IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

INVESTIGATION OF EFFECT ON VAPOUR COMPRESSION REFRIGERATION SYSTEM BY USING NANOADDITIVES BLENDS REFRIGERANTS"

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ABSTRACT

In India, nearly 90% of the refrigeration systems viz., domestic refrigerators, deep freezer units, food storage devices use R134a as the common working fluid. The Global Warming Potential (GWP) of R134a is high of the order of 1300. Usage of R134a refrigerant causes continuous depletion of ozone layer and global warming effect. The Chloro fluoro carbon (CFC) substances not only damages the ozone layer of atmosphere, but also bring green house effect to earth and badly affect telluric environment and human health. The Montreal and Kyoto Protocol suggested minimizing the usage of green house gases along with hydroflurocarbons (HFCs) to use as refrigerants in refrigeration system. R134a is not miscible with the lubricant oil of the compressor unit. Some of the European countries have banned the usage of R134a as refrigerant in refrigerators. The focus of this investigation is to try out and establish a suitable alternative to the conventional R134a. The proposed eco-friendly refrigerant in this work is R152a which has an advantage of zero Ozone Depleting Potential (ODP) and a significant reduced GWP value of 140 only.

In this investigation three types of studies were carried out. The most commonly used commercial refrigerant R134a and the proven alternative R152a were blended and the new hybrid refrigerant was prepared and the corresponding performance of the system was investigated. The experimental results and analysis clearly indicate that there is a possibility of retrofitting the blend of R152a and R134a without any system modification. nanoadditive such as Al2O3 were blended with R152a refrigerant at 0.05% v, 0.1 % v and 0.15%v concentration were investigated. The compressor suction pressure, discharge pressure, vapour pressure, compressor input power, volumetric cooling capacity and coefficient of performance (COP) were computed and analysed. An experimental test rig is designed and fabricated indigenously in the lab to carry out these investigations. Nano refrigerant was found to work safely and with system improvement.

Keywords: compressor suction pressure, discharge pressure, vapour pressure, compressor input power, volumetric cooling capacity, coefficient of performance (COP)

INTRODUCTION

Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature. One of the most important applications of refrigeration has been the preservation of perishable food products by storing them at low temperatures. Refrigeration systems are also used extensively for providing thermal comfort to human beings by means of air conditioning.

INDIAN SCENARIO

The refrigeration and air conditioning sector in India has long history from the early years of last century. India is presently producing R134a, R22, R717 and hydro carbon based refrigeration and air conditioning units in large quantities. The use of CFC refrigerants in new systems was stopped since the year 2002. The factors that dictate the adoption of a particular refrigerant apart from its suitability for the specific application are its availability and cost. The halogenated refrigerants such as R12, R22, R134a and natural refrigerant like R717 are readily available at low prices. The Hydrocarbon (HC) and Hydro Fluro Carbon (HFC) mixtures (such as R404a, R407, and R410A) are not currently manufactured indigenously and hence have to be imported at a higher cost. This is likely to affect the growth in refrigeration and air conditioning sector in India and also the total conversion to environmental friendly alternatives in the near future.

DOMESTIC REFRIGERATION

The Indian household refrigerator industry is more than 50 years old. Eight major domestic refrigerator manufactures were catering this market, of which four are manufacturing hermetic compressors. Domestic refrigerators manufactured in India range in capacities from 65 to 580 *l*. Most of the currently produced Indian refrigerators uses R134a as refrigerant. The choice of alternative to R134a is narrowed down to R152a and hydrocarbon refrigerants. Refrigerators manufactured before 2000 were still running on R12. To full fill the objectives of the Montreal Protocol, R12 has to be replaced by either hydrocarbon mixtures or R134a/hydrocarbon mixtures without modification in the existing system.

COMMERCIAL AND INDUSTRIAL REFRIGERATION

Most of commercial freezers like chest freezers, bottle coolers, visi coolers, display cabinets, water coolers and walk in coolers are using R134a and R12 as the refrigerant. Annual production of commercial refrigerated cabins (such as chest freezers, display cabinets, bottle coolers and visi coolers), water coolers and walk in coolers in India were estimated to be about 40,000, 27000,and 500 units respectively. About 80% of these units are manufactured by small and medium enterprises (Ministry of Environment and Forest, 2005). The choice of suitable alternative to R134a in commercial applications is R152a and hydrocarbon mixtures. The estimated population of milk chilling and cold storage in India was about 14,000. Most of the cold storage and milk chilling plants are working on ammonia and some on R502. Ammonia will dominate the industrial refrigeration sector due to its favorable environment properties (zero ODP and GWP). The alternative choice for R502 is 507 and hydrocarbon mixtures for low temperature industrial applications.

AIR CONDITIONERS, HEAT PUMPS AND CHILLERS

In India it is estimated that one million room air conditioners is being manufactured with R22 as refrigerant every year, which compromises of window, split and packaged air conditioning units (Devotta *et al.*, 2005). The capacity of the windows air conditioners ranges from 0.5 TR to 2 TR. The choice of alternative to R22 in air conditioning applications is R407 and R410 which are available in the Indian market. Annually about 4000 central air conditioning chillers were installed, most of these chillers was based on R22 and R11. Very limited chillers were presently installed with R123 due to the lack of availability on this refrigerant. The long – term alternative to R11 and R22 for the chiller applications is R123.

LITERATURE SURVEY

Anarghya Ananda Murthy, Alison Subiantoro, Stuart Norris, Mitsuhiro Fukutab (2019)

[1] "A Review on Expanders and their Performance in Vapour Compression Refrigeration Systems" This paper reviews progress reported in the open literature of the use of expanders to recover expansion power to improve the energy efficiency of vapour compression refrigeration systems. Pioneering works in the field are first discussed, and then a variety of expander mechanisms, including reciprocating piston, rolling piston, rotary vane, scroll, screw and turbine are reviewed together with their reported performance. Most of the reported works have been for transcritical CO_2 refrigeration systems, which have reported improvements in the coefficient of performance (COP) of up to 30%. In a non-CO_2 system, the maximum reported increase in the COP was 10%.

Mohd Waheed Bhat, Gaurav Vyas, Ali Jarrar Jaffri, Raja Sekhar, Dondapati (2018) [2] "Investigation on the thermo physical properties of Al_2O_3, Cu and SiC based Nano-refrigerants'' The demand for energy is increasing dramatically, therefore energy conservation and reduction of emissions become compulsory for sustainable development.

However, the enormous development in technology has led to energy shortage and environmental global warming. Domestic refrigerators have been identified as huge emission contributor globally due to usage of high Ozone Depleting and Global Warming Potential Chlorine or Fluorine based refrigerants. Globally substantial amount from total energy budget is consumed to run domestic refrigerators working on R134a refrigerant. From literature survey, it has been found that use of Hydrocarbon refrigerants such as R290; R600a etc. have proved to be energy efficient and eco-friendly to the environment. Also, use of nano particles in refrigerants enhances thermo-physical properties such as thermal conductivity, density, viscosity and specific heat, therefore enhances the performance of refrigeration systems. In this study, the calculation of thermo physical properties of mixed nano refrigerants have been carried out using NIST database standard 4 (SUPERTRAPP®) versions 3.2.1

Bourhan M.TashtoushMoh'd A.Al-Nimr Mohammad A.Khasawneh (2017) [3] Investigation of the use of nano-refrigerants to enhance the performance of an ejector refrigeration system this work, the performance of an ejector refrigeration system using nano- refrigerants is investigated. A new hypothesis is proposed for flow boiling modeling, where nanoparticles are assumed to not migrate to the vapor phase as phase changes occur continuously; this causes a significant increase in nanoparticle mass fraction for high vapor quality values. This assumption shows a reasonable correlation with previously published data for R113/CuO mixtures, where an average deviation of 9.24% was obtained. A parametric analysis is performed to investigate the variation in heat transfer coefficient (HTC) with temperature, nanoparticle type, size, and mass fraction. Finally, the effect of nanoparticles on the coefficient of performance (COP) of the ejector refrigeration cycle as a response to the augmented flow boiling HTC is investigated by simulating a 5-kW cooling refrigeration cycle. Considering the advantage of using nano-refrigerants, a higher quality vapor was attained at the evaporator exit, resulting in an increase in the enthalpy difference in the evaporator in the ejector cooling cycle.

Jiaheng Chen, JianlinYu, GangYan (2016) [4] "Performance analysis of a modified autocascade refrigeration cycle with an additional evaporating subcooler" A modified autocascade refrigeration cycle with an additional evaporating subcooler is proposed, which can make good use of the temperature glide characteristic of zeotropic mixtures. The energy and exergy performance comparison between the modified cycle and a basic auto cascade refrigeration cycle using the zeotropic mixture of R23/R134a is carried out by the simulation method.

Aklilu Tesfamichael Baheta , Suhaimi Hassana , Allya Radzihan Reduana , (2015) [5] the objective of this paper is to investigate the performance of a transcritical CO_2 compression refrigeration cycle for different parameters and evaluate its COP. To achieve that, a refrigeration cycle was modeled using thermodynamic concepts. Then, the model was simulated for various parameters that were manipulated to investigate the cycle performance. Maintaining other operating parameters constant the highest COP was 3.24 at 10MPa gas cooler pressure. It was also observed that the cycle is suitable for air-condition application than refrigeration cycle, as COP increases when the evaporator temperature increases. Simulations were conducted using EXCEL developed program. The results can be used in the design of CO2 refrigeration cycle.

Q.W.Pan, R.Z.Wang, Z.S.LuL., W.Wang (2014) [6] "Experimental investigation of an adsorption refrigeration prototype with the working pair of composite adsorbent-ammonia" A 4- valve adsorption refrigeration prototype, which utilizes the composite adsorbent of calcium chloride/activated carbon and the refrigerant of ammonia, is developed and tested. System reliability is significantly improved because the integrated adsorbers are adopted, the closed circulation for heating and cooling processes is designed, and the system operation is optimized. Experiments showed that the prototype can start quickly, and the operation of the system is very stable. The influences of mass recovery time, cycle time, heating temperature, evaporating temperature and cooling water temperature on system performance have been studied.

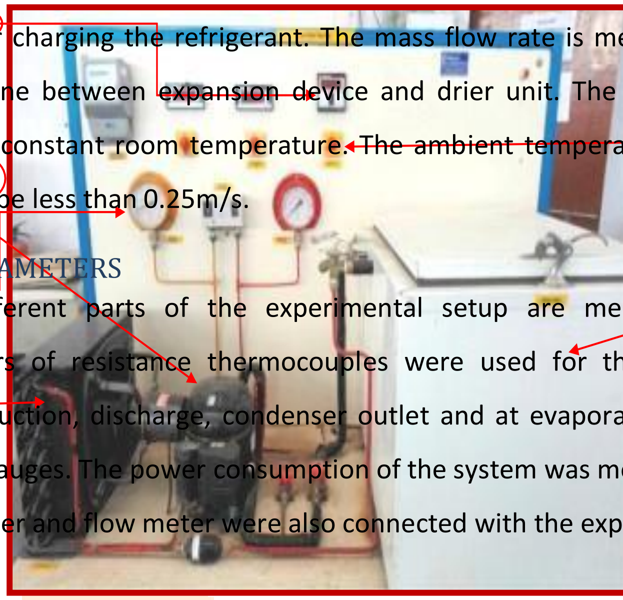
Michael S. Saterile *et al.* (2013) [7] studied the power agglomeration and thermal conductivity in copper-based nanofluids. After careful determination of morphology and purity, they systematically and rigorously compared all three of the surfactants for the production of viable copper-based nano fluids during synthesis of copper nano powders has important consequences on the dispersion of the powders in a base fluid. The oleicacid- prepared powders consisted of small particles of ~ 100nm that did not change with addition of dispersant.

Abhishek Tiwari *et al.* (2012) [8] conducted on experimental study of R404a and R134a, environment-friendly refrigerants with zero ozone depletion potential (ODP) and low global warming potential (GWP), to replace R134a in domestic refrigerator. A refrigerator designed and developed to work with R134a was tested, and its performance using R404a was evaluated and compared with its performance when R134a was used. The results obtained showed that the design temperature and pulldown time set by International Standard Organization (ISO) for small refrigerator were achieved earlier using refrigerant R-401a than using R-134a. The system consumed less energy when R134a was used. The performance of R404a in the domestic refrigerator was constantly better than those of R134a throughout all the operating conditions, which shows that R404a can be used as replacement for R134a in domestic refrigerator.

EXPERIMENTAL SET UP

FABRICATION OF EXPERIMENTAL SETUP

The experimental consists of a compressor, fan cooled condenser, expansion device and an evaporator section as shown in Fig. 5.1 and 5.2. Capillary tube is used as an expansion device. The evaporator is of serpentine coil type which is loaded with water. Service ports are provided at the inlet of expansion device and compressor for charging the refrigerant. The mass flow rate is measured with the help of flow meter fitted in the line between expansion device and drier unit. The experimental setup was placed on a platform in a constant room temperature. The ambient temperature was ±1.5°C. The air flow velocity was found to be less than 0.25m/s.



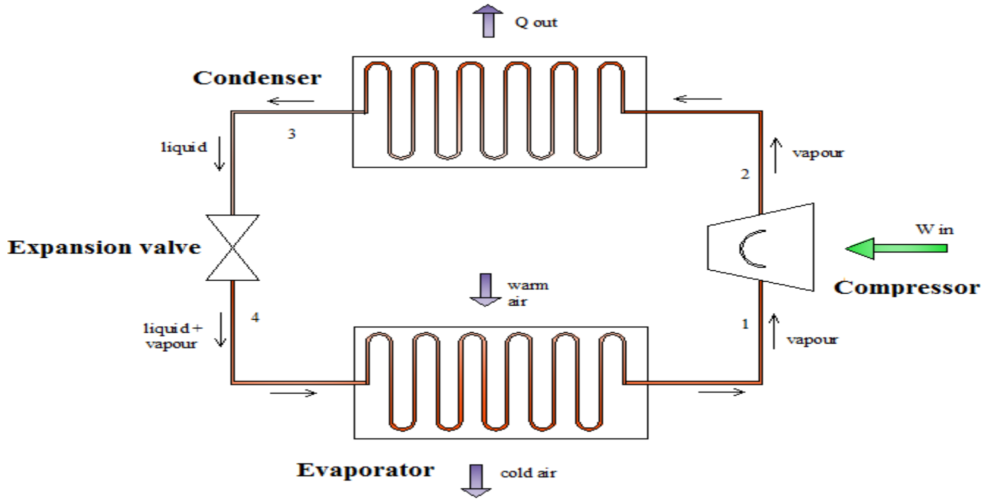
. MEASUREMENT OF PARAMETERS

The temperatures at different parts of the experimental setup are measured using resistance thermocouples. 8 numbers of resistance thermocouples were used for the experimentation. The pressures at compressor suction, discharge, condenser outlet and at evaporator outlet are measured with the help of pressure gauges. The power consumption of the system was measures by a digital Watt-hr meter. A digital wattmeter and flow meter were also connected with the experimental setup.

Table 3.1 summarized the characteristics of the instrumentation.

Variable	Device	Range
Temperature	Pt100 PID controller	50 to 199°C
Pressure	Pressure Gauge	0-10 bar
Power	Digital Watt/Watt-h meter	5-20A

Fig.4.1. Photograph of the experimental setup



CALCULATIONS USED BY SOFTWARE

2.1 Calculations:

From the pressure measuring device only gauge pressure is measured convert that into absolute pressure.

Absolute pressure = gauge pressure + atmospheric pressure.

$$\mathbf{P_{abs} = P_{gauge} + P_{atm}}$$

1) Refrigeration effect

The amount of heat taken by the refrigerant in the evaporator is called refrigerant effect.

Refrigerant effect = m_w cp (dT).. (1.1)

2) Actual C.O.P

It is the ratio of refrigerant effect to the power consumed by the compressor.

$$\text{C.O.P actual} = \frac{h_1 - h_4}{h_2 - h_1} \quad \text{(1.2)}$$

3) Capacity of VCR system (TR) = $\frac{\text{Refrigerant Effect/min}}{210}$ ....(1.3)

4) Mass flow rate (ṁ) kg/s = $\frac{\text{Refrigerant Effect/s}}{h_1 - h_4}$ ....(1.4)

5) Power consumption by the compressor (P) = volts *amps (V*I) (j/s)… (1.5).

6) Energy input o the compressor = Power *Time = p*t (kj)......................(1.6)

RESULTS AND DISCUSSION

This chapter deals with the experimental procedure adopted, relevant parameters during the course of the present investigation. In developing country like India, most of the vapour compression based refrigeration, air conditioning and heat pump systems continue to run on halogenated refrigerants due to its excellent thermodynamic and thermo-physical properties apart from the low cost. However, the halogenated refrigerants have adverse environmental impacts such as ozone depletion potential (ODP) and global warming potential (GWP). Hence it is necessary to look for alternatives refrigerants to full fill the objectives of the international protocols (Montreal and Kyoto) and to satisfy the growing worldwide demand.

BLENDING OF R152a AND R134a

The system was charged with the help of charging system and evacuated with the help of vacuum pump to remove the moisture. After charging each refrigerant, data were collected and different evaporator temperatures using equation 3.1 to 3.7. The following parameters were obtained using the above equations. a) vapour pressure b) compressor input power c) co-efficient of performance d) volumetric cooling capacity and e) pressure ratio. Initially a performance test is made with the system loaded with pure R134a. The data is treated as the basis for the comparison with the refrigerant mixtures. The mixture composed of R152a and R134a was considered as an alternative to R134a. This mixture is further referred in this work as HCM. Blend mixtures HCM of R152a and R134a by mass in the proportion of HCM 30:70 (30% weight of R152a and 70% weight of R134a), HCM 50:50 (50% weight of R152a and 50% weight of R134a) and HCM 70:30 (70% weight of R152a and 30% weight of R134a) were charged through the charging port in the compressor and the performance tests were conducted. The results of the performance comparison of the investigated mixture of the refrigerants (R152a and R134a) in the vapour compression refrigeration system are given below.

VARIATION OF DISCHARGE TEMPERATURE

Blend mixtures HCM of R152a and R134a by mass in the proportion of HCM 30:70 (30% weight of R152a and 70% weight of R134a), HCM 50:50 (50% weight of R152a and 50% weight of R134a) and HCM 70:30 (70% weight of R152a and 30% weight of R134a) were charged through the charging port in the compressor and the performance tests were conducted. The results of the performance comparison of the investigated mixture of the refrigerants (R152a and R134a) in the vapour compression refrigeration system are given below.

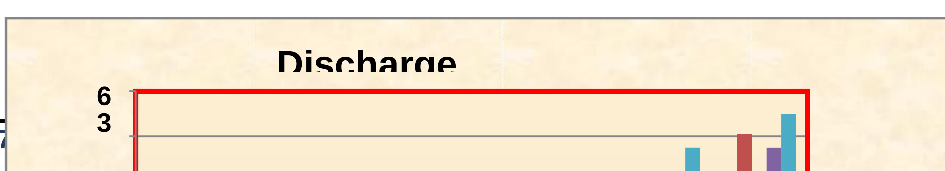


Fig. 4.1 Variation in discharge temperature as a function of time

VARIATION OF DISCHARGE PRESSURE

Fig.4.2 shows that the discharge pressure decreases with the variation in time. The discharge pressure was recorded to be highest for R152a followed by HCM 70:30, HCM 50:50 and HCM 70:30. The discharge pressure was found to be lowest for pure R134a.

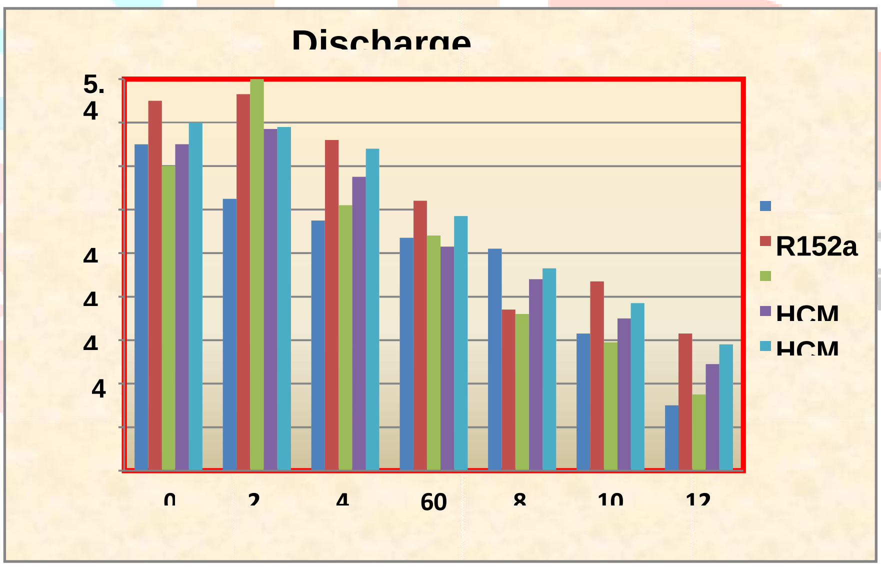


Fig. 4.2 Variation in discharge pressure as a function of time

VARIATION OF DISCHARGE PRESSURE

The variation of saturation pressure of a function of evaporator temperature for three refrigerant mixtures is shown in Fig.4.3. R152a as lowest pressure and R134a recorded the highest pressure. The HCM 70:30 recorded the lowest pressure among the three mixtures. Refrigerant with low pressure is desirable in the system because the higher the pressure the heavier must be the equipment parts and accessories. Usage of R152a owing to the lowest vapour pressure reduces the heaviness of the various components of the refrigeration system .

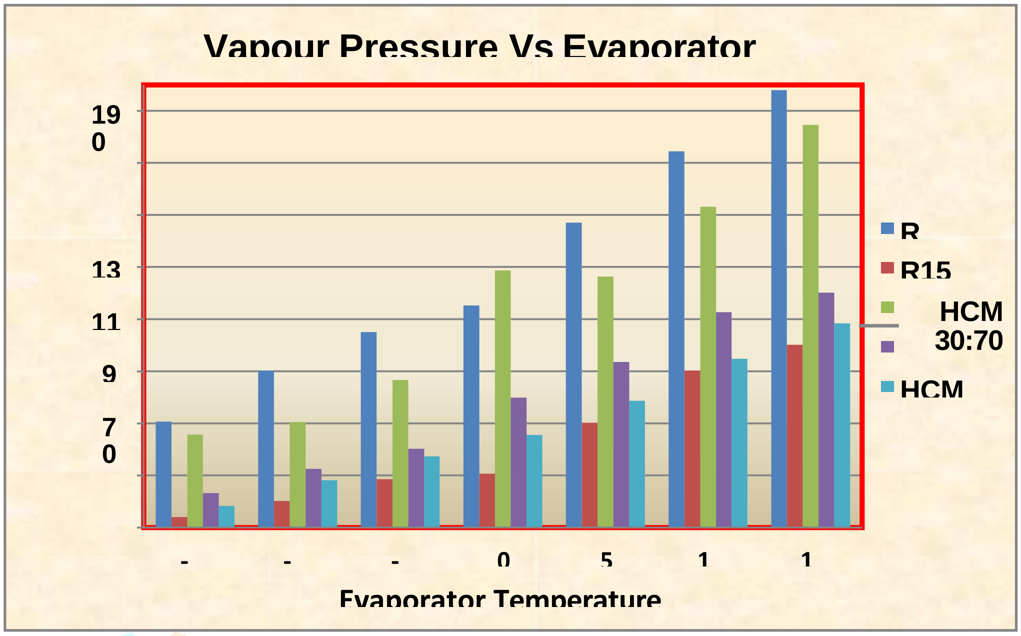


Fig. 4.3 Variation **of vapour pressure with varying evaporator temperature for R152a, HCM mixtures and R134a**

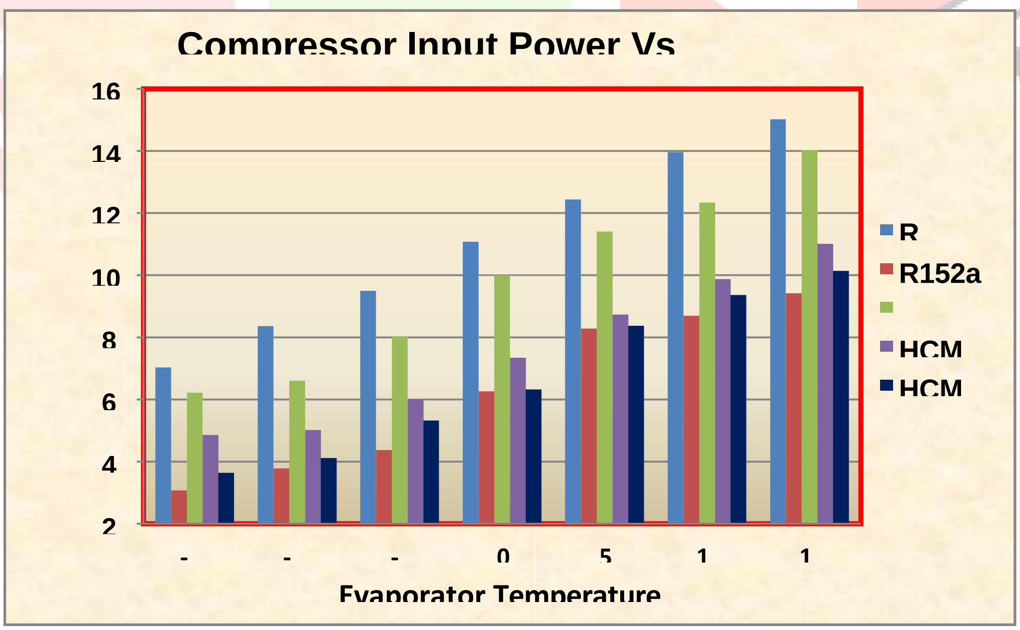


Fig. 4.4 Variation of Compressor input power with varying evaporator temperature for R152a, HCM mixtures and R134a

CONCLUSIONS

An experimental study was conducted in chapter 6 with the blend of R152a and R134a in vapour compression refrigeration system. Based on the present investigation, the following specific conclusions could be drawn.

- ❖ The discharge temperature and the discharge pressure of the compressor were found to be lowest for HCM 70:30 when compared with other mixtures.
- ❖ HCM 70:30 recorded the lowest vapour pressure among the mixtures which reduces the heaviness of the components of the refrigeration system by using this blend.
- ❖ The average pressure ratio for HCM 70:30 was lowest with the value of 4.3 which promises the life extension of the compressor.
- ❖ The average input power to the compressor for HCM 70:30 was found to be 9.5% lower than R134a. Usage of this blend reduces the power consumption of the system.
- ❖ The heat removal rate was higher for HCM 70:30.
- ❖ Higher volumetric capacity of 4.9% higher for HCM 70:30 was observed when compared to other blends of refrigerants. This ensures increasing cooling effect for the same size of the compressor as used for pure R134a.
- ❖ Highest COP value of was obtained for HCM mixture 70:30.
- ❖ The system works safely with the replacement of R152a blend with the conventionally used R134a.
- ❖ No system modification was done for the retrofitting process which is a major advantage of the present research.
    - ❖ Addition of nano additives with R152a decreases the vapour pressure of the refrigerant. Nano refrigerant with low vapour pressure will desirable the system as it reduces the weight of the components of the system and its accessories. The vapour pressure of 0.1% CuO was found to be lowest with the mean pressure of 7.23% lower than pure R152a.
    - ❖ The pressure ratio decreases with the addition of nano additives. The average lowest pressure was 3.6 for 0.1% CuO which 12.3% lower than 0.5% CuO. Decrease in pressure ratio improves the life of the compressor.
    - ❖ The compressor vapour pressure was found to decrease on the addition of nano additives. The average compressor input power for 0.1% CuO was 9.5% lower than the other concentration and other nano additives. This value is 23.7% lesser than pure R152a refrigerant.

- Increase in evaporation temperature due to the increase in cooling capacity improves the COP of the system with the reduction in power consumption of the compressor. The COP of 0.1% of CuO is found to be highest among the other nano additives. The decreasing order of nano additives on the basis of COP can be given as CuO, Al2O3 and ZnO. Thus the usage of 0.1% CuO nano additive with R152a which has low GDP value of 140 and zero ODP ensures safe and clean environment with less power consumption.

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