

Performance Evaluation of VCR System using Hydrocarbon Mixture as a Working Medium with Diffuser and Nozzle



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ABSTRACT In today's world, refrigeration systems have shown significant applications in both industrial and domestic sectors. The majority of the domestic sector refrigerators work on vapour compression system. The leakages of widely used hydro fluorocarbon refrigerants from refrigerator show a severe impact on the environment like global warming, ozone depletion, etc. In order to overcome these problems, eco-friendly refrigerants like hydrocarbons, their Mixtures, etc. are to be used in place of HFCs. In this experiment, the HC Mixture of both R600a and R290 is used. HC refrigerant has negligible GWP (0-3) and zero ODP. In the domestic refrigerator, the power requirement to compressor increases with an increase in compression load. The Diffuser reduces the mechanical work required for the compressor by providing extra work to the refrigerant and nozzle enhances the Refrigeration effect by providing an increase in velocity to the refrigerant. Experiments are conducted to analyse the performance.

Keywords- Hydrocarbon Mixture (R600a/R290), GWP, ODP, Diffuser, Nozzle, COP.

I. INTRODUCTION

Most of the domestic sector refrigerators work on vapour compression system. . The leakages of refrigerants from refrigerator show a severe impact on the environment like global warming, ozone depletion, etc. In order to overcome these problems, the HC Mixture of both R600a and R290 is used [1]. This refrigerant has zero ODP and negligible GWP (0-3) [2]. HC Mixture is an Eco-Friendly Refrigerant which is available at Low Cost can be used as an alternative to HFCs like R-134a [3]. For a refrigeration system, the coefficient of performance can be enhanced either by the reduction of compressor input work or by increasing the refrigeration effect [3]. Compressor input work can be reduced with the installation of the diffuser at the inlet of the condenser section. The diffuser converts the kinetic energy of a vapour refrigerant leaving compressor into pressure energy, which leads to a reduction of work input to the compressor.

Apart from this, the diffuser also reduces the vibrations that are occurred at the heat rejection section (condenser) due to refrigerant's high velocity at the compressor outlet [4]. Also, a nozzle is installed at the heat absorption section (evaporator) inlet to convert pressure energy into kinetic energy, with the installation of nozzle further expansion takes place leads to enhancement of refrigeration effect [6].

II. EXPERIMENTAL SETUP & METHODOLOGY

The main components used in the present work are proposed diffuser, proposed nozzle, R600a compressor, condenser, expansion valve (capillary tube) and evaporator. The line diagram of the proposed refrigeration system is shown in fig1. The proposed diffuser and the proposed nozzle are made of copper and figures are as shown in fig2&fig3 respectively. Line diagrams of the proposed diffuser and proposed nozzle are shown in fig4&fig5 respectively. For the tested refrigeration system, the Diffuser is installed between compressor and condenser converts the kinetic energy of a vapour refrigerant leaving compressor into pressure energy, reduces the work input to the compressor [4]. Also, a nozzle is installed at the inlet of the heat absorption section (evaporator), enhances the cooling rate of a refrigerator [7]. The Diffuser & Nozzle setup in a refrigeration system are as shown in fig6&fig7 respectively.

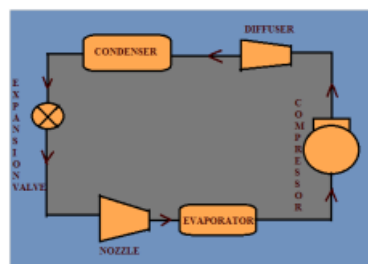


Fig 1: Proposed Refrigeration system



Fig 2: Proposed Diffuser

Revised Manuscript Received on 30 July 2019.

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Fig 3: Proposed Nozzle



Fig 7: Nozzle Experimental Setup

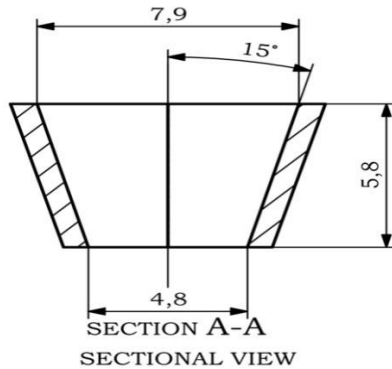


Fig 4: Line Diagram of Diffuser [4]

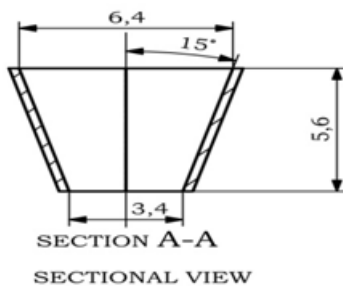


Fig 5: Line Diagram of Nozzle [6]



Fig 6: Diffuser Experimental setup

III. REFRIGERANT AND EXPERIMENTAL PROCEDURE

3.1 Hydrocarbon Mixture:

HC (Hydrocarbon) mixture can be used as an alternative refrigerant to HFC refrigerants as there is no fluorine element. A hydrocarbon (HC) includes naturally occurring substances like isobutane and propane. In many ways, Hydrocarbons has better properties like better efficiency, critical point, low toxicity, solubility, transport, energy efficiency, heat transfer properties, and environmentally sound but the major concern is HC's are flammable in nature [8]. About 35% of refrigerators in northern Europe are based on hydrocarbons. The Properties of Hydrocarbon Mixture Refrigerant are as follows [9] The Properties of Hydrocarbon Mixture Refrigerant are as follows [8]

3.2 Experimental Procedure:

The experimental test rig is developed from the 220L Refrigerator. At first R600a compressor is fixed and then nitrogen gas is filled in the Refrigeration system and then leak detection test (namely soap bubble test) was conducted and confirmed that there are no leakages In the system. Then vacuum is created by another compressor and then Hydrocarbon (propane+butane) Mixture refrigerant charged into the compressor [3]. At required places, Pressure and Temperature readings are noted by using pressure gauges and thermocouples respectively.

IV. PERFORMANCE PARAMETERS CALCULATION:

$$\text{Net Refrigeration Effect (NRE)} = h_1 - h_4$$

$$\text{Work of compression (W}_c) = h_2 - h_1$$

$$\text{Diffuser work (W}_d) = h_d - h_2$$

$$\text{Reduction in Compressor Work (W)} = W_c - W_d$$

$$\text{Coefficient of Performance (COP)}$$

$$= \text{NRE} / W$$

The values of enthalpies h_1, h_2, h_d, h_3, h_4 are taking from p-h chart.

V. RESULTS AND DISCUSSION:

A) COMPARISON OF REFRIGERATION EFFECT:

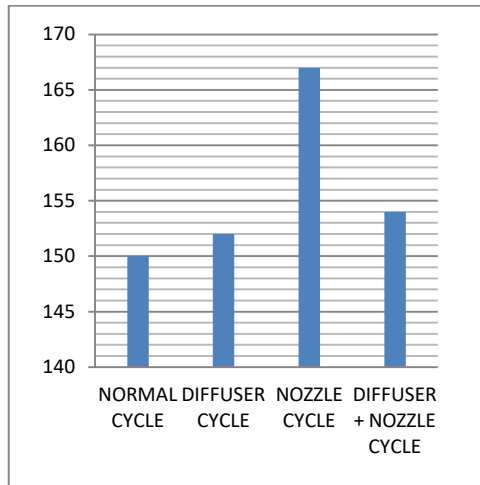


Fig 8: Comparison of Refrigeration Effect

The figure8 shows that the cooling capacity (Refrigeration Effect) for HC Mixture with nozzle at outlet of Expansion valve (capillary tube) is high when compared with other cycles, the refrigeration effect (Cooling Capacity) for Nozzle cycle is more because of the nozzle at the inlet of evaporator it increases the velocity of refrigerant into the heat absorption section (evaporator) and it reduces the cooling time of evaporator, this enhances the refrigeration effect [7].

B) COMPARISON OF COMPRESSOR WORK:

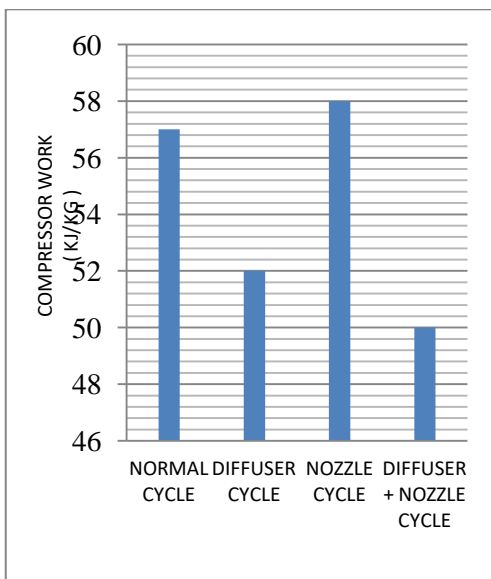


Fig 9: Comparison of Compressor Work

The figure9 implies that work required for compression is less for HC Mixture with diffuser and nozzle when compared with other cycles. The Diffuser reduces the

mechanical work required for the compressor by providing extra work to the refrigerant [4]. Therefore the compressor work required for a ton of refrigeration is less for the diffuser with nozzle when compared with HC Mixture refrigerant in all the remaining cases.

C) COMPARISON OF COP:

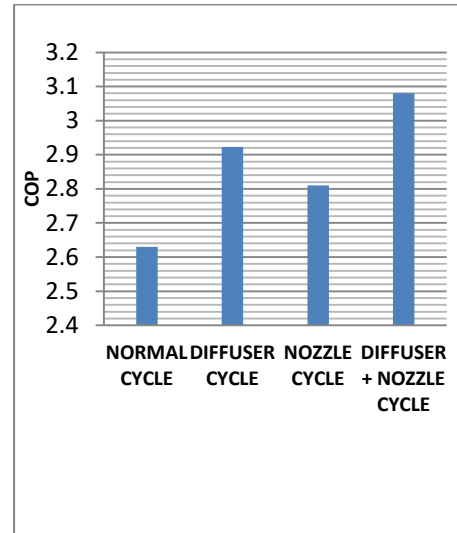


Fig 10: Comparison of COP

The figure10 implies that coefficient of performance (COP) is more for HC Mixture with diffuser and nozzle when compared with other cycles. Because of the reason that Diffuser reduces the mechanical work required for the compressor by providing extra work to the refrigerant [5] and nozzle enhances the Refrigeration effect by providing an increase in velocity to the refrigerant [6]. Therefore the COP is more for the diffuser with nozzle when compared with HC Mixture refrigerant in all the remaining cases.

D) TIME VS EVAPORATOR TEMPERATURE:

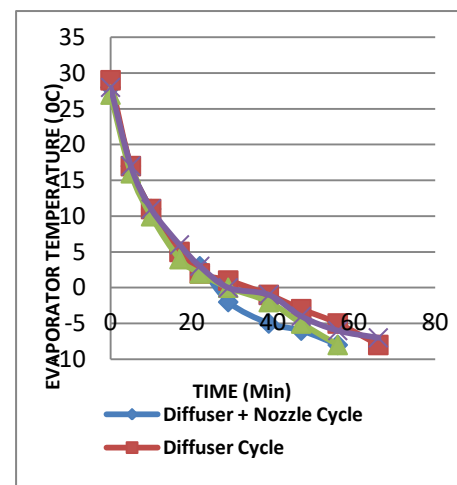


Fig 11: Time vs Evaporator Temperature

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The above figure 11 shows the relation of Evaporator temperature and Time. Diffuser and Nozzle Cycle has taken less time to reach -5°C , then followed by cycle with Nozzle, Diffuser and Normal cycle. Time taken to reach -5°C for the cycle with Diffuser and Nozzle is 39 min.

VI. CONCLUSION

The experimental work is carried out on VCR system and performance of domestic refrigerator is evaluated with Hydrocarbons (propane + butane) Mixture as a refrigerant and the system is run for Four Different cases, They are normal cycle, Diffuser cycle, Nozzle cycle, Diffuser and Nozzle cycle. For these four cases, the performance parameters like Refrigeration effect, Compressor work and COP are evaluated.

In the case of Hydrocarbon Refrigerant with Nozzle at the evaporator inlet, the refrigeration effect is increased approximately by 11.33% when compared with the normal cycle.

In the case of Hydrocarbon Refrigerant with diffuser and Nozzle, the compressor work is decreased approximately by 12.28% and the overall COP is increased approximately by 17.11% when compared with a normal cycle.

Hence it can be concluded that the Diffuser and Nozzle Cycle has better performance and take less time for the freezing capacity when compared with a normal cycle.

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Bala Kartheek graduated from Sree Vidyanikethan Engineering College, (affiliated to JNTUA University) Tirupati. Presently pursuing Post-Graduation from JNTU College of Engineering, Ananthapuramu, in the specialization of Refrigeration and Air-Conditioning of Mechanical Department.

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