging of R134a refrigerant in the presence of nano lubricant

Every time charging of the lubricant into the compressor has been done and noted the readings of each volume fraction of nano lubricant like 0.01%, 0.015%, 0.02%, and 0.025%. Then compared various parameters for better results. And then run the cycles for taking the readings for each volume fraction of lubricants. Compare the results with each other for different parameters.Commercially available nanoparticles of copper oxide with average size 40-80 nm and with density 6.35 g/cm^{3}were used for preparation of nanorefrigerant. An investigational test shows that the stable distribution of copper oxide nanoparticles will be added with refrigerant when charged to system by the main valve before compressor from refrigerant cylinder by pressure different and it is injected first time pure refrigerant R134a. After removed PAG oil from compressor shell and injected nano lubricants (CuO + PAG oil) one after another as sown in below Table 1 .

2.3 Neodymium rare earth disc magnets

Fig 12. N35 grade [3/8" * 1/16"] neodymium disc magnets

Tab 1.Specifications of N35 grade neodymium disc magnets

Material	Sintered NdFeB
Grade	N35
Type	Disc
Dimension	3/8" * 1/16"
Pulling force	1.5lbs
Gauss Rating	11,800 Gauss
Coating	Ni+Cu+Ni 3 layer coated.

2.4 Copper oxide nanoparticle

Fig 13. Copper-Oxide nano particles (APS: 40-80nm)

Tab.2.Properties of CuO nano particles

Diameter size (nm)	40-80
Nano particle Morphology	Spherical
Specific surfaceArea (m^2/g)	20
Density (g/cm^3)	6.315
Average particle size(nm)	40-80

3. Results and Discussion

In this experimental study, on VCR system no magnetic imposition to liquid channel had taken as reference.

3.1 Impact of Magnetic field on simple VCR system

The fall in thickness of the refrigerant with expanding magnetic field quality will bring about raised mass stream rates of the refrigerant and henceforth enhanced refrigerating impact. Fig.12clearly represents fall in temperature of water (Improvement in cooling impact) due to increment in the digit of magnetic sets combines until the fourth set. Beyond fourth magnetic set diminishment in cooling impact was watched. By employing magnetic power for R134a refrigerant demonstrated a change in refrigeration executed. Notices have demonstrated that the utilization of magnetic power decreases the thickness of refrigerant plus improves the development of refrigerant that brings about expanded mass stream rate of refrigerant and consequently brings about improved capacity of evaporator. Expanded mass of refrigerant stream rates increments capacity of evaporator and hence boosted fall in water temperature can be identified as shown in below Fig 14-16**.**

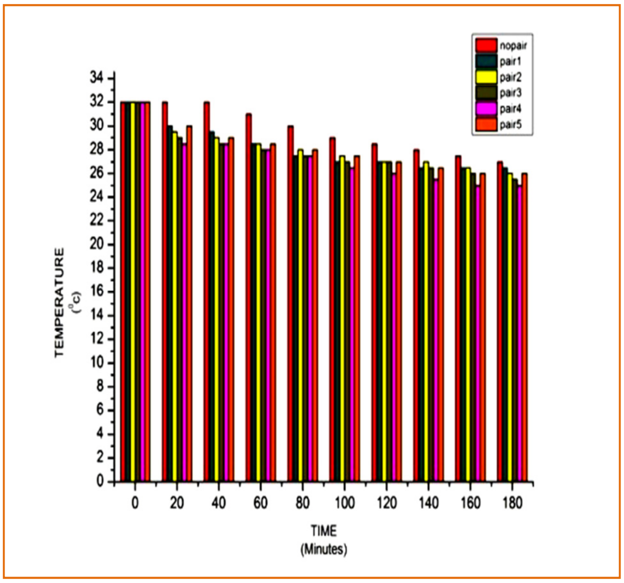

Fig 14. Temperature vs Time vs Number of magnetic sets

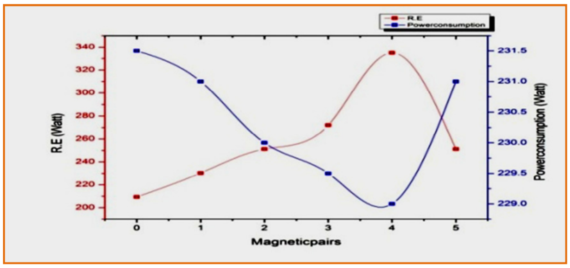

Fig15.Magnetic power on R.E. and Power consumption

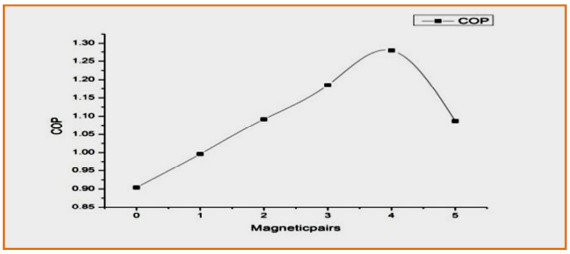

Fig.16. Impact of addition of magnetic sets on COP (R134a).

Fig.13 speaks to impact of magnetic intensity on the prompt power utilization of the compressor and refrigeration impact. It discovered that information input power requirement to the compressor diminishes with increment in sets of magnets. It was accounted for that thickness of the refrigerant is depends on capacity of the connected magnetic field, as the magnetic intensity of field raises, absolute viscosity continues diminishing; consequently, bring down required compressor input power is to draw a similar measure of passing refrigerant. If digit of magnetic sets increases, refrigerating impact likewise increments until fourth magnetic set, since large measure of refrigerant can be flowed with respect to time because of the diminishment in refrigerant molecules specific volume, that prompts refrigerating impact ,change in the heat exchange rates. Magnetic power influences nature of liquid. The variation in the liquid properties happens because of progress in bonds shaped, compound structure and because of electrons sharing. Sets of shared electron between two atoms might be equivalent or vary. Stableness of particles relies purely on covalent bonds. Covalent bonds are atomic forces that affect sub-atomic behaviours. Intermolecular forces are in charge of picking the atoms together plus furthermore a thermo physical behaviour of substance relies on those things. Intermolecular forces of liquid were physically intense that of achieve part, experience difference in stage. Increment in velocity of liquid refrigerant leads to get variation in flowing refrigerant's phase. Increment in performance happens due to defeating of these intermolecular forces or bonds. Magnetic field improves the heat exchange rate yet it relies on recurrence of the interior unsettling influences of the atom, attractive field area, and force of attractive field. Further magnetic field quality, entropy creation will happen promptingdrop in refrigerating impact. By procuring magnetic field, it positively affects cooling capacity and power utilization which prompts the change in the COP of VCR. Fig. 14 indicates the connection amidst the quantity of the sets of magnets also change in COP for refrigerant R134a. At the point when magnetic power is connected middle of the exit of condenser and entry of expansion device of VCRsystem, indicates upgrade in performance inside the scope of **10.238 – 41.528%** for R134a.

3.2 Impact of Magnetic Field on Nano lubricant (CuO + PAG Oil) Equipped VCR System

The performance characteristics were shown in the below graphs form by using given formulae with application of magnetic field on liquid line of the nano lubricant (PAG oil + CuO) equipped VCR system with refrigerant R134a for different concentrations of volumetric additions (0.01%, 0.015%, 0.02%, 0.025%) of copper nano particles to the compressor lubricating oil(PAG oil) as shown in below Fig 17-29.

3.2.1 For 0.01% volumetric addition of CuO nano particles to PAG oil

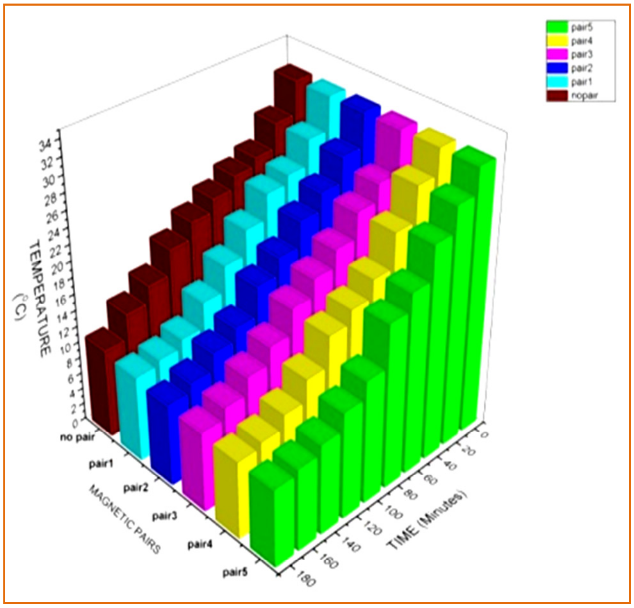

Fig 17. Temperature vs Time vs Number of magnetic sets

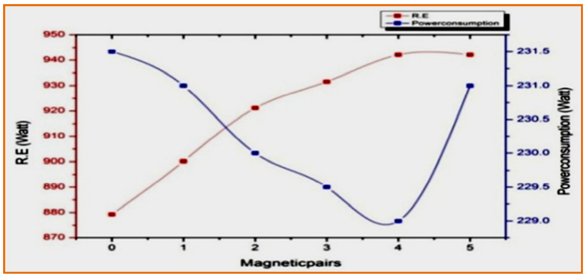

Fig18.Magnetic power on R.E. and Power consumption

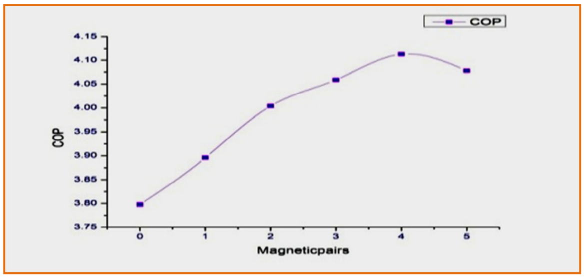

Fig.19. Impact of magnetic power on COP (R134a).

3.2.2 For 0.015% volumetric addition of CuO nano particles to PAG oil

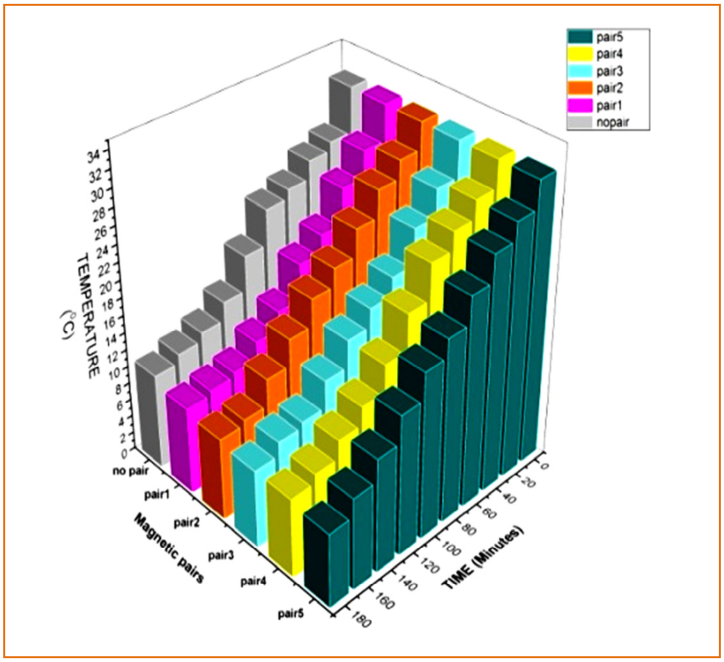

Fig 20. Temperature vs Time vs Number of magnetic sets

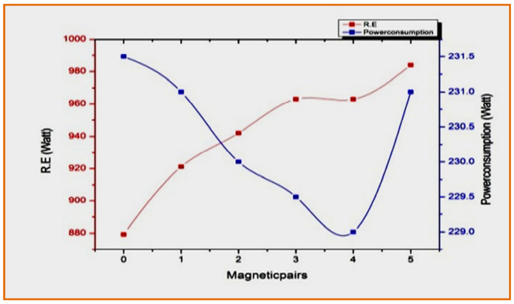

Fig21.Magnetic power on R.E. and Power consumption

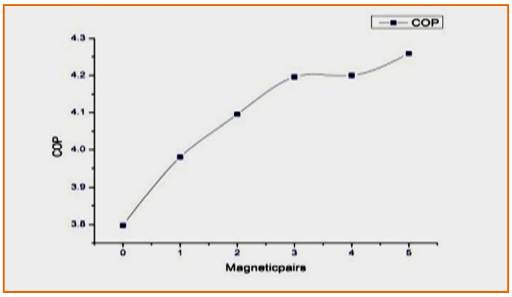

Fig.22. Impact of magnetic power on COP (R134a).

3.2.3 For 0.02% volumetric addition of CuO nano particles to PAG oil

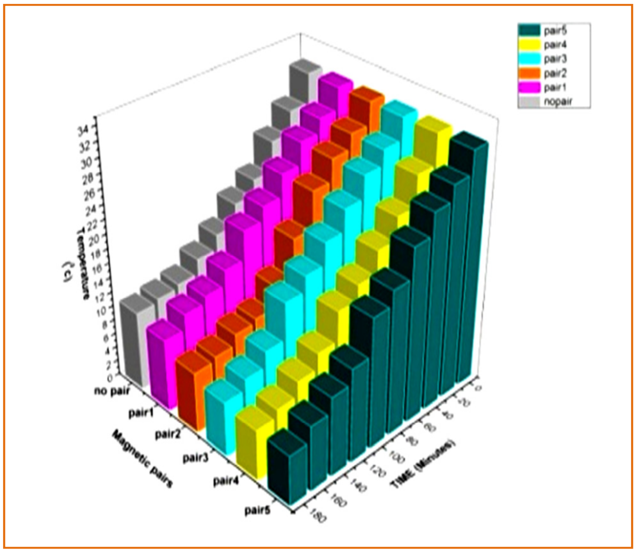

Fig 23. Temperature vs Time vs Number of magnetic sets

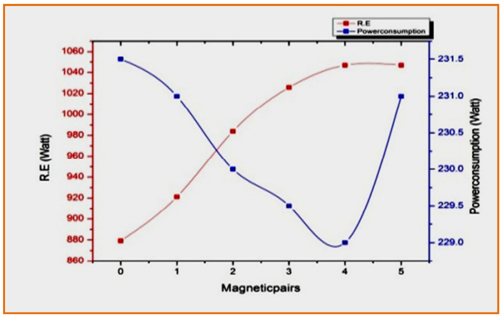

Fig24.Magnetic power on R.E. and Power consumption

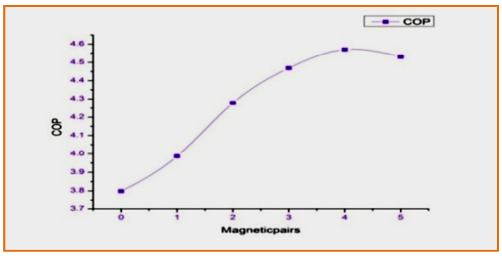

Fig.25. Impact of magnetic power on COP (R134a).

3.2.4 For 0.025% volumetric addition of CuO nano particles to PAG oil

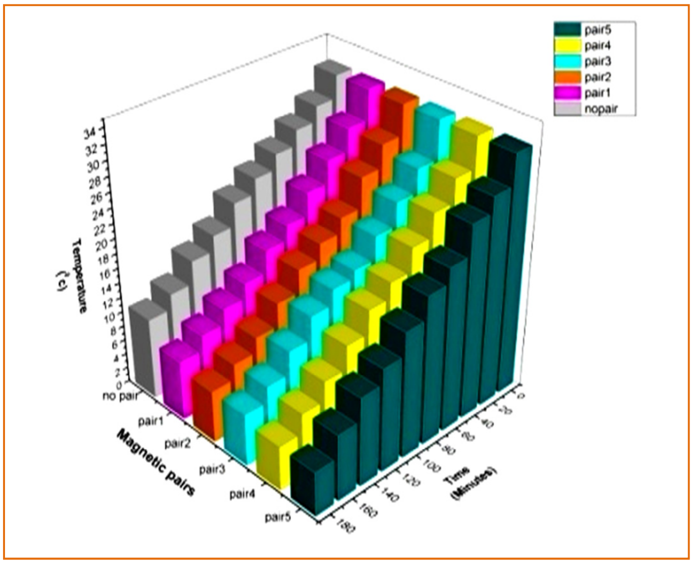

Fig 26. Temperature vs Time vs Number of magnetic sets

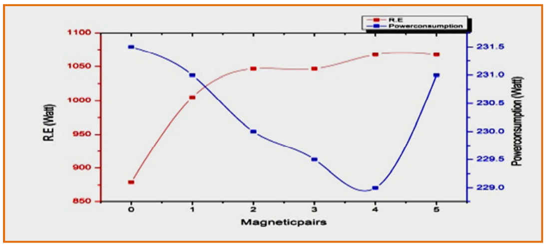

Fig27.Magnetic power on R.E. and Power consumption

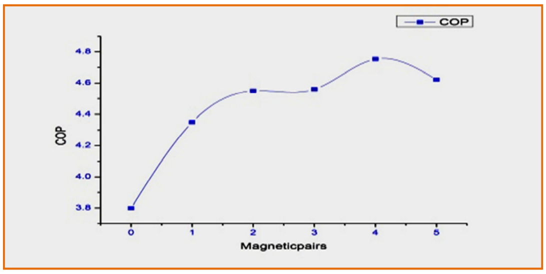

Fig.28. Impact of magnetic power on COP (R134a).

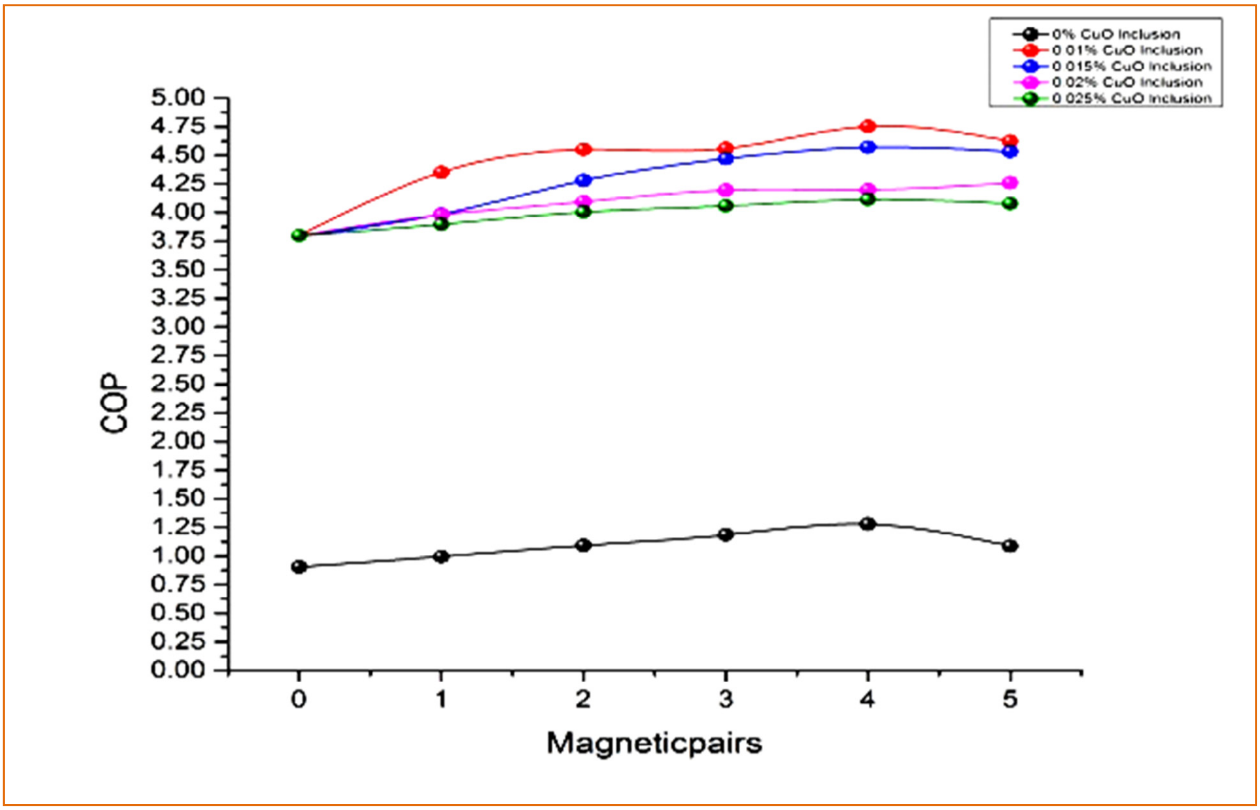

Fig29. Magnetic strength Vs COP Vs Inclusion of CuO particles

Conclusion

In this experimental study of vapour compression refrigeration system with the utilization of magnetic power on to the liquid refrigerant channel (from exit of condenser to inlet of capillary tube) and by using nano lubricant (CuO+PAG Oil) can enhance the performance parameters of VCR system. The magnetic power was raised by adding the digit of magnetic sets procured to the liquid channel. The COP measured at starting in the absence of magnetic power, and next magnetic field procured to liquid phase refrigerant channel has been raised by adding digits of sets of magnets were 1 to 5. Capacity of every magnetic set noted as 11,800 Gauss. Similarly The COP was measured without addition of copper-Oxide nano particles to lubricating oil, and then adding copper nano particles to the lubricating oil was increased by adding the percentage of volumetric addition of coppernano particles were 0.01%, 0.015%, 0.02%, 0.025% to the compressor lubricating oil (PAG oil). Finally this experimental analysis gives net effect of magnetic field effect and lubrication effect.

1. By the impact of magnetic field among all five magnetic sets, the coefficient of the performance of the system enhanced up to **41.528%** for R134a refrigerant at fourth magnetic set.

2. By the impact of lubrication effect the COP of the system enhanced up to **31.99%** for 0.025% volumetric addition of nano particles to PAG oil with R134a refrigerant.

3.Finally by combining these two magnetic effect and lubrication effect, the coefficient of performance of the system enhanced up to **25.14%** for R134a refrigerant at fourth magnetic set by the procurement of magnetic field on liquid channel with the 0.025% volumetric addition of copper nano particles to the compressor lubricating oil (PAG oil), when compared to simple VCR.

References

1. PralhadTipole et.al Applying a magnetic field on liquid line of vapour compression system is a novel technique to increase a performance of the system. a novel technique to increase a performance of the system. Appl Energy 2012; 20:08–16.
2. Khovaylo VV et.al Magneto caloric effect in ‘‘reduced” dimensions: thin films, ribbons, and micro wires of Heusler alloys and related compounds. Physica Status Solidi 2014;251:2104–13.
3. Brück E et.al Advancements in magneto caloric refrigeration. J Phy D: Appl Phy2005;38(23):381
4. Trevizoli PV et.al The reversibility of the magnetocaloric effect and its consequences for the active magnetic regenerator refrigeration cycle. In: Proceedings of ENCIT. Uberlandia, MG, Brazil.
5. Christensen DV et.al Spatially resolved measurement of the magnetocaloric effect and the local magnetic field using thermography. J ApplPhy 2010;108:063913.
6. Pecharsky KV et.al Magnetocaloric effect and magnetic refrigeration. J MagnMagn Mater 1999;200:44–56.
7. Pecharsky KV et.al Magnetocaloric effect from indirect measurements: magnetization and heat capacity. J ApplPhy 1999;86:565–75.
8. Pecharsky KV et.al Thermodynamics of the magnetocaloric effect. Physical Rev B 2001;64:1444061–14440613.
9. Tagliafico LA et.al Performance aalysis of a room temperature rotary magnetic refrigerator for two different gadolinium compounds. Int J Refrig 2006;29:1307–17.
10. BansalPradeep et.al Status of not-in-kind refrigeration technologies for household space conditioning, water heating, and food refrigeration. Int J Sustain Built Environ 2012;1:85–101.
11. BiS.,ShiL.and Zhang L. 2007. Performance study of a domestic refrigerator using R134a/mineral oil/nano-TiO2 as working fluid. ICR07-B2-346.
12. Bi S., Shi L. and Zhang L., 2008. Application of nanoparticles in domestic refrigerators. Applied Thermal Engineering, Vol. 28, pp.1834-1843.
13. Jwo et.al, 2009. Effect of nano lubricant on the performance of Hydrocarbon refrigerant system. J. Vac. Sci. Techno. B, Vol.27, No. 3, pp. 1473-1477.
14. Shengshan Bi, Performance of a Domestic Refrigerator using TiO2-R600a nano-refrigerant as working fluid, Int J of Energy Conservation and Management, Vol. 52, 2011, 733-737.
15. Ching-Song Jwo, Efficiency analysis of home refrigerators by replacing hydrocarbon refrigerators, *Int J of Measurment*, Vol. 42, 2010, 697-701.
16. Henderson et al. (2010) Experimental analysis on the flow boiling heat transfer of R134a based nanofluids in a horizontal tube. IJHMT , Vol. 53, pp. 944-951
17. Bobbo S. et.al, 2010. Influence of nanoparticles dispersion in POE oils on lubricity and R134a solubility. International Journal of Refrigeration, Vol.33, pp. 1180-1186.
18. Bi S., Shi L. and Zhang L., 2008. Application of nanoparticles in domestic refrigerators. Applied Thermal Engineering, Vol. 28, pp.1834-1843.