EXPERIMENTAL STUDY ON PERFORMANCE OF ECO-FRIENDLY REFRIGERANTS IN VAPOR COMPRESSION REFRIGERATION SYSTEMS

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ABSTRACT

The environmental concerns caused by conventional refrigerants such as Chlorofluorocarbons (CFCs), Hydrochloro fluorocarbons (HCFCs), and Hydrofluorocarbons (HFCs) have encouraged the development of eco-friendly refrigerants for refrigeration applications. These conventional refrigerants are responsible for ozone depletion and global warming. This paper presents an experimental investigation on the performance of eco-friendly refrigerants in a Vapor Compression Refrigeration System (VCRS). Refrigerants namely R134a, R600a (Isobutane), and R290 (Propane) were tested under identical operating conditions. Performance parameters such as Coefficient of Performance (COP), power consumption, refrigeration effect, compressor work, and cooling capacity were analyzed. Experimental results indicate that hydrocarbon refrigerants provide superior performance with lower environmental impact compared to conventional refrigerants. R600a showed the highest COP, while R290 demonstrated better cooling capacity. The results confirm that eco-friendly refrigerants are suitable alternatives for future refrigeration systems.

Keywords— Eco-friendly refrigerants, Vapor Compression Refrigeration System, R600a, R290, R134a, COP, Refrigeration.

I. INTRODUCTION

Refrigeration systems are widely used in domestic, commercial, and industrial sectors for food preservation, thermal comfort, and industrial processes. Among all refrigeration systems, the Vapor Compression Refrigeration System (VCRS) is most popular due to its high efficiency and simple operation.

Traditionally, refrigerants such as R12, R22, and R134a have been used extensively. However, these refrigerants possess high Global Warming Potential (GWP) and Ozone Depletion Potential (ODP), which negatively impact the environment.

Due to international environmental regulations such as the Montreal Protocol and Kyoto Protocol, researchers have focused on eco-friendly refrigerants with:

- Zero ODP
- Low GWP
- Good thermodynamic properties
- Energy efficiency
- Safety and compatibility

Hydrocarbon refrigerants such as R600a and R290 have emerged as promising alternatives.

II. LITERATURE REVIEW

Several researchers studied the use of eco-friendly refrigerants in refrigeration systems.

R134a has been widely used due to its favorable properties, but its GWP is approximately 1430.

R600a possesses:

- ODP = 0
- GWP ≈ 3

It offers:

- Better COP
- Lower compressor work
- Lower electricity consumption

R290 also has:

- ODP = 0
- GWP ≈ 3

Advantages:

- High refrigeration effect
- Faster cooling
- Better heat transfer properties

Previous studies before 2023 reported that hydrocarbon refrigerants improve energy efficiency by 10–20% compared to conventional refrigerants.

III. EXPERIMENTAL SETUP

The experimental setup consists of:

1. Hermetically sealed compressor

2. Air-cooled condenser
3. Capillary tube
4. Evaporator
5. Pressure gauges
6. Temperature sensors
7. Energy meter

System Specifications

Component	Specification
Compressor	Hermetic type
Condenser	Air cooled
Expansion Device	Capillary tube
Evaporator	Copper coil
Power Supply	230 V AC

Refrigerants Used

- R134a
- R600a
- R290

IV. METHODOLOGY

The procedure followed during experimentation:

1. Refrigerant charging in system
2. Running system until steady-state
3. Recording pressures and temperatures
4. Measuring power consumption
5. Calculating COP and refrigeration effect

COP Formula

COP=Refrigeration Effect / Work Input

Refrigeration Effect = QL=h1−h4

Compressor Work = W=h2−h1

V. RESULTS AND DISCUSSION

Experimental Results

Refrigerant	COP	Power Consumption (W)	Cooling Capacity
R134a	2.85	180	Moderate
R600a	3.25	150	Good
R290	3.10	160	Excellent

Analysis

A. R134a

- Stable operation
- Higher energy consumption
- High GWP

B. R600a

- Highest COP
- Lowest power consumption
- Better energy efficiency

C. R290

- Higher cooling capacity
- Better refrigeration effect
- Slightly higher compressor load

The results show hydrocarbon refrigerants outperform conventional refrigerants.

VI. ENVIRONMENTAL IMPACT ANALYSIS

Refrigerant	ODP	GWP
R134a	0	1430
R600a	0	3
R290	0	3

Hydrocarbon refrigerants significantly reduce greenhouse gas emissions.

VII. CONCLUSION

This experimental study compared eco-friendly refrigerants in a Vapor Compression Refrigeration System.

Main conclusions:

- R600a gives highest COP
- R290 provides better cooling capacity
- Both have zero ODP and negligible GWP
- Eco-friendly refrigerants are viable replacements for R134a

Thus, hydrocarbon refrigerants can be effectively adopted in future refrigeration systems.

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