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A Review on Effect of Magnetic Field on Refrigeration

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***Abstract*: Current paper presents review of Effect of magnetic field on refrigeration. Magnetic field as source of energy shows influence on various materials and fluids which respond to the magnetic field. Energy of permanent magnets used for the treatment of vehicle fuel, for reduction of fuel consumption, as well as reducing the emission of some pollutants. Magnetic field being a source of energy shows influence on various materials and fluids which respond to the magnetic field. The vapour compression cycle is a well-established refrigeration technique used in most household refrigerators, air conditioners, and many large commercial and industrial refrigeration systems. This article has studied various literatures presenting effect of magnetic field on functioning, fluid properties for different applications using hydrocarbons viz. Engine, Refrigeration.**

***Keywords*: Magnetic field, Refrigeration, VCC**

1. Introduction

Emil Gabriel Warburg (1846-1931) was a German physicist who during his career was professor of physics at the Universities of Strassburg, Freiburg and Berlin. He carried out research in the areas of kinetic theory of gases, electrical conductivity, gas discharges, ferromagnetism and photo chemistry. In 1881 he discovered the magneto caloric effect in an iron sample, which heated a few Milli kelvins when moved into a magnetic field and cooled down again, when removed out of it. This technology was successfully applied in low temperature physics since the 1930's to cool down samples from a few Kelvin to a few hundred of a Kelvin above the absolute zero point (-273.15 K). But today, because of two important aspects, also applications for the refrigeration market seem feasible. The first one is the availability of magneto caloric materials with Curie temperatures at room temperature and above. Furthermore, by the "giant" magneto caloric effect new magneto caloric materials have become a factor two to three more performing [11].

The effect of magnetic field on refrigerants depends upon chemical formula, chemical structure and thermo physical properties such as viscosity, surface tension, thermal conductivity and thermal capacity. The highest specific heat and thermal conductivity of refrigerant has a low response to magnetic field and vice-versa (Samuel M. Sami, R.J.Kita, 2005).The magnetic effect at condenser exit pipe increases the refrigerating effect and reduces the compressor power. Compressor consume more power to evaporate liquid refrigerant enters in compressor due to incomplete evaporation of refrigerant. When magnetic field applied at condenser exit its changes refrigerant properties and increases the evaporation rate of liquid refrigerant. This reduces the liquid refrigerant that boils in compressor (A Kotb, H.E.Saad 2014). The effect of magnetic field on some new refrigerant mixtures is studied and its effect on performance of vapour compression system is analyzed. The test results showed that increasing magnetic strength on condenser exit line increases the COP by reducing compressor power (Samuel M. Sami, Shawn Aucoin, 2003). The effect of magnetic field on refrigerant mixture R290/R600a showed that magnetic field reduces the compressor power consumption and depends on the magnetic field strength. The increasing magnetic strength decreases compressor power and result in increasing COP [1].

The effect of magnetic field on hydrocarbon, viscosity and surface tension decreases as the magnetic strength increases resulting increased mass flow rates hence heat transfer in evaporator and condenser. The performance of air conditioning system under the various magnetic field strength has a positive effect on COP of the air conditioning system. (Mr. Amod P. Shrotri. Mr. Nikhil S. Mane, Mr. Vishal P. Patil, Mr. Sawan A. Wani, 2015) [1].

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. 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 [2].

A. Types of magnetic material

They can be classified into the following five major groups:

1) Diamagnetic substances

Diamagnetism is a weak magnetism and is the fundamental property of all matter. Diamagnetism is mainly due to the non-cooperative behavior of the orbital electrons under the application of external magnetic field. In diamagnetic substances, all the atoms have paired electrons and there are no unpaired electrons in the shells. Thus the net magnetic moment of the atom of a diamagnetic substance is zero. However, when an external magnetic field is applied on these substances, these materials are magnetized opposite to the field direction. Thus they have negative magnetization .That means for diamagnetic substances the susceptibility is negative. The other characteristic behavior of diamagnetic substances is that their susceptibility is independent of temperature.

2) Paramagnetic substances

In these materials, the atoms or ions have unpaired electrons in partially filled orbital's. That means each atom in a paramagnetic substance has a small net magnetic moment. But, there is no interaction between these atomic magnets. In the presence of an external magnetic field there will be a partial alignment of these atomic magnetic moments in the direction of applied magnetic field resulting in a net positive magnetization and positive susceptibility. When the applied field is zero, the magnetization also becomes zero.

If the temperature of the paramagnetic substance increases, then alignment of the atomic magnets will be disturbed. That means the magnetic susceptibility depends on temperature. The magnetic susceptibility of is inversely proportional to the absolute temperature. This law is called curies law.

3) Ferromagnetic substances

When we think of magnetic materials, the most common materials that come into our mind are iron, nickel, and magnetite. These are generally called ferromagnetic substances. In these substances, there exists a strong interaction between the atomic magnets. These interaction forces are exchange type of forces. The interaction force between the atoms is due to exchange of electrons. The exchange types of forces are very large and are of magnitude 1000 Tesla. This strength is almost 108 times the strength of the earth's magnetic field. Atomic magnets are aligned parallel to each other under the influence of these exchange forces.

4) Spontaneous magnetization

The net magnetization existing in a uniformly magnetized microscopic volume under the absence of external magnetic field. The magnitude 10 of spontaneous magnetization depends on the spin magnetic moments of spinning electrons. The measurable property corresponding to spontaneous magnetization is saturation magnetization. The saturation magnetization is the maximum, induced magnetic moment that can be induced by a magnetic field; beyond this field there will be no further increase in the magnetization. The difference between spontaneous magnetization and the saturation magnetization has to do something with magnetic domains. Saturation magnetization is an intrinsic property that is independent of particle size but is dependent on temperature. Paramagnetic susceptibility is slightly greater than 1 and is positive but, ferromagnetic susceptibility is high and positive. When compared with paramagnetic materials, the magnetization in ferromagnetic materials is going to be saturated in moderate magnetic fields, at high temperatures.

5) Super paramagnetic

Super paramagnetic is an interesting phenomenon that comes into play when ferromagnetic or ferromagnetic particles become very small. At particle sizes of about 10 nanometers, these materials begin to exhibit paramagnetic behavior, even when they are below their curie temperature. This is because, below Curie temperature, the thermal agitations are not strong enough .The interaction forces between the individual atoms dominate the thermal agitations. But, the thermal agitations succeed in changing the direction of magnetization of the entire particle. As a result, the directions of magnetic moments of the particles in the crystal are arranged randomly. Thus the net magnetic moment is zero; this phenomenon gives rise to the limitation of how small magnetic recording media can get because super paramagnetic will cause the particles to lose their memory from thermal influences. Super paramagnetic particles are therefore often used in many magnetic systems in the biomedical field because not only are they small, but they also do not retain any magnetic permanence. The latter reason is important because it means that the particles will not aggregate due to magnetic forces, however the trade-off is that the particles are paramagnetic in behavior and therefore it is more difficult to achieve a high magnetization. For these reasons, this research aimed to use particles that were in the size range of a few hundred nanometers, thus allowing them to retain their ferromagnetic properties yet still be small enough to flow through blood capillaries if necessary. As we will see in the experimental chapter, the particles are very soft magnets and have only a small remnant magnetization.

B. Hydrocarbon refrigerants

1) R290/R600a (Propane + Isobutane)

It is an azeotropic mixture of propane (R290) & isobutane (R600a). It has properties very similar to R12 &R134a which are the commonly used refrigerant nowadays. It contains 60%propane+40%iso butane. It is named as mint gas because it has cooling property like mint. Moreover it has zero ozone depletion potential and a reliable global warming potential (the two property due to which we need to replace the CFC's). This blend is used for domestic refrigerators because of its following reasons: [3]

1. Zero GWP
2. Compatible with mineral oil.
3. Pressure same as in R12 system. Almost like a drop in substitute.
4. Low discharge/winding temperatures.
5. Quantity of charge very small.
6. Easily available.

2) R-12 Dichlorodifluoromethane (CCL2F2)

R-12 is a very popular refrigerant. It is a color less almost odorless liquid with boiling point of -290C at atmospheric pressure. It is non-toxic, non-corrosive, non-irritating and non-flammable. It has a relatively low latent heat value which is an advantage in small refrigeration machines. R-12 has a pressure of 0.82 bar at -150C and a pressure of 6.4 bar at 300 c. The latent heat of R-12 at -150Cis 159KJ/kg [3].

3) R-134a Tetraflouroethane (C2H2F4)

The preferred replacements of R-12 can be the HFC refrigerants R-134a. This has a boiling point of -26.20C which bears reasonable comparison with the boiling point of R-12 (-29.80C). R-134 is a not a drop in replacement of R-12 because the refrigerating effect is slightly different. This would appear to be non-flammable and nontoxic substitute for R-12 at extreme pressure ratios [3].

4) R152a

R152a or difluroethane is an ecological refrigerant for positive temperature refrigeration, direct replacement for R134a is being commonly used as an aerosol propellant, foaming agent, or as a component in several refrigerant blends.

2. Procedure carried out to check effect of magnetic field on refrigeration (Literature survey)

Experimentation is carried out with and without the application of magnetic field. Following procedure is to be followed while carrying out experimentation [2].

- Plug in and switch on the setup.
- Ensure that the suction and discharge pressure is constant.
- Connect all the thermocouples to the points specified.
- Switch the thermocouple setting to Kelvin.
- Take the first reading of the temperatures after starting the setup.
- Repeat the above point after the interval of 20 to 30 min.
- Repeat it until the compressor stops working and note down the temperature.
- Now use permanent magnets of different strengths at condenser exit and repeat the whole procedure.

3. Effect of magnetic field

A. Compressor power

When magnetic field is applied to the condenser exit line, its increases vaporization of liquid refrigerant and reduces compressor power consumption. Hence, increases in gauss level decrease the compressor power. Figure1 show compressor power versus magnetic field strength for R134a, R152a, R407A As the gauss level increases compressor power decreases.

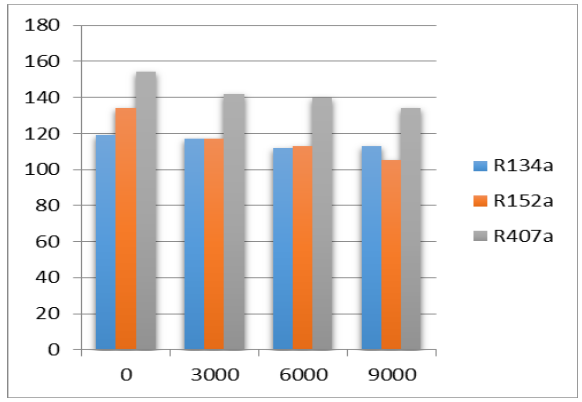

Fig. 1. Compressor power vs. Magnetic field

B. Refrigeration effect

The Fig. 2, represent effect of magnetic field on the refrigeration effect As the number of magnetic pair increases, the refrigerating effect also increases up to third 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.

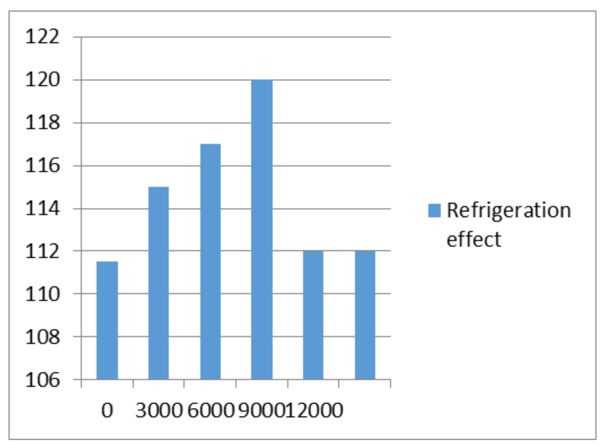

Fig. 2. Refrigeration effect vs. Magnetic field

C. COP

The Fig. 3, shows relationship between the number of magnetic pairs and improvement in COP for R134a With the application of magnetic field up to 3 pairs the refrigerant effect increases and drops in power required by the compressor, hence improvement in the COP was observed, beyond the 3 pair's evaporative capacity drops resulting in a drop in the COP.

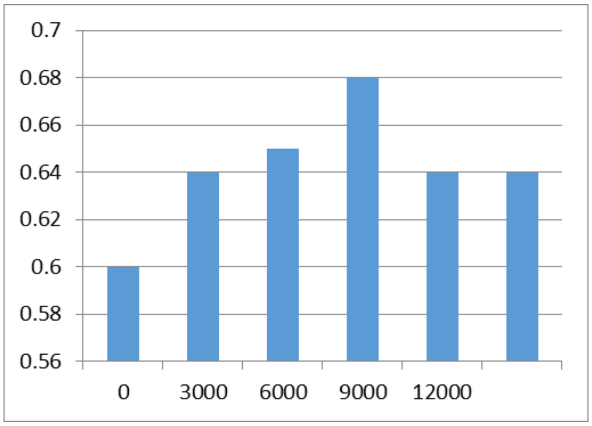

Fig. 3. COP vs. Magnetic field

4. Conclusion

This study concludes that improvement in COP refrigerant systems on application of magnetic field. The compressor power savings of vapour compression refrigeration system with the different refrigerants like R134a, R151a, R407a under the effect of magnetic field is studied. Non-Hydrocarbon refrigerant (R134a) did not show improvement in performance on application of magnetic field.

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