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Simulation and Performance Analysis of Vapour Compression Refrigeration System Using MATLAB

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Abstract - The ever-increasing demand for efficient and environmentally sustainable refrigeration systems necessitates a comprehensive analysis of energy and exergy performance in Vapor Compression Refrigeration Systems (VCRS). , focusing on key refrigerants, namely R134a, R1234yf, and their mixtures, employing advanced tools such as MATLAB simulation and Refprop software. The report delves into the environmental impacts associated with the use of different refrigerants, contributing to the broader discourse on sustainable refrigeration solutions. A detailed exploration of the working principles of VCRS follows, elucidating the thermodynamic processes within each component compressor, condenser, expansionvalve, and evaporator. This understanding is crucial for contextualizing the subsequent energy and exergy analyses. The project leverages MATLAB simulation to model and analyze the VCRS, simulating diverse scenarios to assess performance under varying conditions. Additionally, Refprop software is employed to extract precise thermo physical properties of R134a, R1234yf, and their mixtures, enhancing the accuracy of the simulation. Individual analyses of R134a and R1234yf provide insights into their specific contributions to energy and exergy efficiency. Furthermore, a meticulous examination of mixture configurations aims to identify synergies or trade-offs in performance, guiding future refrigerant selection and system design.

Key Words: Refrigerant, hydro fluorocarbons, NIST REFPROP

1. INTRODUCTION

The landscape of refrigeration and air conditioning systems has undergone a transformative journey marked by technological advancements and a growing awareness of environmental impacts. The quest for energy efficiency and sustainable practices within these systems has prompted an in-depth exploration of their energy and exergy performances. From the early use of toxic and flammable substances to the advent of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), the refrigeration industry has witnessed significant milestones. These milestones, however, were accompanied by unintended consequences, particularly regarding environmental sustainability. This historic agreement marked a commitment to safeguarding the Earth's ozone layer, paving the way for the gradual phase-out of the first-generation refrigerants. The subsequent generations of refrigerants, including HCFCs and hydrofluorocarbons (HFCs), were introduced as interim solutions, offering reduced ozone-depleting potential. However, with the realization that HFCs contribute significantly to global warming, discussions intensified around identifying environmentally friendly alternatives. This led the emergence of fourth-generation refrigerants, such as Hydrofluoroolefins (HFOs) like R1234yf, designed to address both ozone layer depletion and global warming concerns Against this backdrop, the present project seeks to conduct a detailed analysis ofthe energy and exergy performances of VCRS, focusing on the implications of transitioning through various generations of refrigerants. By examining the historical context and the impact of international agreements like the Montreal Protocols, the project aims to contribute insights into the evolution of refrigerants, emphasizing the need for sustainable practices in the design and operation of refrigeration systems. Through rigorous analyses and consideration of environmental factors, this study aims to inform future decisions in refrigerant selection, aligning with global efforts towards energy efficiency and environmental stewardship.

2. LITERATURE REVIEW

[1] P Saji Raveendran and S Joseph Sekhar evaluate the performance of low and medium temperature refrigeration systems of capacities 190 and 285 liters, respectively, using different hydrofluoroolefin/hydrofluorocarbon (HFO/HFC) mixtures. Mathematical simulation is employed to assess the performance of these systems. The software tool 'MATLAB' and the refrigerant property database 'REFPROP' are utilized for simulation purposes. The simulation results indicate that the coefficient of performance (COP) of HFO refrigerants and their mixtures decreases by 2.4 to 15.7% compared to HFC-134a. Among the mixtures investigated, HFO-1234ze/HFC-134a (90/10) demonstrates superior performance. Its predicted COP and exergetic efficiency are 4-8.3% and 5.1- 10.5% higher, respectively, than those of the other mixtures considered in this study.

[2] Tauseef Aized , Muhammad Rashid did comprehensive first- and second-law analysis of vapor compression refrigeration to identify working fluids with reduced global warming potential (GWP) and exergy destruction, suitable replacements for R134a. The study evaluates six refrigerants: R717, R1234yf, R290, R134a, R600a, and R152a.The analysis revealed that the compressor consistently exhibited the highest exergy destruction among the components. R152a emerged as the most promising refrigerant due to its zero ozone depletion potential (ODP), relatively low GWP of 140, and reduced exergy destruction and irreversibilities. Its favorable thermodynamic characteristics and ease of use make it a suitable replacement for R134a, requiring minimal modifications to existing systems.

[3] Xiucan Jia, Jian Wang and Xiaopo Wang R1234yf and R1234ze(E) have emerged as promising alternatives to HFC-134a, a widely used refrigerant with a high global warming potential (GWP). However, the phase behavior and thermodynamic properties of these refrigerants, particularly in the presence of lubricants, are not fully understood. This study investigates the solubility, enthalpy, enthalpy change ratio, and non-evaporated quantity of R1234yf/POE75 and R1234ze(E)/POE75 mixtures at various oil circulating mass fractions and superheats. The study provides valuable insights into the phase behavior and thermodynamic properties of R1234yf/POE75 and R1234ze(E)/POE75 mixtures. The findings suggest that the presence of oil significantly influences the enthalpy, enthalpy change ratio, and non-evaporated quantity of these refrigerants. These results can inform the design and optimization of refrigeration systems using R1234yf and R1234ze(E) as environmentally friendly alternatives to HFC-134a.

3. OBJECTIVE OF PROJECT WORK

3.1 MATLAB Simulation:

- Develop a robust simulation model using MATLAB to replicate thedynamic behavior of the VCRS under various operating conditions.

- Utilize the simulation model to analyze the system's response to changes in parameters, providing insights into its transient behavior and performance stability.

3.2 Refprop Software Utilization:

- Employ Refprop software to obtain accurate thermophysical properties of refrigerants, ensuring the precision of simulation results.
- Validate the simulation outcomes by comparing them with data derivedfrom Refprop, enhancing the reliability of the analysis.

4. ENVIRONMENTAL IMPACTS

4.1 Ozone Layer Depletion (ODP)

Ozone layer depletion is a serious environmental concern associated with certain refrigerants, particularly chlorofluorocarbons (CFCs) and some hydrochlorofluorocarbons (HCFCs). These substances have the potential to release chlorine and bromine atoms into the stratosphere, leading to the breakdown of ozone molecules.

4.2 Global Warming Potential (GWP):

Global Warming Potential is a measure of the heat-trapping ability of a substance relative to carbon dioxide over a specified time period. It addresses the role of refrigerants in contributing to climate change, with a focus on the greenhouse effect.

5. REFPROP SOFTWARE

REFPROP is a computer program developed by the National Institute of Standards and Technology (NIST) that provides thermodynamic and transport property data for pure fluids and mixtures. It is widely used in engineering and scientific applications for a variety of purposes, including:

- Designing and analyzing thermalsystems
- Predicting the behaviour of fluids in various processes
- Developing and calibrating models of fluid behavior

6. MATLAB SOFTWARE

MATLAB is a proprietary programming language and numeric computing environment developed by MathWorks. It is widely used in academia and industry for a variety of purposes, including:

- Data analysis and visualization
- Algorithm development
- Modelbuilding and simulation
- Application prototyping
- Education

MATLAB is based on the matrix programming paradigm, which allows for efficient manipulation of matrices and arrays. It also includes a comprehensive set of built- in functions for a variety of mathematical and engineering tasks.

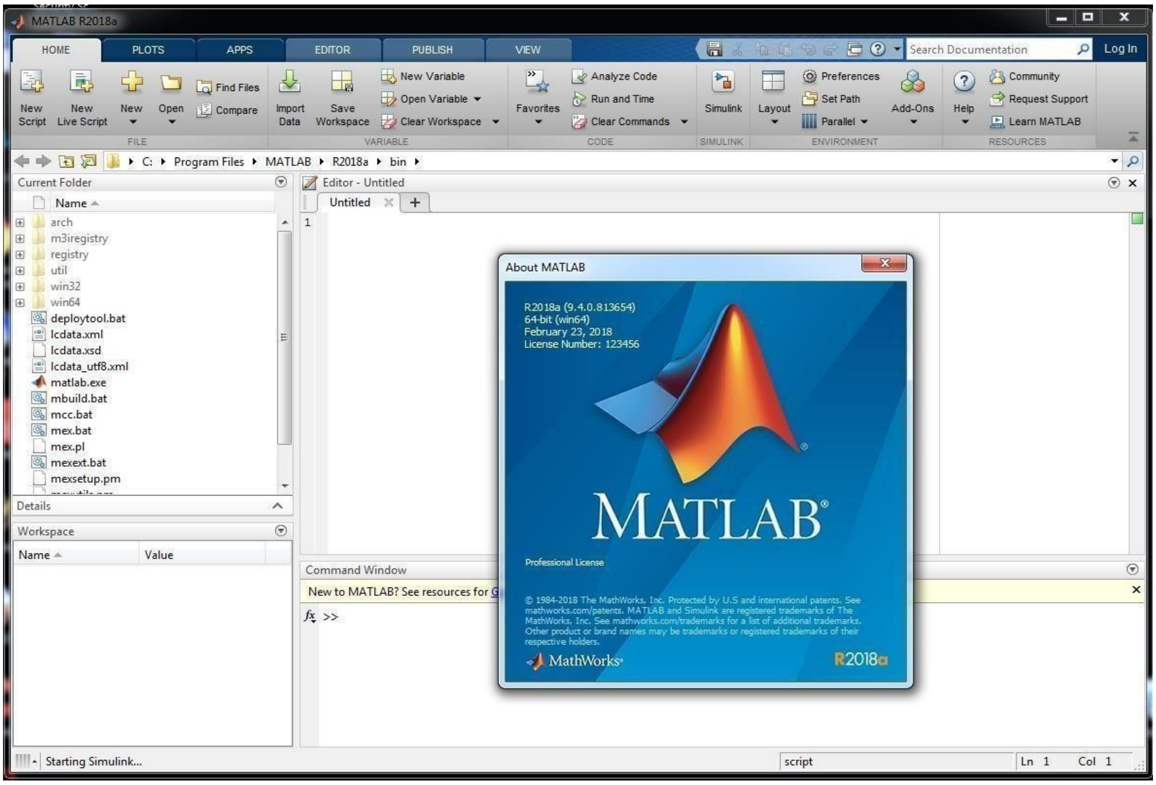

Fig 6.1 MATLAB software

7. ANALYSIS OFMIXTURE

In the study of multiple refrigerant combinations of R134a, R1234yf, R32 and R152a. The following combination given the better performance:

7.1 44% of R134a and 56%of 1234yf:

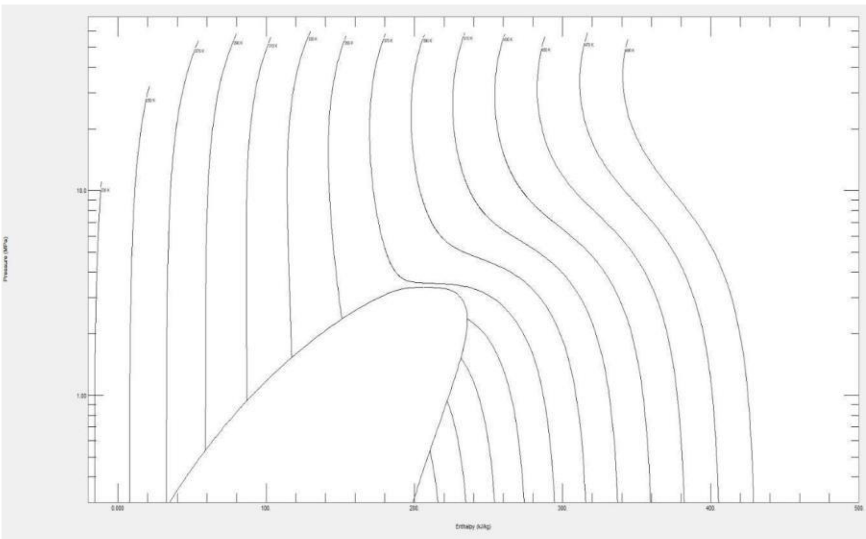

Fig 7.1 Pressure Vs Enthalpy plot

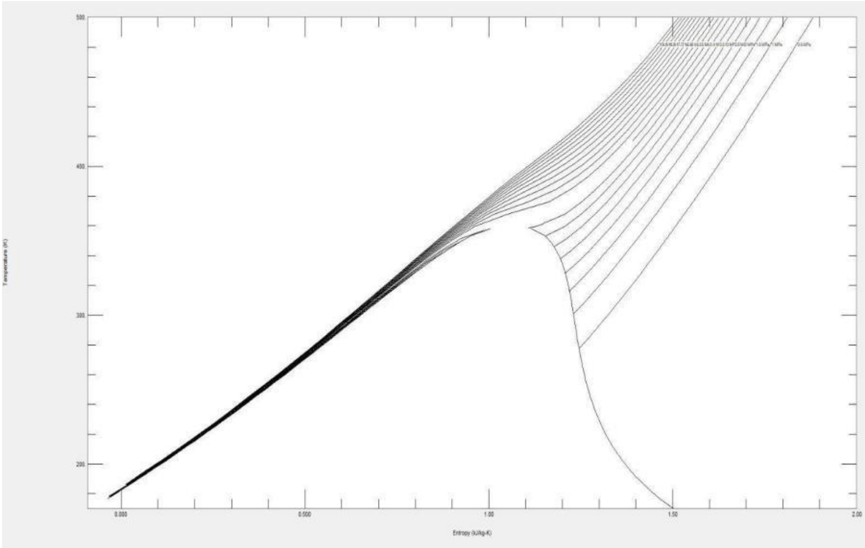

Fig 7.2 Temperature Vs Enthalpy plot

72 70% of R1234yf and 12% ofR152a and 18%of R32:

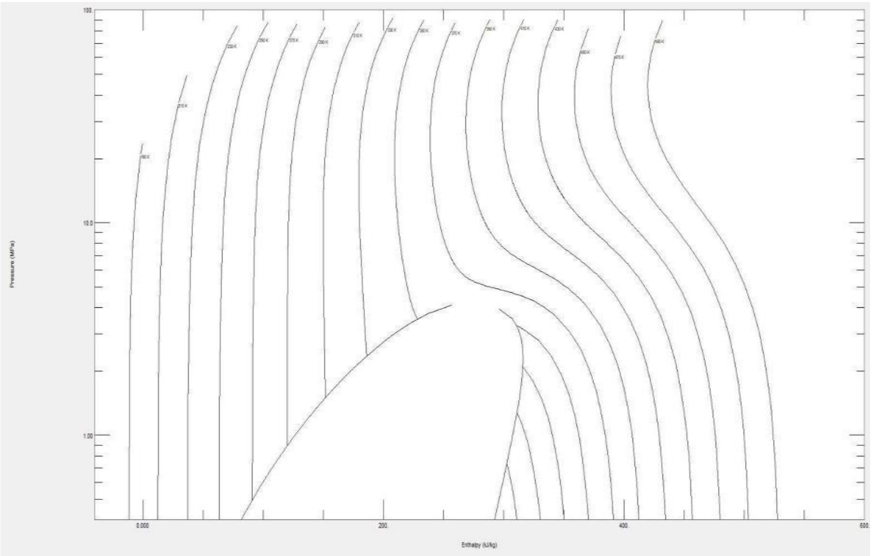

Fig 7.3 Pressure Vs Enthalpy plot

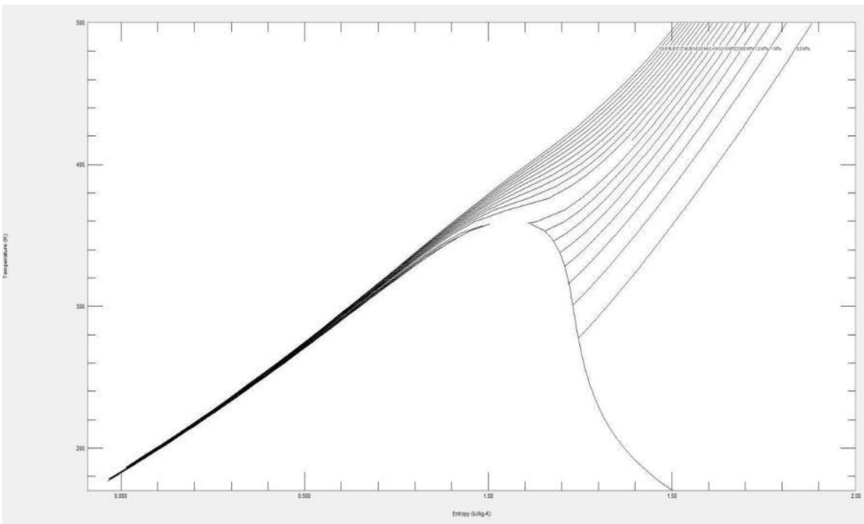

Fig 7.4 Temperature Vs Enthalpy plot

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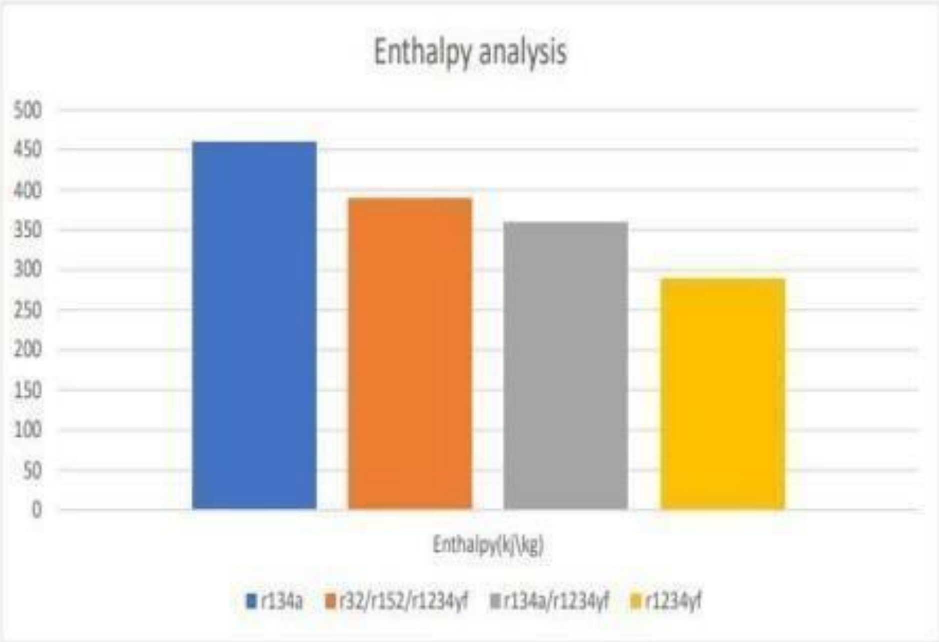
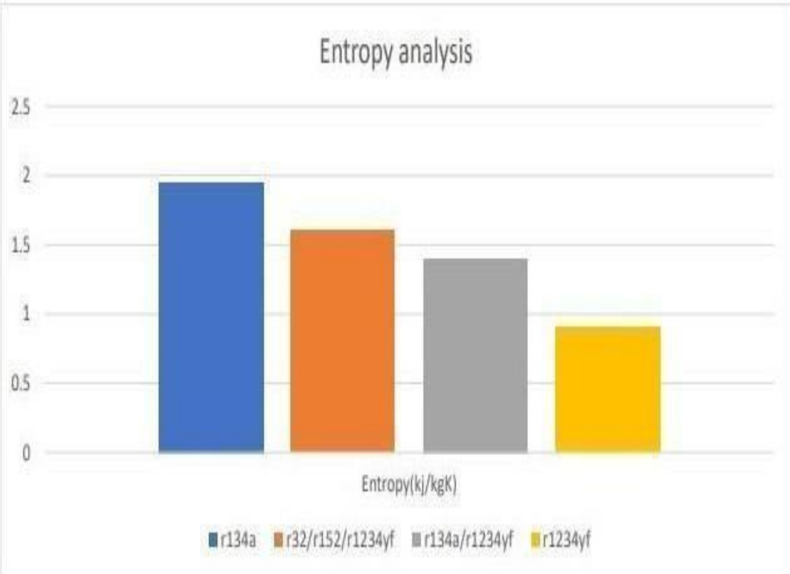
8. RESULT AND DISCUSSION

Refrigerant	r134a	r32/r152/r1234yf	r134a/r1234yf	r1234yf
Enthalpy(kj\kg)	460	390	360	290



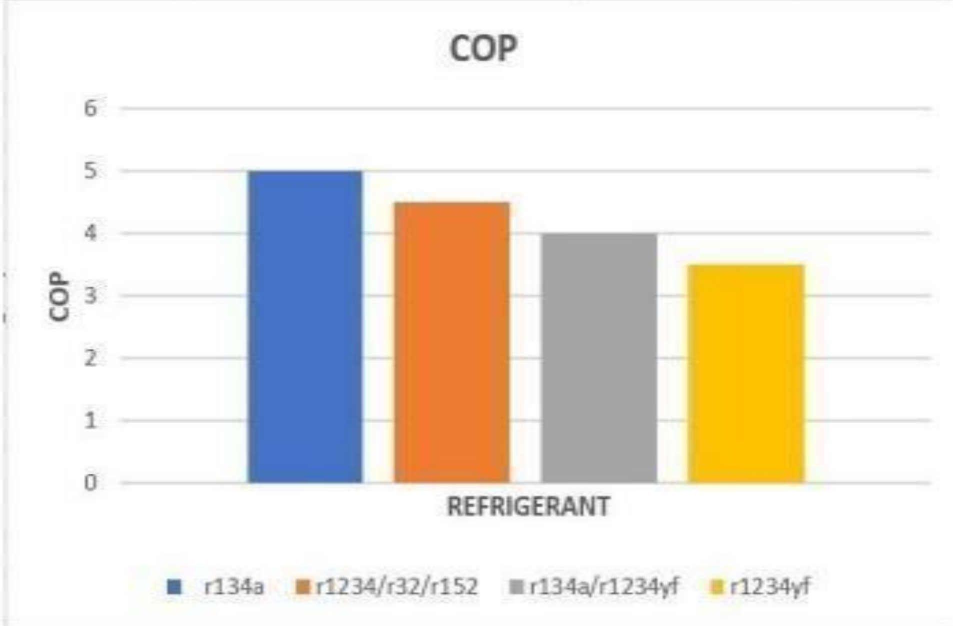
Graph 8.1 Enthalpy analyses (1bar@300k)

Refrigerant	r134a	r32/r152/r1234yf	r134a/r1234yf	r1234yf
Entropy(kj/kgK)	1.95	1.6	1.4	0.9



Graph 8.2 Entropy analyses (1bar@350k)

refrigerant	r134a	r1234/r32/r152	r134a/r1234yf	r1234yf
cop	5	4.5	4	3.5



Graph 8.3 COP Analysis

9. CONCLUSION

Experimental Analysis have been done using MATLAB for the refrigerants R32,R152a,R1234yf and R134a its mixtures of various compositions in vapor compression refrigeration systems with condenser temperature at 40 °C an evaporator temperature at 15 °C. From the results following conclusions were made:

- The COP of the system for the refrigerant mixture composition (R32/R152a/R1234yf) is nearer and slightly lesser to baseline refrigerant R134a by 1.05%.
- Refrigeration effect of the system is increased 3 % for the mixture composition (R32/ R1234yf/R152a) (18:70:12) and the average value of this mixture is 6.1594. (R134a – 5.98)
- Compressor work required is decreased 2.8 % for the mixture composition (R32/R1234yf/R152a) and the average value of this mixture is 7.3872. (R134a – 7.6)
- Compressor discharge temperature is decreased upto 3.5% for the mixture composition (R32/R1234yf/R152a) and the average value of this mixture is 81°C. (R134a – 84°C)

Hence it is concluded the mixture composition of (R32/R152a/R1234yf)(18:70:12) will be a best alternative for R134a in a vapour compression refrigeration system.

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