Experimental Investigation of Effect of Magnetic Field on Hydrocarbon Refrigerant in Vapor Compression Cycle

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Abstract*—current paper presents experimental results of effect of magnetic field on Hydrocarbon fluid flow (Refrigerant-R600). Magnetic field being a source of energy shows influence on various materials and fluids which respond to the magnetic field. Literature has been reported on energy of permanent magnets used for the treatment of vehicle fuel, to reduce fuel consumption, as well as reducing the emission of certain pollutants. Literature reports use of permanent magnets with different intensity (2000, 4000, 6000, 9000 Gauss) installed on the fuel line of the two-stroke engine, and study its impact on gasoline consumption, as well as exhaust gas emissions and compared with performance without application of magnetic field to estimate the performance improvement. This present article has studied various literature presenting effect of magnetic field on performance, fluid properties for different applications using hydrocarbons viz. I. C. Engine, Refrigeration. It also presents experimental results of effect of magnetic field on non hydrocarbon (R-134a) and hydrocarbon (R-600) refrigerant.

Keywords— ***Diamagnetic, Paramagnetic, Ferromagnetic, susceptibility, permeability, TXV (thermal expansion valve).***

I. INTRODUCTION

A magnet is a material that produces a magnetic field. This magnetic field is invisible but is responsible for the most notable property of a magnet, a force that pulls other ferromagnetic materials, such as iron, and attracts or repels other magnets. A magnet produces a vector field, the magnetic field, at all points in the space around it. A magnetic field can be created with moving charges, such as a current-carrying wire. A magnetic field can also be created by the spin of magnetic dipole moment, and by the orbital magnetic dipole moment of an electron within an atom.

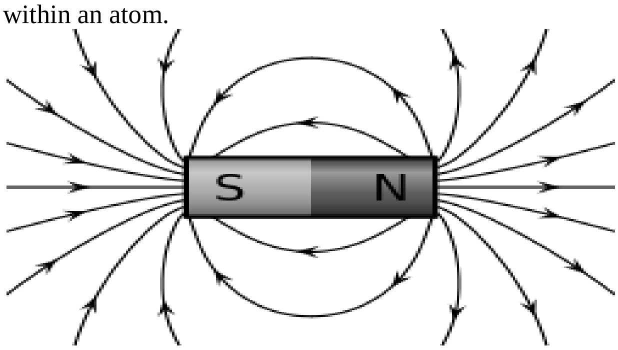

Fig.1 Magnet and magnetic field

The magnetic moment of a magnet is a quantity that determines the force that the magnet can exert an electric current and the torque that a magnetic field will exert on it. A loop of electric current, a bar magnet, an electron, a molecule, and a planet all have magnetic moments. Both the magnetic moment and magnetic field may be considered to be vectors having magnitude and direction. The direction of the magnetic moment points from the south to North Pole of a magnet. The magnetic field produced by a magnet is proportional to its magnetic moment as well. More precisely, the term magnetic moment normally refers to a system's magnetic dipole moment, which produces the first term in the multiple expansion of a general magnetic field.

II. TYPES OF MAGNETIC MATERIALS.

The term magnet is typically reserved for objects that produce their own persistent magnetic field even in the absence of an applied magnetic field. Only certain classes of materials can do this. Most materials, however, produce a magnetic field in response to an applied magnetic field; a phenomenon known as magnetism. There are several types of magnetism, and all materials exhibit at least one of them.

A.Diamagnetic

Substances that mostly display diamagnetic behavior are termed diamagnetic materials, or diamagnets [7]. Materials called diamagnetic are those that non-physicists generally think of as non-magnetic, and include water, wood, most organic compounds such as petroleum and some plastics, and many metals including copper, particularly the heavy ones with many core electrons, such as mercury, gold and bismuth. Diamagnetic materials have a relative magnetic permeability that is less than or equal to 1, and therefore a magnetic susceptibility less than 0. This means that diamagnetic materials are repelled by magnetic fields.

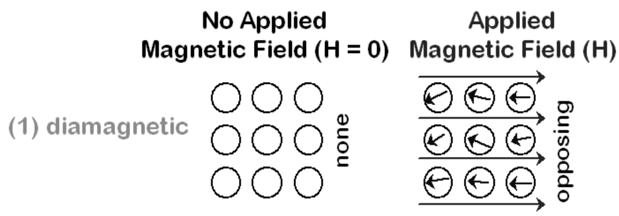

Fig. 2 Molecules of diamagnetic material

B. Paramagnetic

Substances, such as platinum, aluminum, and oxygen, are weakly attracted to either pole of a magnet. This attraction is hundreds of thousands of times weaker than that of ferromagnetic materials, so it can only be detected by using sensitive instruments or using extremely strong magnets. Paramagnet materials have a small, positive susceptibility to magnetic fields[6].These materials are slightly attracted by a magnetic field and the material does not retain the magnetic properties when the external field is removed.

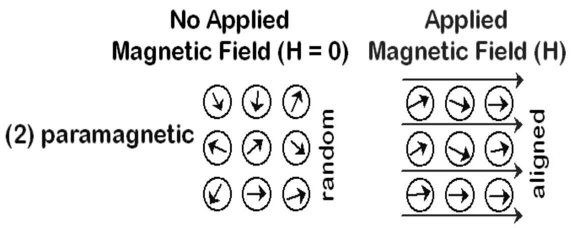

Fig. 3 Molecules of paramagnetic materials

C.Paramagnetic

Unlike para-magnetism with incompletely balanced orbital or spin moments which are randomly aligned, for some materials unbalanced spin can lead to significant permanent magnetic moments.[5] The permanent moments are further enhanced by coupling interactions between magnetic moments of adjacent atoms so that they tend to align even without an external field. These materials are the only ones that can retain magnetization and become magnets; a common example is a traditional magnet.

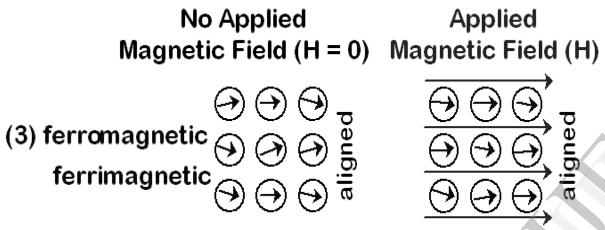

Fig. 4 Molecules of ferromagnetic materials

III. IMPACT OF MAGNETIC FIELD ON FUEL [4]

The overall performance and exhaust emission tests showed a good result. The fuel saving percentage was ranged between 9 to 14% according to the literature and increment is depending on the intensity of magnetic field, as well as the engine speed. It was found that the percentages of exhaust gas components like CO was decreased by 30% where HC by 40%, but CO2 percentage increased up to 10% because of the complete combustion of the hydrocarbon fuel.

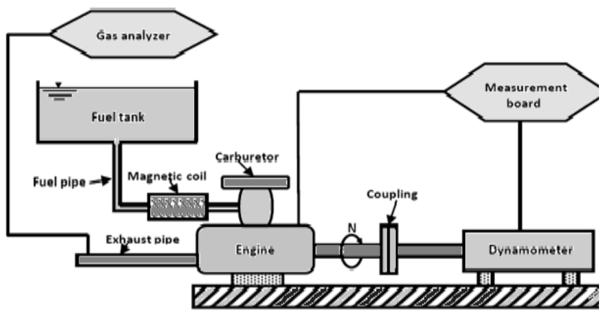

Fig. 5 setup for testing impact of magnetic field on fuel

A. Magnetic devices

The magnetic device used for the instrument had been made in the laboratories of the Water Research Centre / Ministry of Science and Technology. A device contains the number of permanent magnets arranged in stages. The magnetic field strength of magnets used in the device is varying from (2000, 4000, 6000, and 9000) gauss. The magnetic device is held between the fuel tank and the carburetor so that the liquid fuel passes through the pipe is exposed by the magnetic field.

B.Engine

Two-Stroke Engine with spark ignition, Chinese origin TWP20C with a capacity of up to 5.5 hp was used for the implementation of the experiments. An external tank includes a volumetric scale to measure the amount of fuel consumed during operation and for each experiment.

IV. PROCEDURE CARRIED OUT TO CHECK EFFECT OF MAGNETIC FIELD ON IC ENGINE(LITERATURE SURVEY)

Three accelerated rotation of the engine (3500, 4500, and 5000) r.p.m, was selected, to know the amount of fuel consumption in each of these speed at all magnetic intensities. An Engine had been started after putting a certain amount of fuel in the external tank, and speed set is selected for the experiment. Process is carried out for two hours and for each test, during which the exhaust gas was measured at several times for accuracy.

After that, the amount of consumed fuel is calculated in the end of the experiment. This process is repeated for the second speed to know the amount of consumed fuel and the amount of exhaust gases. The above process is again repeated after installing the magnetic device with intensity 2000 Gauss on the fuel line.

The exhaust gases during operation were measured, as well as the amount of consumed fuel after the end of the operation. The amount of consumed fuel after the installation of the magnetic device was deducted from the quantity before the installation of the magnet to know the quantity saved, and the same principle applies to the exhaust gases.

V. DE-CLUSTER OF FUEL

Magnetic fuel treatment works on the principle of magnetic field interaction with hydrocarbon molecules of fuel and oxygen molecules [8]. Liquid fuel is a mixture of organic chemical compounds like carbon and hydrogen atoms - hydrocarbons. Because of various physical attraction forces, they form densely packed structures called pseudo compounds which can further organize into clusters. These structures are relatively stable and during air-fuel mixing process, oxygen atoms cannot penetrate into the interior of the cluster. This result in the incomplete combustion of fuel and causes the formation of carbon particles and carbon monoxide also increased quantities of hydrocarbons emitted into the environment causes pollution.

a hydrocarbon fuel can be polarized by exposure to external force of magnetism. The effect of such magnetism is the production of a moment created by the movement of the outer electrons of a hydrocarbon chain moving the electrons into states of higher principal quantum number. This state effectively breaks down the fixed valance electrons that partake in the bonding process of the fuel compounds.

These states create the condition for free movement of fuel particulars. In so doing, the hydrocarbon fuel becomes directionalized that is they are aligned which is not a new hydrocarbon chain but more explainable aligns the conduced magnetic moment into a dipole relationship within itself.

This magnetic alignment then permits rapid bonding with the oxidizing media. The result of which is more oxygen is get bonded with the hydrocarbon fuel and cause rapid burning of the fuel. Hydrocarbon fuel molecules, influenced by the magnetic field tend to de- cluster, creating smaller particles more readily penetrated by oxygen, causing better combustion.

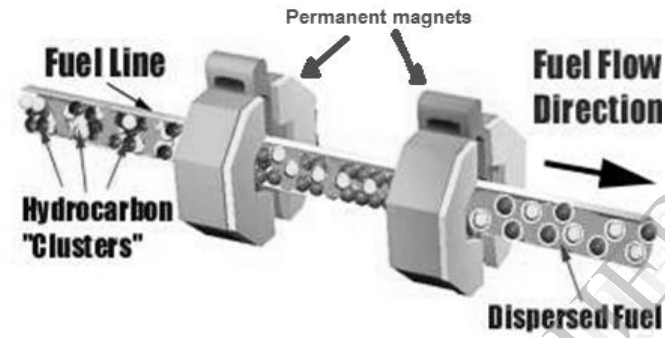

Fig. 6 De-cluster of fuel molecules [5]

There is a very strong binding of hydrocarbons with oxygen in such magnetized fuel, which ensures optimal burning of the mixture in the engine chamber.

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VI. EFFECT OF MAGNETIC FIELD ON FUEL CONSUMPTION AND EXHAUST GASES [6]

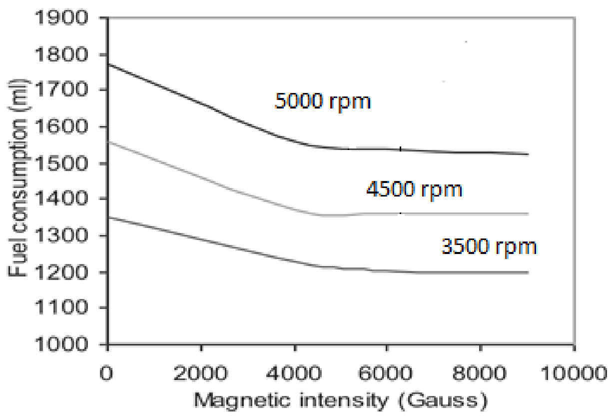

Fig. 7 reducing the amount of consumed fuel with increasing magnetic field intensity

Fig. 7 represents the amount of fuel consumed with the intensity of the magnetic field varying from 3500 gauss to 5000 gauss for three different engine speeds. Maximum fall in consumption in fuel is recorded for 5000 gauss magnet.

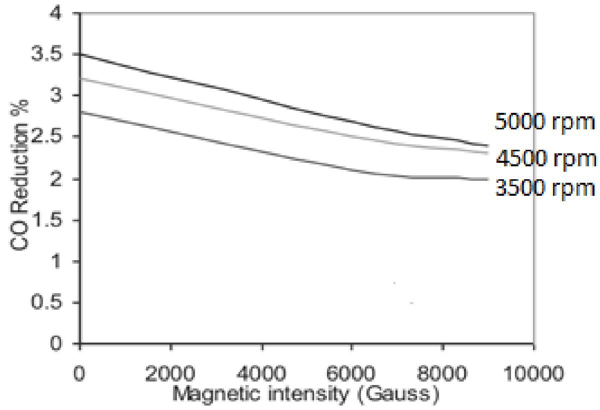

Fig. 8 Decrease rate of CO gas with magnetic intensity.

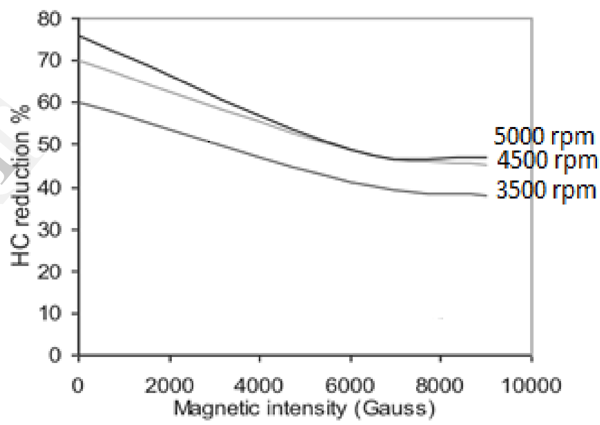

Fig. 9 Decrease rate of HC gas with magnetic intensity.

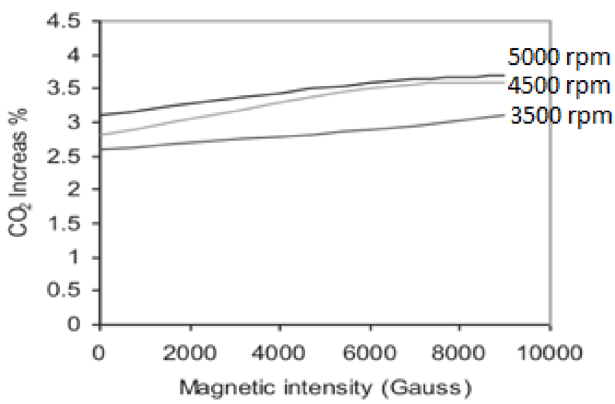

Fig. 10 Decrease rate of unburned hydrocarbons HC with magnetic intensity.

Fig. 8 and Fig. 9 shows the reduction in the percentage of CO and HC for the different magnetic fields .reduction in their percentage shows the complete combustion of fuel. From the Fig. 10 increase in the percentage of CO_2 shows the complete combustion because the CO_2 and the H_2O are the two main products of combustion.

By taking reference to above experiment and its remarkable results one can conclude that the magnetic field has the impact on the fuels that contains hydrocarbons so it must have the impact on the hydrocarbon refrigerants also.

This theory has got the relevance from the testing the impact of magnetic field on the fluid properties as discussed below.

VII. IMPACT OF MAGNETIC FIELD ON FLUID PROPERTIES. (LITERATURE SURVEY)[1]

A. Viscosity

The viscosity decreases of magnetized methylcyclohexane and cyclohexane. It is apparent that the viscosity decrease of magnetized alkenes. The viscosity decreases more rapidly below 0.2 T is observed.

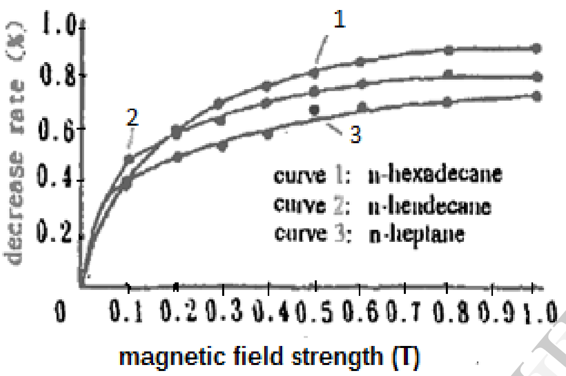

Fig. 10 viscosity decrease rate of normal paraffins vs. magnetic field strength [1] .

B. Surface tension

The relationship between the decrease rates of the surface tension of magnetized n/octane is discussed below. The surface tension of the individual hydrocarbons decreases after magnetization.

At some certain magnetic fields the surface tension decreases comparatively considerably while at others it decreases comparatively unnoticeably. The reason for that could be the different behavior of the hydrocarbon at different magnetic field strength so it can be easily concluded that the surface tension of hydrocarbons decreases with the increase in magnetic field strength.

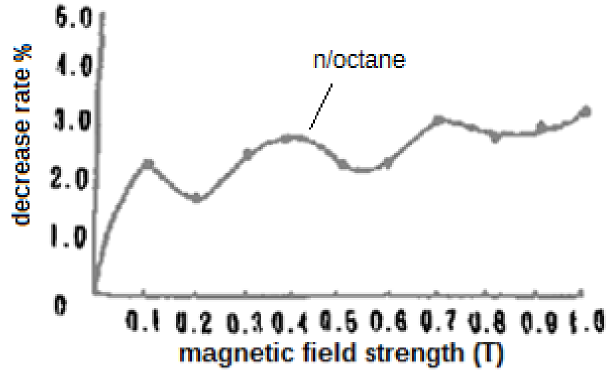

Fig. 11 surface tension decrease rate of n octane vs. magnetic field strength

VIII. EXPERIMENTAL INVESTIGATIONS ON IMPACT OF MAGNETIC FIELD ON REFRIGERANT (PRESENT WORK)

Experiments were been conducted on the refrigerants viz. a hydrocarbon (R-600) and non hydrocarbon (R-134a) to check the impact of magnetic field on system performance.

The set up with the location of the permanent magnet applied is shown in Fig. 12. The magnetic field is applied in between the condenser exit and expansion valve inlet (liquid line) as the effect of magnetic field has been reported on liquid line.

Permanent magnets of varying magnetic field strength have been used (2000, 4000, 6000, 8000) gauss.

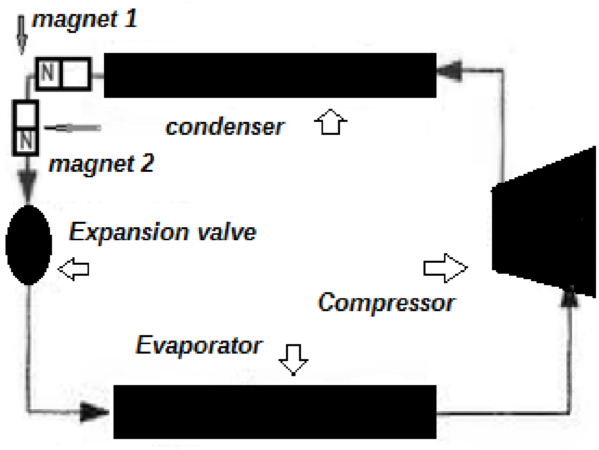

Fig. 12 setup for testing impact of magnetic field on refrigerant

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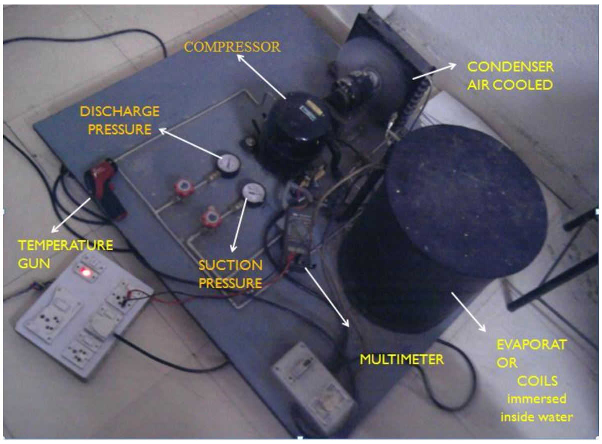

Fig. 13 actual setup for testing effect of magnetic field

A.Test set up

Experiments were carried out on simple vapor compression unit consisting of a compressor, condenser, evaporator and thermal expansion valve.

This set up is designed to cool down water in the evaporator tank, wherein the evaporator tubes are completely submerged inside the water to be cooled.

Same set up was initially charged with R134a and later replaced with R600 with necessary changes.

The temperature at various locations in the set up was measured using a non-contact infrared temperature gun. And the Voltage and current passing through the compressor motor is measured with the multimeter.

The temperature was measured at TXV outlet, condenser, water and the power consumed by compressor.

Magnetic field was applied on the liquid line, after the condenser and the strength of the field was increased by adding additional pair of magnets.

The observation from the experiments performed is discussed in this article.

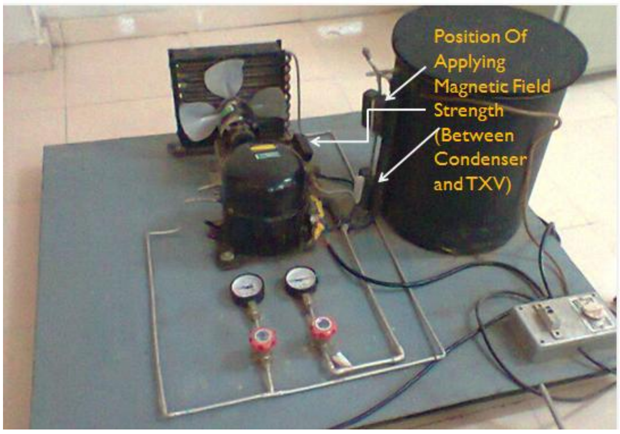

Fig.14 positioning of permanent magnet in VCC

B. An observations from the Experiment performed

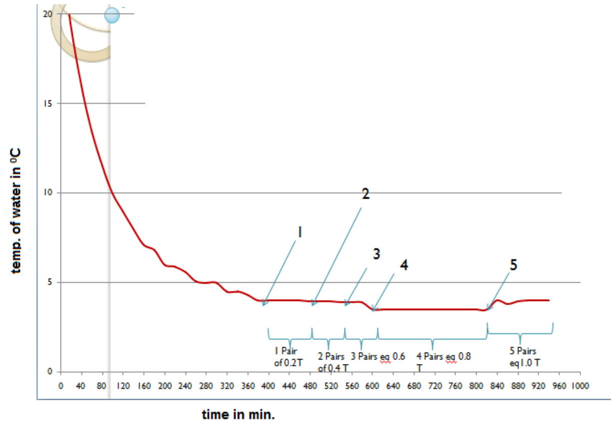

Fig.15 Temp. of water cooled vs. time (R600)

In the Fig. 15 the various regions marked indicate the field strength applied to the liquid line,
1-2 - 0.2 T magnetic field applied.
2-3 - 0.4 T magnetic field applied
3-4 - 0.6 T magnetic field applied
4-5 - 0.8 T magnetic field applied
Beyond 5 – 1 T magnetic field applied.
From Fig.15 region 1 to 2 (0.2 T field applied) and 2 to 3 (0.4 T field applied) represents no significant drop in temperature of water. Which indicate that the field strength has no visible impact on the performance of the vapor compression unit.
When higher magnetic field of the order of 0.6 T and 0.8 T are applied, the temperature of water drops is visible, which indicates the magnetic field applied has decreased the viscosity of the refrigerant [1] leading into increase in the flow rates and cooling capacity & decrease in the compressor power in turn increasing the COP of the set up.
The reason for drop in the water temperature even after the stability in the water temperature is due to the improvement in the fluid properties of refrigerant like decrease in surface tension and viscosity.
For 1 T and beyond the temperature of the water increases which was difficult to understand and analyze experimentally. The probable reason for this could be excessive magnetic field resulting in over heating of the refrigerant flowing resulting into drop in the performance of the system.

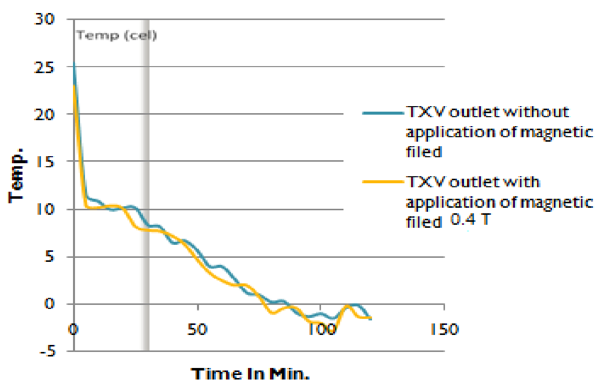

Fig.16 TXV outlet temp vs time graph for R-134a

The TXV temperature at the outlet is measured for R134a with and without application of the magnetic field to the liquid line.
Similar experiments were carried for R134a for different magnetic fields which showed negligible improvement in the performance of the system.
The readings are taken for magnetic field strength for which the reading taken is 0.4 T.
The time required to fall in temperature in both the cases is nearly the same, and the reason could be the nature of the refrigerant. As R143a is a non hydrocarbon its individual molecules do not respond to the magnetic field strength.
So being the non hydrocarbon R143a shows no change in the fluid properties like the surface tension, viscosity etc

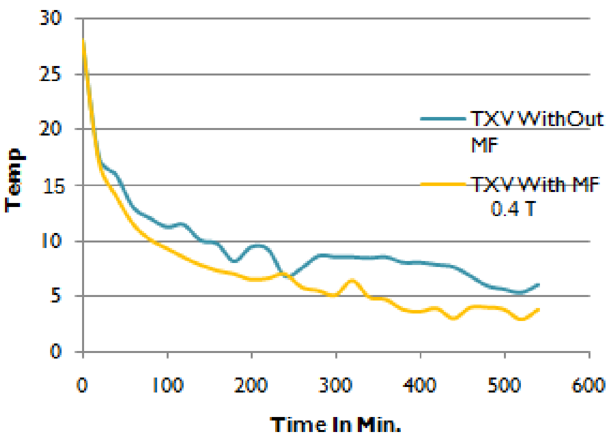

Fig. 17 TXV outlet verses Time graph for R-600

When the refrigerant R600 is replaced as a refrigerant in the VCC and the temperature at the outlets are observed it has been seen that the time required for temperature drop (with and without magnetic field) is different.
The time required for fall in TXV outlet temperature with magnetic field (0.4 T) is less than time required without magnetic field.
The possible reason for this could be the improved fluid properties like the surface tension and viscosity.
Decrease in the viscosity of refrigerant results in increase in the fluidity and reduction in the compressor power so more fluid passes through the coils for the same period of time.

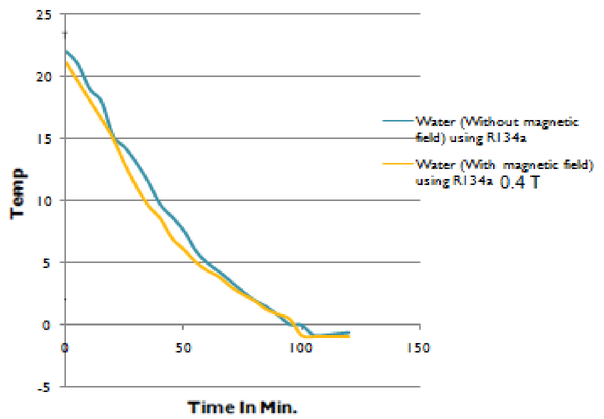

Fig. 18 water temperature Vs time for R-134a

For the refrigerant R 134a when time required to get the constant temperature of water is measured throughout the experiment it turned outs to be 130 min in both the cases (with and without application of magnetic field).
The reason for no variation in time required for temperature drop is that the R143a is not a hydrocarbon and hence it doesn't responds to magnetic field.

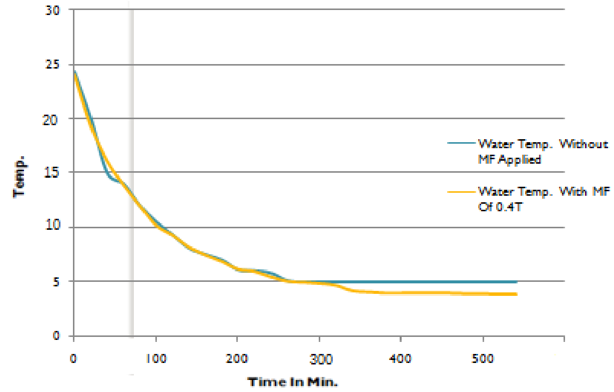

Fig. 17 Water temperature Vs time for R-600

Application of magnetic field with the hydrocarbon refrigerant R600 showed improvement in cooling performance with application of magnetic field.
Improved fluid properties cause more refrigerant flow to through the evaporating coils and enhancing cooling capacity hence further drop in the water temperature is observed (Refer Fig. 17).

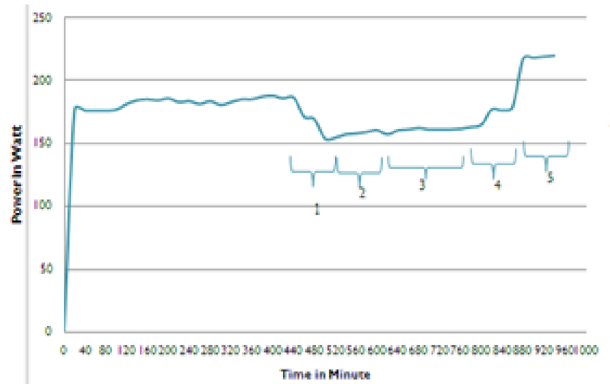

Fig. 18 Compressor power consumption vs. time (R600)

For Fig. 18 Magnetic field is applied in same sequence as discussed in Fig. 15 (1 to 5).
Fig.18 is the representation of the power consumed by the compressor when different strengths of magnetic fields are applied to the experimental set up.
The various regions from the curve are shown by the digits 1 to 5 for different magnetic field strengths (from 0.2 T to 1 T)
It was observed that power consumption by compressor in VCC decreases with increase in the magnetic field and again increases.

The reason for increase in the power consumption at higher magnetic field strength is possibly over heating of refrigerant due to excessive field strength.

IX. OBSERVATIONS

For the hydrocarbons, fluid properties like viscosity, surface tension decreases with increase in the magnetic field strength. As the viscosity decreases, mass flow rate of the refrigerant increases, compressor power decreases which results in improvement in the COP of the system. Non-Hydrocarbons like R134a do not show much improvement in the system performance.

Thus this study has been able to validate the reported phenomena of improvement in COP of Hydrocarbon refrigerant systems on application of magnetic field between condenser outlet and TXV.

X. CONCLUSIONS

1. Only Hydrocarbon fluids (R600) show improvement in performance on application of magnetic field.
2. Non-Hydrocarbon refrigerant (R134a) did not show improvement in performance on application of magnetic field.
3. As the field strength was increased the cooling performance was enhanced till certain magnetic field strength (up to 0.8 T).
4. For higher magnetic field strength 1 T and beyond cooling performance detoriated possibly due to heating of the refrigerant due to excessive magnetic field.
5. There is a limit to the maximum field strength which can be applied beyond this limit the performance of the vapor compression system degrades.

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