ISSN : 2455-9679
Impact Factor : 3.805

ijrtsm

IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"AN EXERIMENTAL ANALYSIS INTO THERMAL PERFORMANCE OF A DOMESTIC REFRIGERATION SYSTEM BY USING R290 WITH Al203/ CuO"

Md Zarrar Salam [1], Dr. Suresh Kumar Badholiya [2], Prof. Rohit Kumar Choudhary [3]

[1] Research Scholar, Department of Mechanical Engineering, Bhopal Institute of Technology & Science. Bhopal, India

[2] Associate Professor, Department of Mechanical Engineering, Bhopal Institute of Technology & Science. Bhopal, India

[3] HOD & Associate Professor, Department of Mechanical Engineering, Bhopal Institute of Technology & Science. Bhopal, India

ABSTRACT

In today's world refrigeration systems play a vital role to fulfil the human needs and a continuous research is being carried out by many researchers in order to improve the performance of these systems. The performance of nanorefrigerant R290 & Al2O3+CuO Based domestic refrigeration Experimental setup was used varying load conditions. The Performance of the refrigeration system depends upon the various factors like; individual Component's performance, nature and properties of the refrigerant being used, Environmental conditions etc. Experimentation conducted to discuss the effect of nanoparticles on the performance of the refrigeration system.

Hydrocarbon R290 used as a replacement of R134a due to its almost similar thermodynamic and physical properties. In order to improve the performance using nanorefrigerant R290 & Al2O3+CuO conventional domestic refrigerant system . Nanoparticles are injected along with the R290 to increase the heat transfer capacity, to reduce the power consumption and thereby to increase the performance of the system. Al2O3+CuO nanoparticles used in the refrigeration system with its three different concentrations (0.20, 0.30 and 0.40 gm). It has been found that addition of Al2O3+CuO nanoparticles to the refrigerant result in an improvement in the thermo physical properties and heat transfer characteristics of the refrigeration system. There is more temperaturedrop across the condenser for the nanorefrigerant (14.4% – 20%) compared to R134a hydrocarbon refrigerant. Similarly, a gain in the evaporator temperature (2.33% –5.55%) has been observed. An improvement in COP (3.68% – 11.05%) is also observed during the investigations.. Similar improvements are also observed when refrigeration system is operated at 35–45 0C evaporator temperature load conditions. A reduction in the power consumption (13.6% - 30.04%) .The experimental studies indicate that the refrigeration system with nanorefrigerant works normal like any conventional refrigeration system. Thus, Al2O3+CuO nanoparticles can be used to improve the performance of a R290 refrigeration system .

Key Words: *Refrigerant , Compressor , Evaporator , R290 , Al2O3 , CuO , Nanorefrigerant , COP , Domestic refrigerant.*

I. INTRODUCTION

Global demand for commercial refrigeration equipment is projected to rise 5.2% per year through 2014 to $29.7 billion [1]. The global industry analysts announced that the global market of air conditioning is expected to reach 78.8 million units in volume sales by 2015 and this global demand is significant in areas of warm climate and high capita income.

ISSN : 2455-9679
Impact Factor : 3.805

Currently, most of the above demand is met by mechanical vapour compression systems driven by high grade electrical power input and utilises environmentally harmful refrigerants [2-4]. Refrigeration and air conditioning systems consume around 30% of total worldwide energy consumption [5]. Based on the new environmental regulations (Kyoto protocol, Vienna Convention and Montreal Protocol) CFCs and HCFCs phase-out have been agreed. Moreover, HFCs were one of the six addressed greenhouse gases by Kyoto protocol and countries may seek to limit its use to meet its legally binding greenhouse gas emissions targets.

.

II. NANOFLUIDS

Nanofluids (nanoparticle fluid postponements) is the term coined by (Choi et al.,1995) 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 fluid suspension. When a small amount of nanoparticles,

Table No.1 Micro Partical Vs Nano partical

Property	Micro-Particle	Nano-Partical
Stability	Settle	Stable
Surface/volume ratio	1	1000 times larger
Thermal conductivity	Low	High
Clog to microchannel	Yes	No
Erosion	Yes	No
Pumping power	Large	Small
Nanoscale phenomena	No	Yes

1. Nanoparticle materials :-

- Oxide ceramics –Al2O3,
- CuO
- Metal carbides –SiC
- Nitrides –AlN, SiN
- Metals –Al, Cu
- Nonmetals –Graphite, carbon nanotubes

2. Base fluids include:

- Water
- Ethylene- or tri-ethylene-glycols
- Refrigerant other coolants
- Oil and other lubricants
- Bio-fluids
-

R290 (CARE ® 40) R290, also known as CARE® 40, is refrigerant grade propane, a natural, or "not in kind", refrigerant suitable for use in a range of refrigeration and air conditioning applications. The use of R290 is increasing due to its low environmental impact and excellent thermodynamic performance.

R290 Properties

Selection of a refrigerant is a complex process involving detailed analysis of environmental, thermo physical and safety properties.

ISSN : 2455-9679
Impact Factor : 3.805

Table No. 2 : Properties of Refrigerants

Refrigerant	R 600a	R 134a	R 12
Name	Isobutane	TetraFluro – Ethane	Chlorofluorocarbon
Formula	C_4H_{10}	CH_3CH_2F	CCL_2F_2
Critical Temp °C	135	101	112
Molecular W in kg/k mole	58.1	102	120.9
Normal Boil point	-11.6	-26.5	-29.8
Pressure at -25 °C in bar (absolute)	0.58	1.07	1.24
Liquid density kg/lit	0.60	1.37	1.47
Vapour density kg/m^3	1.3	4.4	6.0
Volumetric capacity k J/m^3	373	658	727

III. PREPARATION AND DESCRIPTION

Preparation of nanofluids is the first step in experimental studies with nanofluids. Nanofluids are not simply liquid-solid mixtures only. Some important special requirements are essential e.g. even and fixed suspension, durable suspension, negligible agglomeration of particles, no any chemical change of the fluid, etc. Nanofluids are produced by dispersing nanometer scale solid particles into base liquids such as water, ethylene glycol, oils, refrigerant, etc. [6] As per the recommendation from Montreal Protocol to out of CFCs and HCFCs and Kyoto Protocol even new developed HFCs refrigerants. Due to their high global warming potentials. Most commonly used condensing and evaporating temperatures 550C and -250C respectively. [7] Global warming which affect the environment by the use of refrigerant and aim is to reduce the effect of global warming as well as optimize the performance of domestic refrigerators by using the latest refrigerants. Performance of refrigerator is increased by using different refrigerants. Which has zero ozone depletion potential and almost good thermodynamic properties, The higher GWP due to emissions from domestic refrigerators leads to identifying a long term alternative to meet the requirements of system performance, Therefore it is going to be banned very soon for environmental safety. [8] Hydrocarbon mixture is an alternative refrigerant for Hydro Fluorocarbon and Chlorofluorocarbon compounds due to their lower GWP and zero Ozone Depletion Potential. The impact on the environment is also reduced due to usage of hydrocarbon mixture in different mass ratio. [9]The manufacturers of refrigerants and refrigeration, air conditioning equipment, governmental agencies, and environmental groups continue working together toward the goal of reduced environmental impact via reduced emissions and improved energy efficiency. Examples of progress are presented for several sectors of refrigeration and air conditioning, followed by projections for further significant reductions. Looking forward refrigeration has adverse effect on environment. [10] Performance of refrigerator is increased by using different refrigerants. Domestic refrigeration and other vapor compression system having zero ozone depletion potential and almost good thermodynamic properties, but it has a high Global Warming Potential . Some new refrigerants is been found by researchers which are environmental friendly refrigerants having low GWP and low ODP. Hydrocarbon refrigerants particularly propane, butane and isobutene are proposed as an environment friendly refrigerants. [11] Indian traditional cooler and much more quantity of water has been used every year. Also to make this efficient woods product known as “wood wool / khas” have been used which became a major reason of deforestation. The refrigerant R134a absorbs the heat from air and makes the cool air by getting vaporised in evaporator and then the cooled air is sent outward from the opening in the research model with help of fan running on motor and gives the cooling effect. This use of VCRS system with eco -friendly refrigerant reduces the consumption of the water, electricity consumption and tree which is used for making wood wool in conventional cooler. This ultimately reduces the global warming.Air Conditioners. In 21st century the world facing problem of electricity and water to overcome this problem worldwide many researches going on. Further cooler uses water so as cooling air, for this application [12] This consumes large amount of water and

ISSN : 2455-9679
Impact Factor : 3.805

electricity so for reducing the use of these main sources research involves the use of VCRS system which include eco-friendly refrigerant R134a in cooler system. This system is mounted in the research model in a proper manner so that it is compact in size. The refrigerant R134a absorbs the heat from air and makes the air cooled, itself getting vaporized in evaporator and then the cooled air is sent outward from the opening. In the research model with help of fan running on motor and gives the cooling effect. This use of VCRS system with eco -friendly refrigerant reduces the consumption of the water, electricity consumption and tree which is used for making wood wool in conventional cooler.

[13] There are many kind refrigerants, which are used to transfer heat from low temperature reservoir to high temperature reservoir by using vapour compression refrigeration system. There are various obstacles faced in working of different refrigerants due to their environmental impact, toxicity, flammability and high pressure which makes them more hazardous than other working fluids according to safety and environmental issues. Keeping in mind the present scenario of climatic change and demand comfort of modern human age the researcher and inventors must have to be taking steps on all possible ways to protect/prevent or save the earth and its environment in terms of global warming effect. Refrigerants are one of the

[14] Refrigeration systems has find wide applications, and so therefore, it becomes necessary to focus on the performance of these systems. Performance of refrigeration systems depend upon heat rejected at high temperatures, which is accomplished by condensers. In condensers, latent heat of the refrigerant is removed. In present research work, performance of condenser for a domestic refrigerator is targeted by using different condenser materials, and also byusing different refrigerants, and heat flux and thermal gradient values are proposed for different combinations using ANSYS. [15] The environmental problems of ozone depletion and global warming are of major concern in the world. Refrigeration and air-conditioning have been identified as major causes for ozone layer depletion and global warming. Thus, there is a great need to search for alternative refrigerants which can be used to replace the conventional CFC and HFC refrigerants used in the refrigeration and air-conditioning systems .This paper presents a detailed study on identifying various alternative refrigerants based on exergetic analysis of vapour compression refrigeration system. The alternative ecofriendly refrigerants for different systems like domestic refrigeration, air-conditioning and automobile air-conditioning have been proposed in this study.

IV. Refrigerant Selection & Mathematical Formulation

Copper oxide nanoparticles (CuO) :

The distribution of CuO nanoparticles at nanoscale can be observed under a Scanning electron microscope. Preparation of nanofluids is an important stage. Nanofluids are prepared in a systematic and careful manner. Stable Nanofluid with uniform particle dispersion is required and the same is used for measuring the thermo physical properties of nanofluids.

Fig. No. 1., Copper oxide nanoparticles

Aluminum oxide nanoparticles

Nanocrystalline ceramic materials are those with size smaller than 100 nm which have great importance in the field of nanotechnology. Nano-sized materials have properties superior to bulk materials, including improved surface area-to-volume ratio and high strength and toughness. Aluminum oxide has a chemical formula Al_2O_3. It is amphoteric in nature, and is used in various chemical, industrial and commercial applications.

ISSN : 2455-9679
Impact Factor : 3.805

Fig. No. 2 Aluminum oxide nanoparticles

- Thermal conductivity of refrigerant based nanofluid is calculated by Hamilton – Crosser equation.

$$K_{rn} = K_r\left(\frac{K_n+2K_r-2\varphi(K_r-K_n)}{K_n+2K_r+\varphi(K_r-K_n)}\right)$$

Where:-
Krn– Thermal conductivity of nano refrigerant
Kr - Thermal conductivity of pure refrigerant R290
Kn - Thermal conductivity of nano particle
φ - Particle volume fraction of nano particle

- The dynamic viscosity of nano refrigerant is calculated by Brinkman equation.
 Dynamic viscosity of nano refrigerant

$$\mu_{rn} = \mu_r \frac{1}{(1-\varphi)^{2.5}}$$

Where,
μr– Viscosity of pure refrigerant
φ – Particle volume fraction

- The volume fraction of nano particles used in the above given equations can be obtained using the below relation

$$\phi = \frac{\omega\rho_r}{\omega\rho_r+(1-\omega)\rho_n}$$

Where,
ω - Mass fraction of nano particle
ρr - Density of pure refrigerant
ρn - Density of nano particle

- The volume fraction of nano particles used in the above given equations can be obtained using the below relation

$$\phi = \frac{\omega\rho_r}{\omega\rho_r+(1-\omega)\rho_n}$$

Where,
ω - Mass fraction of nano particle
ρr - Density of pure refrigerant
ρn - Density of nano particle

ISSN : 2455-9679
Impact Factor : 3.805

- The relation for mass fraction of nano particle is given - below

$$\omega = \frac{M_n}{M_n + M_r}$$

Where,
Mn – Mass of nano particles
Mn – Mass of pure refrigerant

- Convective heat transfer coefficient of nano refrigerant is given by the following relation

$$h_{c-rn} = 0.023 \left[\frac{G^4 \times C_{p-rn}{}^2 \times k_{rn}{}^3}{D_i \times \mu_{rn}{}^2}\right]^{\frac{1}{5}}$$

- Mass of water in the evaporator vessel   m = Density of water × Volume of water

$$m = \rho \times \frac{\pi}{4} \times D^2 \times h$$

Where,
ρ - Density of water
D – Diameter of vessel
h – Height of water in vessel

- Actual COP of a vapour compression refrigeration system is given by

$$COP_{Act} = \frac{hA\Delta T}{V \times I}$$

- Coefficient of performance of the refrigeration (COP)actual

COP actual = Refrigeration effect

V. Experimental Setup

This figure shows detailed description of the components and their working for experimentation in this system. The charging and evacuation of nanaoparticles done above fig. is the actual vapor compression refrigeration system rig (domestic) where experimentation of R290 refrigerant along with nanoparticles is performed.

Fig. 3., Actual vapor compression refrigeration system

Experimental methodology

The temperature of the refrigerant inlet & outlet of each component of the refrigerator is measured with copper constantan thermocouples. The thermocouple sensors are fitted at inlet and outlet of the compressor, condenser. It is

ISSN : 2455-9679
Impact Factor : 3.805

important to take temperature measurement is necessary at entry and exit of each component of the system in order to investigate the performance.

VI. Results and Discussion

Evaporator & Condenser Results:-

In the present experimental study the hermetically sealed compressor is made to

i) Nanopartical concentration of CuO & Al_2O_3

ii) Evaporator temperature is 30°C to 35°C and variation is about 40°C - 30°C

It has been found that pressure drop enhancements in condenser are minimum when refrigerant R290 is used. It has been increased nonlinearly with at 2% concentration of CuO & Al_2O_3 and the difference is only 1.42 kpa compared R290.

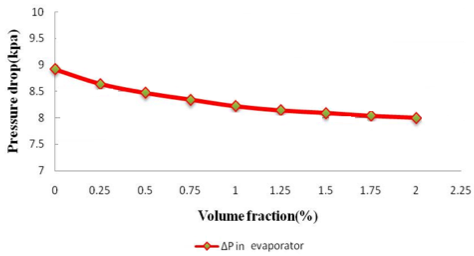

Fig. No. 4. Pressure drop in evaporator

The pressure drop in evaporator at constant cooling load (35-36°C) and at a different volumetric concentration of CuO & Al_2O_3 in refrigerant R290, the pressure drop is the maximum when refrigeration R290 then it has been decreased with concentration and becomes minimum at volume fraction of 2% .

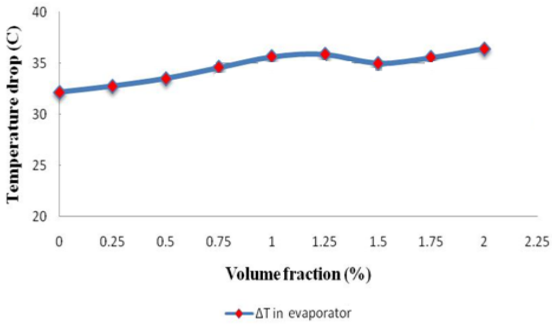

Fig. No 5. Temperature drop Vs Volume Fracion in evaporator

Temperature drop in condenser at constan cooling load (35-40°C) and at constant mass flow rate with different volumetric concentration of CuO and Al_2O_3 in refrigerant R290, temperature drop is minimum when refrigerant R290 is used which is equal 33 °C then it has been increased with concentration and becomes maximum at volume fraction

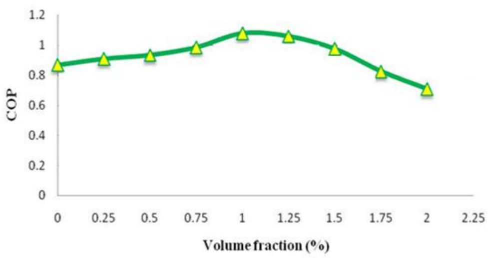

Fig. No 6. , COP VS Fraction of Evaporator

ISSN : 2455-9679
Impact Factor : 3.805

COP of system at constant cooling load (35-40°C) and at mass flow rate of 10 LPH. COP of system increases with increases in concentration and becomes maximum at the concentration equal 1%, where as for pure refrigerant R290 it is equal 0.89.

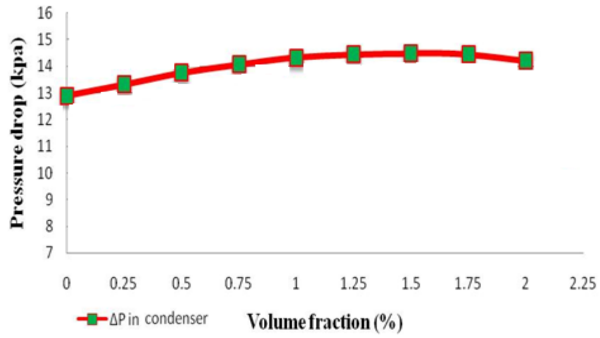

Fig. 7. Pressure drop in condenser

pressure drop in condenser at constant cooling load and at mass flow rate 15 LPH with different volumetric concentration of CuO in refrigerant R290. it has been found that pressure drop enhancements across the condenser is minimum when pure refrigeration R290 is used. It has been increased nonlinearly with concentration and becomes maximum at volume.

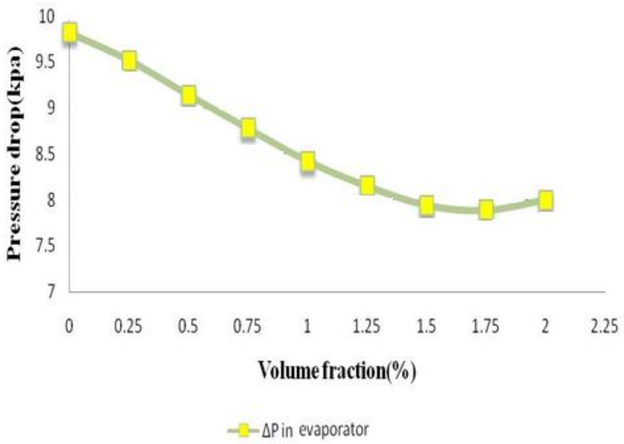

Fig.8: Pressure drop in evaporator at constant cooling load

Temperature drops in condenser at constant cooling load (35-40°C) and at different volumetric concentration of CuO & Al_2O_3 in refrigerant R290. The temperature drop is minimum when refrigeration R290 is used which is equal 35.5 °C. Then it has been found increasing with concentration and becomes maximum at volume fraction 2% which is equal 41.4°C.

Freezing capacity of the system

Evaporator temperature is varied from 40°C to 25 °C and for the different concentrations of CuO+$A_{l2}O_3$ in refrigerant R290 .

The performance at mass flow rate of 10 LPH

ISSN : 2455-9679
Impact Factor : 3.805

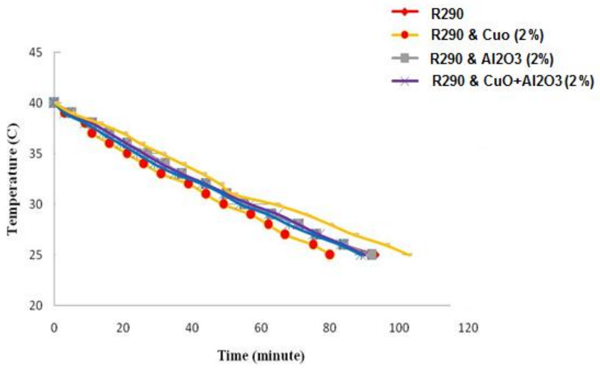

Fig.9: Evaporator temperature & and 10 LPH

Effect of CuO &Al_2O_3 nanoparticle on the freezing capacity

Evaporator freezing capacity

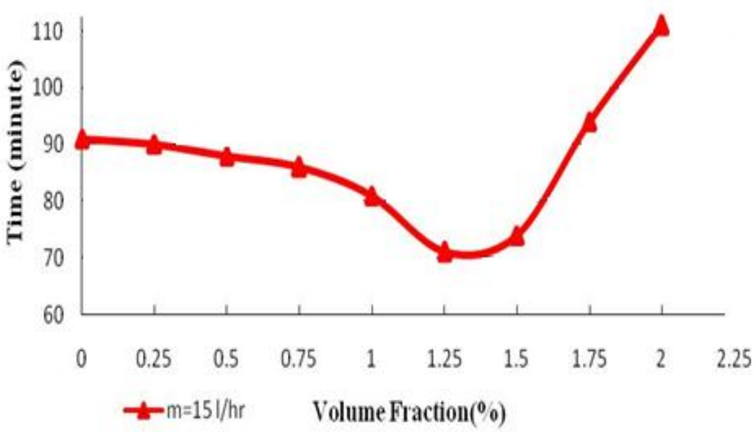

Figure 11: Evaporator freezing capacity at mass flow rate 15 LPH

Evaporator time taken for temperature drop at mass flow rate 15 LPH. The time taken in minutes the effect concentration refrigerant R290 & CuO+Al_2O_3 on reduction time of pure refrigeration at mass flow rate 15 LPH to reduce

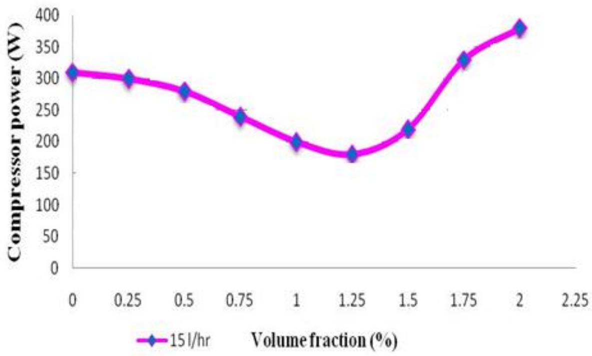

Figure 12: Compressor power consumption for temperature drop

Compressor power consumption at varying cooling load and at mass flow rate of 15 LPH. It has been found decreasing with volume fraction of CuO+Al_2O_3 in R290 refrigerant, and becomes minimum at volumetric concentration 1.25%.

ISSN : 2455-9679
Impact Factor : 3.805

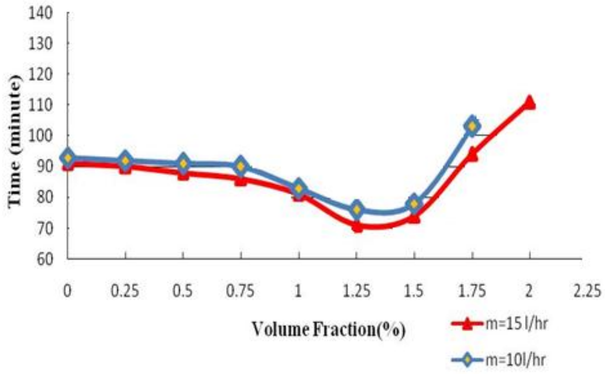

Figure 13 Evaporator freezing capacity for temperature

The percentage reduction in freezing capacity and power consumption are 18.27, 17.4% respectively for 10 LPH. While these are equal 22, 21% respectively for 15 LPH if the is concentration copper oxide mixed nanoparticles

VII. CONCLUSION

ii) R290 refrigerant effectively working in domestic refrigeration system with nanopartical CuO + Al2O3 .
iii) COP and Cooling Capacity with nanopartical concentration increasing upto 2.8 % then decreasing.
iv) Condenser pressure drop is 14.5 % at mass flow rate of 10 LPH and 15.4 % at 15 LPH at 2.5% Concentration of CuO+Al_2O_3 in refrigerant R290.
v) Evaporator temperature drop is 14.4% for 10 LPH and 15.7% for 15 LPH at 1.5% concentration of CuO in refrigerant R290 compared to Al_2O_3 in R290 refrigerant under constant heat range of 35-40 ^oC
vi) Freezing capacity with nanopartical increases in domestic refrigeration system , freezing capacity is maximum increases by 19.80% at 2.35% concentration of CuO+Al_2O_3.
vii) Power consumption of the compressor decreases by 17% for 10 LPH and 12.5% for 15 LPH at 2.50% concentration of CuO+Al_2O_3 & R290.
viii) COP is increases by 20.5% for 15 LPH and 18% for 10 LPH at 2.25 concentration of CuO+Al_2O_3

REFERENCES

[1] Industry market research for business, strategists, decision makers, 2010, The Freedonia Group.

[2] Hassan, H.Z., A.A. Mohamad, and R. Bennacer, Simulation of an adsorption solar cooling system. Energy, 2011. 36(1): p. 530-537.

[3] Verde, M., et al., Modelling of an adsorption system driven by engine waste heat for truck cabin A/C. Performance estimation for a standard driving cycle. Applied Thermal Engineering, 2010. 30(13): p. 1511-1522.

[4] Qureshi, B.A. and S.M. Zubair, erformance degradation of a vapor compression refrigeration system under fouled conditions. International Journal of Refrigeration, 2011. 34(4):

[5] Navarro-EsbrA-, J., et al., A low data requirement model of a variable-speed vapour compression refrigeration system based on neural networks. International Journal of Refrigeration, 2007. 30(8): p. 1452-1459.

[6] Chintankumar B. Lad, Dr. Ragesh G. Kapadia,"Theoretical performance evaluation of R134a and its low GWP Hydrocarbon alternatives in Domestic Refrigerator" 2014 IJEDR , Volume 2, Issue 2 , ISSN: 2321- 9939

[7] D.V.Raghunatha Reddy, P.Bhramara, K.Govindarajulu., "Hydrocarbon Refrigerant mixtures as an alternative to R134a in Domestic Refrigeration system: The state-of the-art review"., International Journal of Scientific & Engineering Research, Volume 7, Issue 6, June-2016 87 ISSN 2229-5518 IJSER © 2016

[8] Sopan R. Arote "Comparative Performance Analysis of Vapour Compression Refrigeration System With R-134a and Blends of Hydrocarbon R290/600a" Global Journal Of Engineering Science And Researches 2(12): December 2015 ISSN 2348 – 8034

[9] A. S. Dhunde1, K. N. Wagh2, Dr. P. V. Washimkar3 “An Effective Combined Cooling with Power Reduction for Refrigeration cum Air Conditioner, Air Cooler and Water Cooler: A Review” International Journal of Engineering Research and General Science Volume 4, Issue 2, March-April, 2016

[10] D.V.Raghunatha Reddy, P.Bhramara, K.Govindarajulu “Hydrocarbon Refrigerant mixtures as an alternative to R134a in Domestic Refrigeration system: The state-of- the-art review”., International Journal of Scientific & Engineering Research, Volume 7, Issue 6, June-2016 87

[11] Aman Gadpandey, Harish Chimurkar., “Comparative Study on Cooler cum Air Conditioner Based On VCRS by using Refrigerant R134a”., International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 03Issue: 04 | Apr-2016

[12] Chaman R. Sarva Aniket S. Dokarimare, “Performance and Analytical Study of Cooler Cum Air Conditioner based on Vapour Compression Refrigeration System “.,IJSTE - International Journal of Science Technology & Engineering | Volume 2 | Issue 10 | April 2016

[13] Lalit Kumar Mishra,Sunil Kumar Chaturvedi .,“Study and Comparative Analysis of Selection of Eco-Friendly Refrigerants and Possible Refrigerants by Mixing Them: A Review”., International Journal for Scientific Research & Development| Vol. 7, Issue 08, 2019

[14] Akash Rathore, Dhananjay Yadav,Anil Verma “A Review paper on Optima selection of Refrigerant & Condenser Material”., Vol-4 Issue-6 2018

[15] Madhu Sruthi Emani, Ranendra Roy, Bijan Kumar Mandal., “Performance Evaluation of Alternative Refrigerants”, IJARSE, Vol. No. 5, issue No. 08, August 2016.