Performance Analysis Of VCR system By Applying Magnetic Field To Liquid Line Using R134a Refrigerant

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Abstract- *This paper represents experimental investigations carried out to study the effect of magnetic field on energy savings in vapour compression refrigeration system. By applying magnetic field to fluid flow, atomization of the fluid will takes place and reduces the specific volume of the fluid molecules. The reduction in specific volume of fluid molecules leads to drop in the viscosity that reduces the pumping power required by compressor as well as increases heat transfer rates in evaporator and condenser due to raised mass flow rates of the refrigerant. The COP was initially measured without application of magnetic field, and then magnetic field applied to liquid refrigerant was increased by increasing the number of the magnetic pairs from 1 to 5. The strength of each magnetic pair was 650 gauss. By the impact of magnetic field among all five magnetic pairs, the COP of the system increased up to 41.528% for R134a refrigerant at fourth magnetic pair when compared to simple VCR.*

Keywords- Magnetic field, HFC refrigerant, Refrigerating effect, Frictional power, Compressor power consumption, COP.

I. INTRODUCTION

In a vapor compression refrigeration (VCR) system, the refrigerant undergoes phase change from liquid to vapour and then from vapor to liquid in a closed cycle absorbing the heat in the evaporator and rejecting it at the condenser. The coefficient of performance (COP), which is the ratio of heat transfer rate at the evaporator to the power input to the compressor, can be increased either by increasing the refrigeration effect or by decreasing the compressor work. Various methods have been tried out for improving the COP of the vapour compression refrigeration system, as reported in literature.

As per the Montreal protocol and Kyotoprotocol these refrigerants need to be phased out and replaced with less harmfulness, having ideally zero ODP and GWP. The HFC (Hydrofluorocarbon) refrigerants having zero ozone depletion potential are recommended as alternatives to the CFC and HCFC. R134a is the long term replacement refrigerant for R12 because of its favourable characteristics such as zero ODP and 0.29 GWP [1,2].

Khovaylo VVet.al have studied and reported the use of magnetic elements for the improvement in the VCC (Vapour Compression Cycle). Magnetism is one of the characteristics of materials to respond at an atomic or subatomic level to an applied magnetic field. The magnetic-field MCE is defined as the heating or cooling of magnetic materials upon magnetic field variation [3,4].

Trevizoli PV et.al , Christensen DV et.al, Pecharsky KV et.al , Tagliafico LA et.al , Bansal Pradeep et.al have studied and reported the use of magnetic elements for the improvement in the VCR (Vapour Compression refrigeration).The magnetic field has a strong influence on physical properties such as an entropy, heat capacity, and thermal conductivity of a magnetic material [5–11].

Warburg first discovered the thermal effect of metal iron when applying for it in a varying magnetic field in 1881; known as MCE (Magneto-Caloric Effect) [12].

Debye and Giauque discussed the nature of MCE and suggested achieving an ultra-low temperature by adiabatic demagnetization cooling. The magnitude of MCE of magnetic material is the keyway to cooling capacity [13,14].

Silva et al. numerically studied AMRR (active magnetic regenerative refrigerator); they used a magnetic field to change the thermal conductivity of the magneto caloric material such as gadolinium [15].

The EHD (Electro-Hydrodynamics) technique has shown an improvement of the heat transfer on the refrigerant side [16].

Jia developed a mechanism by using the electromagnetic field containing the change in characteristics of graphenes in the presence of ice water boundary; the results showed electromagnetic field was encouraging graphene engulfment .

Applying magnetic field introduces a dynamic environment by which the fluids are influenced on boundary resulting in breaking of molecular cluster (de-clusters), with dynamic result (reduction in viscosity) which decreases the pumping power or compressor input .

Globally energy usage for building is 40%. India is 6th ranked place in the world in terms of energy requirement, consumes 3.5% of the world energy which is used for commercial purpose. Most of developing countries in the world face difficult challenges to meet their energy needs and also to provide sufficient amount of energy at reasonable price. To face these challenges government, industries and civil organisations should promote the rapid deployment of the energy efficient technologies. One of the promising directions to achieve this goal is to accelerate the adoption of energy efficient HVAC systems .

Pralhad.Tipole et al. have experimentally investigated the effect of the application of magnetic field on the liquid line for R134a and R600a and discussed the existence of limiting magnetic field.[17].

The purpose of this article is to report the results obtained from the experimental studies on a vapour compression system.

None of the literature review has studied the effect of the application of magnetic field on the liquid line of VCR system. And discussed the existence of limiting magnetic field.

1. Present Work

The work discussed in this paper presents the results of experimental investigations :–

- Effect of magnetic field on R134a refrigerant by comparing the performance with and without application of magnetic field.
- Effect of magnetic field strength (i.e. varying the applied magnetic field by changing the number of
- magnet pairs on liquid line) on COP of the vapour compression system.
- Observed existence of limiting field strength beyond which system performance (COP) degrades .

II. APPARATUS AND PROCEDURE

An experimental setup of vapour compression refrigeration system was built to investigate the performance of R134a. A schematic diagram of the experimental setup is shown in Fig. 1. It consists of loop which is composed of a compressor, condenser, capillary tube and evaporator. The compressor is a hermetically sealed reciprocating type. The condenser and evaporator were of both copper single tubes. In the single tube condenser, the refrigerant flows through the inner tube while air is outside the tubes. The refrigerant then flows into the evaporator through the capillary tube. Low flow glass tube flow meter (0-10 LPH) was used to control the mass flow rate of the refrigerant into the evaporator coils. In the single tube evaporator, the refrigerant flow through the inner tube and water is outside the tubes. For minimizing the heat loss, the tube is well insulated. Five magnetic pairs with a Gauss level of 650 each were employed in this study and placed in the system on liquid line. The readings were taken with increasing number of magnetic pairs. Two pressure gauges were placed in the system to note down the compressor inlet and outlet pressure. Temperatures at various points in the system were noted with the help of 4-channel k-type digital thermometer thermocouple sensor includes: 1 x Meter and 4 Probe sensor (length ~ 95cm each, -30°C to 300°C). The voltage and the current in the system were measured with the help of calibrated energy meter. Six sensor probes were used to measure the temperature at different locations in the refrigeration loop (Evaporator inlet and outlet, condenser inlet and outlet, Cooling water and ambient air). Temperatures at various points mentioned in Fig.1 were measured. Power consumed by the compressor was measured by an energy meter. The two calibrated pressure gauges at the compressor inlet and outlet were used to measure the suction and discharge pressure respectively. The magnets used in this study were neodymium rare earth disc type magnets (N35) with dimensions [3/8" * 1/16"]. In the present study, the initial temperature of the water on the evaporator side is maintained at 320C at starting using electrical heater and stirrer mechanism. The readings were taken at interval of 20 min. Each experiment was repeated twice to reduce errors in the procedure and confirm repeatability. Initially experiment was conducted without applying magnetic field on the liquid line. Later experiments were conducted by applying magnetic field on liquid line of the VCR system. The magnetic field was then increased by increasing number of magnet pairs on liquid line to study the effect of magnetic field on system performance with COP. applying magnetic field on the liquid line. Following experiments were conducted by applying magnetic field on liquid line of the VCR. The number of magnetic pairs applied on the liquid line is varied from one pair to five pairs (650 gauss each) to find out its effect on the compressor power and the COP of the system. The distance between the two magnetic pairs was kept constant,..i.e.13..cm.

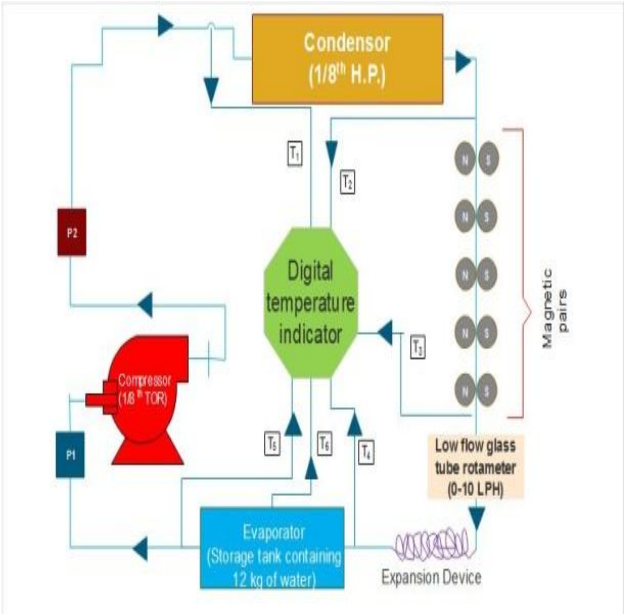

Figure 1. Schematic representation of the VCR system

Where

T1-Condenser inlet temperature
T2-Condenser Outlet temperature
T3-Temperature at inlet of flow meter
T4-Evaporater Inlet Temperature
T5- Evaporator outlet Temperature
T6- Water temperature
P1-Compressor inlet pressure (Suction Pressure)
P2- Compressor outlet pressure (Discharge Pressure).

III. INDENTATIONS AND EQUATIONS

The experimental results on VCR without magnets were used as a reference for this study. In the current experimentation, refrigeration effect and power consumed by compressor were calculated and these parameters are required to calculate the COP of the system. Eqs.(1) and (2) are employed for the calculation of the COP of vapour compression system and sensible heat absorbed from water respectively. The Refrigeration effect (Q) and COP of the system are been calculated as follows:

$$\text{COP} = \frac{\text{Refrigerating Effect}}{\text{Compressor Power}} \quad \text{----------- (1)}$$

$$Q = \frac{m*Cp*dT}{dt} \quad \text{----------- (2)}$$

Where

Q – Refrigerating effect ;
m – mass of the water
dT – change in water temperature
Cp – specific heat of water
dt – time logged corresponding to dT

IV. RESULTS AND DISCUSSIONS

4.1. Effect of Magnetic Field on R134a Refrigerant by Comparing the Performance With and Without Application of Magnetic Field.

The drop in viscosity of the refrigerant with increasing magnetic field strength will result in increased mass flow rates of the refrigerant and hence improved refrigerating effect. Fig. 2 clearly represent drop in water temperature (Improvement in cooling effect) with increase in number of magnetic pairs up to the fourth pair. After fourth magnetic pair decrease in cooling effect was observed. Application of magnetic field for the refrigerant R134a showed improvement in cooling performance. Studies have shown that application of magnetic field reduces the viscosity of refrigerants and enhances the expansion of the refrigerant which results in increased mass flow of refrigerants and hence results in increased evaporative capacity. Increased refrigerant mass flow rates increases evaporative capacity and hence increased drop in temperature of the water was identified

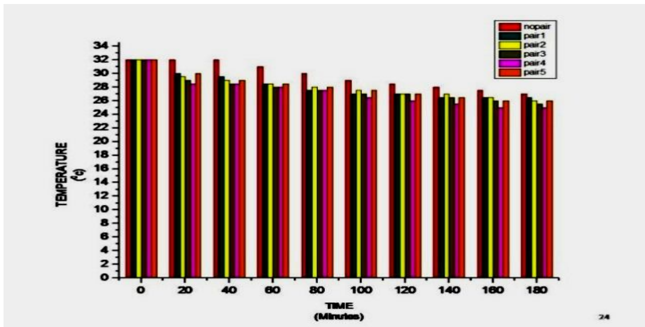

Figure 2. Temperature vs Time vs Magnetic pairs

a) Effect of Magnetic Field on Refrigerating

Effect and Power Consumption

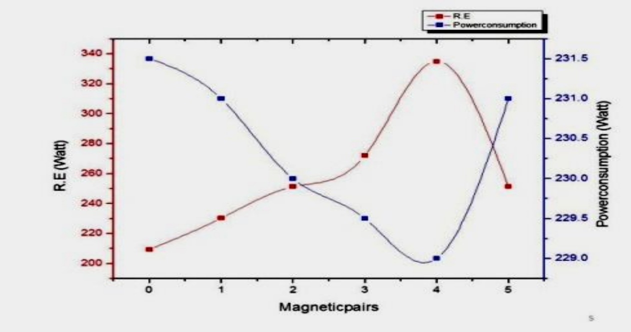

Figure 3. Magnetic pairs vs R.E. vs Power input

Fig.3 represents effect of magnetic field on the instantaneous power consumption of compressor and refrigeration effect. It was found that input power required by the compressor decreases with increase in magnetic pairs. It has been reported that viscosity of the refrigerants is the function of applied magnetic field, as the magnetic field strength increases viscosity keeps on decreasing; hence lower compressor power is required to pump the same amount of the refrigerant. As the number of magnetic pair increases, the refrigerating effect also increases up to fourth magnetic pair, because more amount of refrigerant is circulated per unit time due to a decrease in the specific volume of the refrigerant, which leads to improvement in the heat transfer rate and refrigerating effect. Magnetic field affects the behavior of fluid. The change in the fluid properties occurs due to change in the chemical structure and bonds formed due to sharing of electron (covalent bond). Pairs of electron shared between two atoms may be equal or different. Stability of the molecules depends upon the covalent bond. Covalent bonds are molecular forces which have an impact on molecular properties. Intermolecular forces are responsible for holding the molecules together and also a thermo physical property of the substance depends upon them. Intermolecular forces of liquid are physically a thermo physical property of the substance depends upon them Intermolecular forces of liquid are physically powerful to get split and undergo a change of phase. Increase in kinetic energy of is responsible for change of state of liquid refrigerant. Improvement in the performance will occur due to overcoming of these bonds or intermolecular forces. Magnetic field enhances the heat transfer rate but it depends upon frequency of the internal disturbances of the molecule, magnetic field location, and intensity of magnetic field. Beyond certain magnetic field strength entropy generation will take place leading to drop in refrigerating effect.

b) Effect of Magnetic Field On COP

Application of magnetic field has a positive effect on cooling capacity and power consumption which leads to improvement in the COP of VCR. Fig. 4 shows relationship between the number of magnetic pairs and improvement in COP for R134a. When a magnetic field is applied between the condenser outlet and entry of expansion device of system, shows enhancement in COP within the range of 10.238% – 41.528% forR134a.

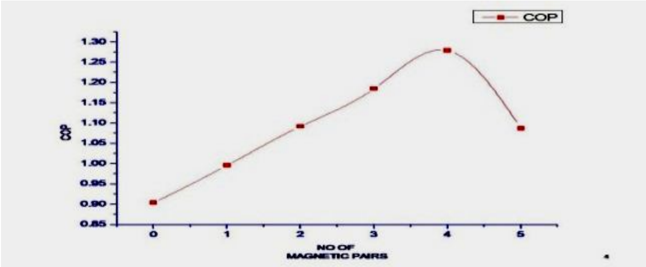

Figure 4. Magnetic pairs vs COP

V. CONCLUSION

In this study of vapour compression refrigeration system with the application of magnetic field on to the liquid line (from outlet of condenser to inlet of expansion valve can enhance the performance parameters of the VCR system. The magnetic field strength was varied by increasing the number of magnetic pairs applied to the liquid line (from outlet of condenser to inlet of expansion valve). The COP was initially measured without application of magnetic field, and then magnetic field applied to liquid refrigerant was increased by increasing the number of the magnetic pairs from 1 to 5. The strength of each magnetic pair was 650 gauss. By the impact of magnetic field among all five magnetic pairs, the COP of the system increased up to 41.528% for R134a refrigerant at fourth magnetic pair, when compared to simple VCR.

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