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Experimental analysis of R134a Vapour Compression Refrigeration System by using permanent magnetic field at liquid line

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ABSTRACT

This paper represents experimental investigation carried out to study the effect of magnetic field on energy savings in vapour compression refrigeration system. By applying magnetic field at liquid line, 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 in vapour 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 in different positions. The strength of each magnetic pair was 100gauss. By the impact of magnetic field by the magnetic pair in different positions at liquid line, the COP increased upto 41.36% for R134a refrigerant when compared to simple VCR.

Keywords – COP, liquid line, magnetic field, magnetic pair, refrigerant

1. Introduction

Heat is transferred from the low temperature source to the high temperature source during the refrigeration process. A refrigerator is a machine that keeps the internal temperature below the ambient temperature. Due to the effects of global warming, people are more interested in appliances that provide thermal comfort, such as refrigerators and air conditioners. Small improvements in the VCR system's performance (i.e., COP) will result in significant increases in energy savings. In a straightforward VCR system, refrigerant circulates across the circuit via pipes. Due to heat interactions, it undergoes phase transitions (from liquid to vapour and back again) as it moves through the circuit.

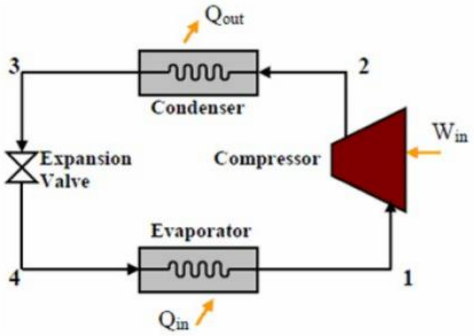


Fig.1. vapour compression cycle

Compressor, condenser, expansion valve, and evaporator are the main four components of a simple VCR system. Compressor and expansion valve were two of the circuit's components intended for pressure fluctuation, while condenser and evaporator were intended for temperature variation.

1.1 T-S diagram of Vapour Compression Cycle

The vapour compression refrigeration cycle's T-S diagram is displayed below, along with a description of each stage.

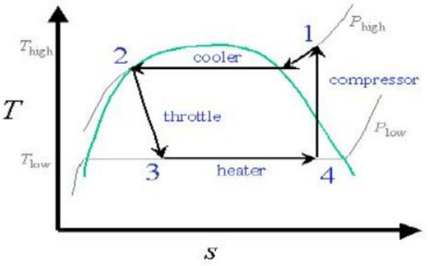


Fig.2. T-S diagram of vapour compression cycle

Compression (Process 4-1): Fig.2, Displays the T-S diagram of the vapour compression cycle, in which the pressure is raised from Plough to Phigh as the refrigerant is compressed using a compressor. Additionally, it boosts the refrigerant's temperature above that of the surrounding air. It finally exits the stage as a hot vapour.Electricity is essential to run a refrigerator since the compressor requires energy.

Condensation (Process 1-2): The heat of the refrigerant is dissipated to the surroundings at this stage by a coiled tube with aluminium fins. The evaporator and this device are quite similar, however they could be of different sizes. The outside air absorbs energy as the hot vapour passes through the condenser, and the refrigerant turns into a saturated liquid.Evaporation, which serves as the foundation for the third step of the process, will now begin with the slightest decrease in pressure.

Expansion (Process 2-3): Since this was the first issue, this procedure holds the key to the entire cycle. Here, a throttle or expansion valve is used to throttle the condensed vapour, causing a sharp reduction in pressure that ultimately lowers temperature. By utilising the auto-refrigeration effect, this is accomplished. This chilly liquid-vapor mixture now moves into the cycle's closing phase.

Evaporation (Process 3-4): A device known as an evaporator, which has a huge surface area and typically consists of a coiled tube surrounded by aluminium fins, is where the refrigerant passes through. A blend of liquid and vapour refrigerant makes up the cold fluid.All of the liquid is evaporated as the refrigerant flows through the evaporator and absorbs heat from the enclosed area (low temperature region). The absorbed energy is used to convert the refrigerant from a liquid to a vapour. The refrigerant's cooling effect is measured by the energy it absorbs. It also decreases the temperature of any food or beverages that may be kept there. As a saturated vapour, the refrigerant leaves this stage and enters the compressor stage, where the cycle is repeated.

2. Literature Review

Previous studies have looked into the usage of magnetic fields in refrigeration systems. These investigations have demonstrated that magnetic fields can significantly affect the coefficient of performance (COP), refrigerant flow, and heat transfer of refrigeration systems. However, a thorough investigation of the precise effects of magnetic fields on the R134a Vapour Compression Refrigeration System is lacking. The purpose of the current study is to experimentally investigate how an R134a Vapour Compression Refrigeration System responds to permanent magnetic fields at the liquid line.

In refrigeration systems, magnetic fields have been employed to increase efficiency and lower energy usage, among other things. By changing the thermodynamic properties of the refrigerant and impacting the flow and heat transfer of the refrigerant, magnetic fields have been proven in earlier research to have a considerable impact on the operation of refrigeration systems.

The effect of magnetic fields on the flow of refrigerant and the transfer of heat in refrigeration systems has been examined in a number of research. Wang et al. (2018), for instance, looked at how a magnetic field affected the flow characteristics of a refrigerant in a horizontal channel and discovered that the magnetic field had a considerable impact on the refrigerant's velocity distribution. Similar to this, Zhang et al. (2016) researched how a magnetic field affected a refrigerant's ability to transmit heat in a heat exchanger and discovered that the magnetic field can greatly increase the heat transfer coefficient.

Magnetic fields can also have an impact on the thermodynamic characteristics of the refrigerant, including density, viscosity, and specific heat. For instance, Li et al. (2019) examined how a magnetic field affected the thermodynamic characteristics of R134a and discovered that it had a considerable impact on the refrigerant's specific heat and viscosity.

3. Methodology

The use of permanent magnetic field in a R134a vapour compression refrigeration system at the liquid line can potentially improve the system's efficiency and performance. However, the methodology for implementing such a system would require careful consideration and analysis. Here are some steps that could be followed

3.1 Experimental setup

The first step is to assemble the experimental setup consisting of a vapour compression refrigeration system with a permanent magnet installed at the liquid line. The refrigeration system include a compressor, condenser, evaporator, expansion valve and refrigerant lines. The permanent magnet should be installed at the liquid line, before the expansion valve. The system should also be equiped with instruments for measuring various parameters such as temperature, pressure. The instruments should be calibrated before used.

Fig.3. Experimental setup of VCRS in Front view

Fig.4. Experimental setup of VCRS in Top View

3.2 System Preparation

Before starting the experiment, the refrigeration system was charged with R134a refrigerant with a charge of 0.7kg. The refrigerant was charged into the system through the suction line. The system was then operated at a pressure of 8 bar and a temperature of 35°C. The system was allowed at stabilize for 30 minutes before the experiment was conducted. The flow rate of refrigerant was measured using a digital flow meter. The temperature and pressure of the refrigerant were measured using digital thermocouples and pressure gauges, repectively. The power consumption of the compressed using a wattmeter. The experimental setup was then ready for testing.

Fig.5. Liquid line without magnet pairs

Fig.6. Liquid line with magnet pairs

3.3 Data acquisition

Data should be collected on the system's performance undner different operation conditions, with and without the magentic field. Record the system's compressor power consumption and other relevant parameters such as evaporator and condenser temperatures, condensing and evaporating pressures, and subcooling and superheating. The data should be collected at regular intervals, and multiple readings should be taken to ensure accuracy.

The data collected from the experiments is analyzed and interpreted to determine the impact of the permanent magnetic field on the refrigeration system's performance and efficiency. This analysis may involve comparing the results with the baseline data and evaluating the effect of varying the magnetic field strength. The analysis may also involve statistical analysis to determine the significance of the results obtained.

Based on the results of the experiments, conclusions are drawn about the effectiveness of using a permanent magnetic field at the liquid line of the refrigeration system. Recommendations may be made for further experiments to explore the effects of different magnetic field strengths or to optimize the placement of the magnet. The conclusions and recommendations should be based on the analysis of the data collected and should be supported by appropriate evidence.

Overall, the experimental analysis of an R134a vapour compression refrigeration system using a permanent magnetic field at the liquid line is a complex process that requires careful planning, execution, and analysis. The results obtained from such experiments can provide valuable insights into the effectiveness of using magnetic fields to enhance the performance and efficioency of refrigeration systems.

4. Significance of R134a

Tetrafluoroethane is a refrigerant that is commonly used in vapour compression refrigeration (VCR) systems. It is a hydrofluorocarbon (HFC) refrigerant that has a low global warming potential (GWP) and ozone depletion potential (ODP), making it a popular choice as a replacement for older refrigerants that have a higher environmental impact. It has the formula CF_3CH_2F which consists of four Flourine atoms, two Hydrogen atoms and two Carbon atoms.

R134a plays a critical role in the refrigeration cycle. R134a is used as the working fluid in this cycle, circulating through the system and undergoing phase changes to transfer heat. The compressor compresses the R134a vapour, raising its temperatures and pressure. The hot, high pressure vapour then flows into the condenser, where it releases heat to the surrounding environment and condenses into a liquid. The liquid R134a then passes through the expansion valve, where it undergoes a pressure drop and flashes into a low pressure, low temperature vapour.This cold vapour then flows into the evaporataor, where it absorbs heat from the surrounding environment, such as the air inside a refrigerator or freezer.After absorbing heat in the evaporator, the R134a vapour returns to the compressor to start the cycle again. This passes of compression, condensation, expansion, and evaporation allows the R134a to effectively transfer heat and provide cooling in vapour compression refrigeration systems.

Table.1. Properties of R134a

Properties	R134a
Boiling Point	-14.9ºF or -26.1ºC
Auto–Ignition Temperature	1418ºF or 770ºC
Ozone Depletion Level	0
Solubility in water	0.11% by weight at 77ºF or 25ºC
Critical Temperature	252ºF or 122ºC
Cyliner Color Code	Light Blue
Global Warming Potential	1200

5. Role of Diffuser in Vapour Compression Refrigeration System

A diffuser is a crucial part of the system's compressor in Vapour Compression Refrigeration (VCR). The compressor is in charge of increasing the refrigerant vapor's pressure and pumping it through the system. The diffuser slows down the high-velocity refrigerant vapour and transforms its kinetic energy into pressure energy. It is situated at the compressor outlet.

Fig.7. Back view and Front view of Diffuser

The refrigerant vapour's velocity is reduced and its pressure is raised as a result of the diffuser's steady rise in the cross-sectional area of the compressor outlet. By requiring less effort to compress the refrigerant vapour, the diffuser increases the compressor's efficiency. This is because the diffuser minimises the amount of energy lost as heat and lessens the pressure losses that happen as the refrigerant vapour passes through the compressor.

The diffuser contributes to the proper distribution of the refrigerant vapour to the system's condenser and evaporator in addition to increasing compressor efficiency. The diffuser ensures that the refrigerant is dispersed uniformly throughout the system by reducing the velocity of the refrigerant vapour. This helps to prevent uneven flow distribution. The VCR system's performance and dependability may be enhanced as a result.

By minimising the effort needed to compress the refrigerant vapour and ensuring that the refrigerant is spread uniformly throughout the system, the diffuser is crucial to the proper operation of a VCR system.

5.1 Specifications of Diffuser

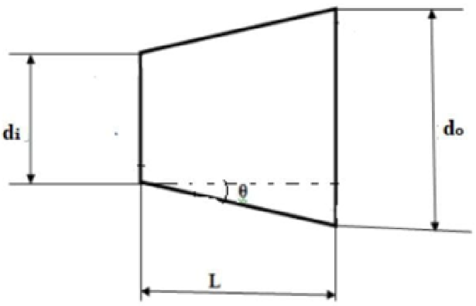


Fig.8. Line diagram of Diffuser

Inlet diameter, di = 6.35mm
Outlet diameter, do = 7.93mm
Length of the diffuser, L = 30.15mm

Tan ɵ = (do – di) / 2 * L
Tan ɵ = (7.93 – 6.35) / (2 * 30.15)
Divergance angle, ɵ = 1.5

6. Observations

6.1 Normal Flow

Table.2. Readings in Normal flow

Magnetic field strength (gauss)	Energy meter reading		Temperatures	
	Initial	Final	Intial	Final
0	3.31	3.41	25.3	4.2
100	2.48	2.57	25.3	3.5
200	2.66	2.74	25.2	3.9
300	2.82	2.89	25.7	4
400	2.96	3.02	25	4

6.2 Diffuser Flow

Table.3. Readings in Diffuser flow

Magnetic field strength (gauss)	Energy meter reading		Temperatures	
	Initial	Final	Initial	Final
0	3.21	3.31	25.3	3.8
100	2.41	2.49	26.6	3.4
200	2.58	2.65	26.4	3.2
300	2.74	2.8	25	4.6
400	2.9	2.95	25.2	4.7

7. Calculations

7.1 Nomenclature

Qc	Cooling capacity of the refrigeration system, J
Win	Input power of the compressor
m	Mass, kg
Cpw	Specific Heat Capacity of water , J/kg*k
ΔT	Temperature Change, °C
Ti	Intitial Temperature, °C
Tf	Final Temperature, °C

7.2 Formulas

The formula for determining a refrigeration system's Coefficient of Performance (COP) is:

COP = Qc / Win (1)

The formula for specific heat capacity is:

Qc = mCpΔT (2)

7.3 COP in Normal Flow

7.3.1 Without magnetic field

Qc = 3.9 * 4.2 * 21.1 = 345.618

Win = 0.1 * 3600 = 360

COP = 0.96

7.3.2 With magnetic field

7.3.2.1 With magnetic strength of 100 gauss

Qc = 3.9 * 4.2 * 21.8 = 357.084

Win = 0.09 * 3600 = 324

COP = 1.10

7.3.2.2 With magnetic strength of 200 gauss

Qc = 3.9 * 4.2 * 21.3 = 348.894

Win = 0.08 * 3600 = 288

COP = 1.21

7.3.2.3 With magnetic strength of 300 gauss

Qc = 3.9 * 4.2 * 21.7 = 355.4

Win = 0.07 * 3600 = 252

COP = 1.4

7.3.2.4 With magnetic strength of 400 gauss

Qc = 3.9 * 4.2 * 21 = 343.98

Win = 0.06 * 3600 = 216

COP = 1.59

7.4 COP in Diffuser Flow

7.4.1 Without magnetic field

Qc = 3.9 * 4.2 * 21.5 = 352.17

Win = 0.1 * 3600 = 360

COP = 0.97

7.4.2 With magnetic field

7.4.2.1 With magnetic strength of 100 gauss

Qc = 3.9 * 4.2 * 23.2 = 380.016

Win = 0.08 * 3600 = 288

COP = 1.319

7.4.2.2 With magnetic strength of 200 gauss

Qc = 3.9 * 4.2 * 23.2 = 380.016

Win = 0.07 * 3600 = 252

COP = 1.5

7.4.2.3 With magnetic strength of 300 gauss

Qc = 3.9 * 4.2 * 20.4 = 334.152

Win = 0.06 * 3600 = 216

COP = 1.54

7.4.2.4 With magnetic strength of 400 gauss

Qc = 3.9 * 4.2 * 20.5 = 335.79

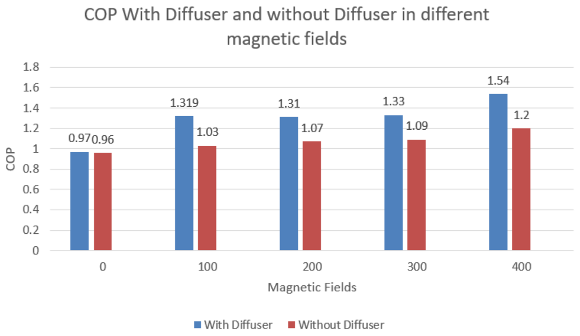
Win = 0.05 * 3600 = 180

COP = 1.86

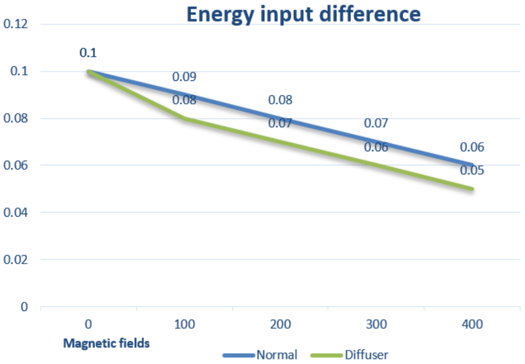
8. Results

Table.4. COP in diffuser and normal flow

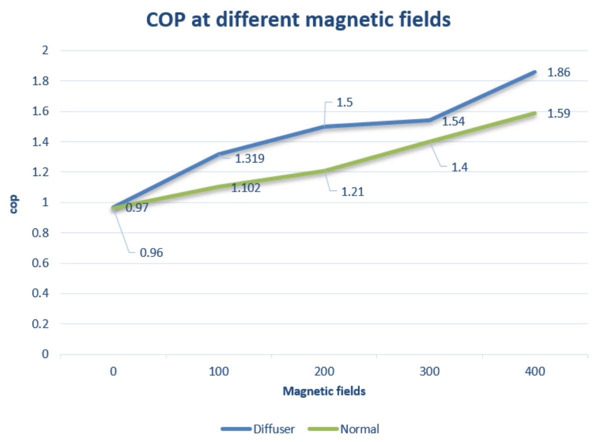
Magnetic field (Gauss)	COP with diffuser	COP without diffuser
0	0.97	0.96
100	1.319	1.102
200	1.5	1.21
300	1.54	1.4
400	1.86	1.59



Graph.1. COP With Diffuser & Without Diffuser



Graph.2. Energy input difference vs Magnetic fields



Graph.3. COP at different magnetic fields vs Magnetic fields

9. Conclusion

The installation of a magnetic field can improve the performance of the system, according to experimental examination of a vapour compression refrigeration system using a permanent magnetic field at the liquid line. Utilising a magnetic field has benefits for the system's cooling capacity and coefficient of performance (COP), as well as for the system's refrigerant flow and heat transfer properties. One limitation is that R134a was the sole refrigerant used in the experiment; it is unknown whether other refrigerants would produce the same findings. The experimental analysis of a vapour compression refrigeration system utilising a permanent magnetic field at the liquid line has shown the potential advantages of using magnetic fields to boost the performance of refrigeration systems.

9. Reference

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