Experimental Investigation of COP of Vapour Compression Refrigeration System with Diffusor at condenser inlet and Heat Exchanger at condenser outlet

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Abstract: Vapour compression refrigeration system is most widely used in domestic as well as in large-scale industry to create refrigeration effect. In order to meet the ever increasing global demand of energy we should find alternative solutions which minimize the energy consumption without compromising the need of the human being. In refrigeration system, we can reduce the power consumption by improving the COP of the system.

In this report, The basic VCR system is modified by inducting I) Diffuser in between the condenser inlet and compressor, II) Heat exchanger at condenser outlet. Diffuser is a conical device made of thick tin plate and Heat exchanger is made by attaching both the outlet pipe of condenser and the outlet pipe of the evaporator with each other and insulating it with foam which makes itself a cross flow heat exchanger. The main objective of this project is to evaluate different performance parameters like cop, refrigeration effect and compressor work of modified refrigerator using R-134a as refrigerant. On Comparing both Conventional and modified VCR system with diffuser and Heat Exchanger, it is found that COP of the system increases by approximately 1.14.

Keywords — Liquid Line-Suction Line Heat Exchanger, Diffusor, Capillary Tube, R-134a, COP, VCR system

I. INTRODUCTION

Refrigeration is the process of reducing and maintaining the temperature of a confined system below the temperature of its surrounding for a significant period. This is a process of removing heat from a low-temperature reservoir and transferring it to a high temperature sink. The goal is to cool some product or space to the required temperature which is colder than surrounding. Refrigeration system has many applications in daily life which includes household applications, industrial applications, cryogenics and air conditioning. Preservation of food products and beverages is one of the most important uses of refrigeration by keeping them at low temperatures. Air conditioning system is also one of the major applications which is used for maintain a certain comfort level temperature for a space. Air Conditioning means that various process done on air so as to simultaneously control its various properties like temperature, moisture content, cleanliness, odor and circulation, as required by occupants, a process, or products in the space. Refrigeration and air conditioning engineering has evolved periodically as per human need and comfort. The history of refrigeration is quite interesting in every aspect from evolution of different refrigerants to various kinds of compressors. However, mechanical refrigeration technology has rapidly evolved in the last century.

In today's world, most of the Refrigeration systems are based on the Vapour Compression Refrigeration system. So, there is a necessity to improve the performance of VCR system.

II. EXPERIMENTAL WORK

II.I WORKING PRINCIPAL OF VCR SYSTEM

A simple refrigeration system consists of several equipments like evaporator, condenser, compressor, and expansion device. A compressor is a device used to compress the refrigerant from the evaporator and to raise its pressure so that the corresponding temperature is higher than that of the surrounding medium. Condenser is a device used in the high pressure side of a refrigeration system. Its function is to remove heat of the hot Vapour refrigerant discharged from the compressor .The evaporator is used in the low pressure side of a refrigeration system. The liquid refrigerant from the expansion device enters into the evaporator where it boils and changes into vapour. The function of an evaporator is to absorb heat from the surrounding location or medium which is to be cooled, by means of a refrigerant. The temperature of the boiling refrigerant in the evaporator must always be less than that of the surrounding medium so that the heat flows to the refrigerant. The high pressure and low pressure of the refrigerator is divided by the expansion valve which is also known as throttling valve [10]. The coefficient of performance can be increased by increasing the refrigerating effect or by decreasing the compression work.

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VCR System rejects large amount of heat to the environment in the condenser in the refrigeration process. The considerable amount of heat that still remains in the condensed refrigerant can be used to increase the enthalpy of vapour refrigerant produced after the evaporating process in the evaporator using heat exchanger because the temperature of the vapour refrigerant coming out from the evaporator is less than the temperature of the liquid coming out from the condenser. Before the expansion process, heat is transferred from the liquid line to the suction line. It sub-cools the condenser's output which increases the refrigerating effect. The suction line exit temperature also increases, eliminating suction line sweating and preventing slugging of the compressor [5].

Diffuser is a device which can be used to increase the pressure of the refrigerant because of its conical design which can reduce the compressor work [2]. In this experiment, we are going to use diffuser for reducing the compressor work and heat exchanger for increasing the refrigeration effect.

II.II METHODOLOGY

The schematic diagram of the vapour compression refrigeration system with diffuser at condenser inlet and heat exchanger at condenser outlet is shown [Figure 1]. The system makes three flow lines using different flow valves. The flow lines can be opened or closed according to the need with the help of flow control valves. First flow line makes the set up as simple Vapour Compression Refrigeration System. The Second one is a flow line with diffuser at condenser inlet and third one is a flow line with diffuser at condenser inlet and with heat exchanger at condenser outlet. Thus different flow lines make three different set up. Three pressure gauges are installed at compressor inlet, compressor outlet and diffuser outlet to measure the pressure of the refrigerant at different points in VCR System flow line. Thus, we can measure the pressure at compressor outlet, with and without diffuser. The experiment is performed one by one making following three different set ups using flow valves:

i) Standard VCR System, ii) VCR system with diffuser at condenser inlet, iii) VCR system with diffuser at condenser inlet and heat exchanger at condenser outlet.

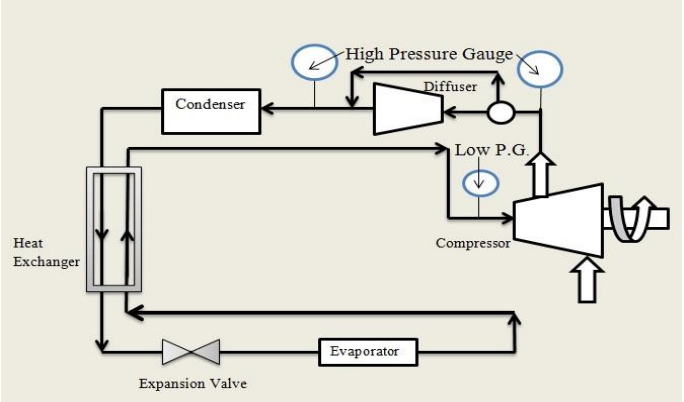

Fig.1 Line diagram for Experimental setup

II.III DESIGN OF ACTUAL WORKING SET UP

Some modifications are done in the existing VCR system by inducting diffuser at the outlet of compressor and heat exchanger at the outlet of the condenser. Following are the components used in this set up.

1 Compressor
2 Condenser
3 Evaporator
4 Capillary Tube as expansion valve
6 Diffusor
7 Connecting Wires / copper pipes
8 Flow valves
9 Pressure gauge
10 Temperature indicators
11 Wooden Box for insulation of Evaporator
12 Foam used for insulating the copper pipes
13 T AND L shape copper pipes for joints
14 Flare nuts

Geometry of diffuser:

Smaller diameter ($d_{1)}$ = 8 mm
Larger diameter ($d_{2)}$ = 77mm
Angle of divergence (θ) = 11.5^0
Length of diffuser (L) = 171 mm

Diffuser is shown below [Figure 2].

Fig. 2 Diffuser

Heat Exchanger:

Here the hot pipe consists of condenser outlet which is relatively at higher temperature where as cold pipe made of the evaporator outlet which is at lower temperature. In the figure 3, both the hot and cold pipes are attached with each other and insulated by foam so that they exchanges maximum heat with each other [Figure 3].

Fig. 3 Heat Exchanger

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II.IV ACTUAL WORKING SET UP

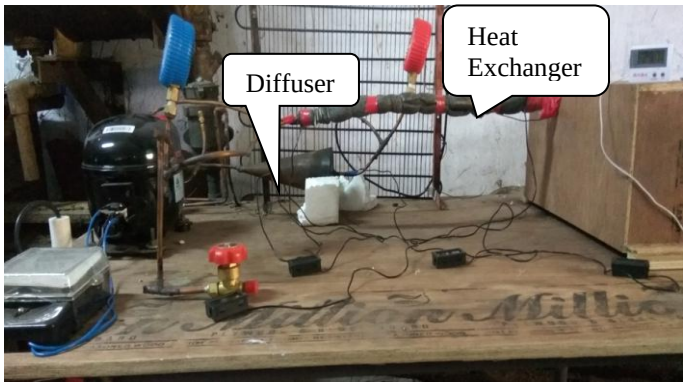


Fig. 4 Modified VCR system with Diffuser and Heat Exchanger

II.V EXPERIMENTAL PROCEDURE

All the components are connected according to the line diagram shown above on an experimental table of plywood. In this experiment, individual testing of 1.Existing system, 2.Modified system with diffuser, 3.Modified system with diffuser and sub-cooling is carried out using R134a as refrigerant. Low pressure gauge is fitted at suction line to the compressor and high pressure gauge is fitted at discharge of the compressor. Before starting of the experiment, vacuum is created to flush out the air present in the whole system. Refrigerant (R134a) is pumped to the flow line. Temperature indicators are placed at different locations for temperature measurements [Figure 4].

Different combination of flow valves are opened to make different flow lines so that different set ups can be made.

III. OBSERVATIONS

After calculating the various refrigerating parameters like Refrigeration effect, Compressor work and COP on the basis of observation table for three different cases, the findings are tabulated and compared through the graphical representation. The data is analyzed according to theory of refrigeration system. The following table is tabulated on the basis of calculations for **30 minutes** after starting of the experiment for all the three cases so that comparison can be done.

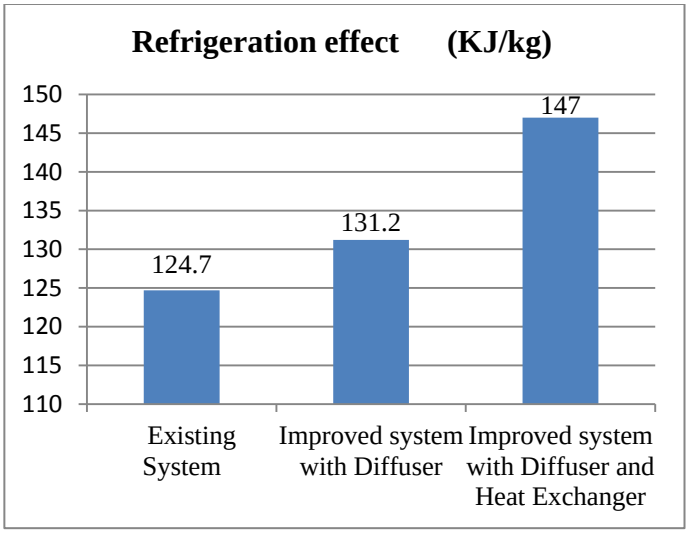
Table Number: 01

Parameter	Existing System	Improved system with Diffuser	Improved system with Diffuser and Heat Exchanger
Refrigeration effect (KJ/kg)	124.7	131.2	147
Compressor Work (KJ/kg)	29	25.2	27
COP	4.3	5.20	5.44

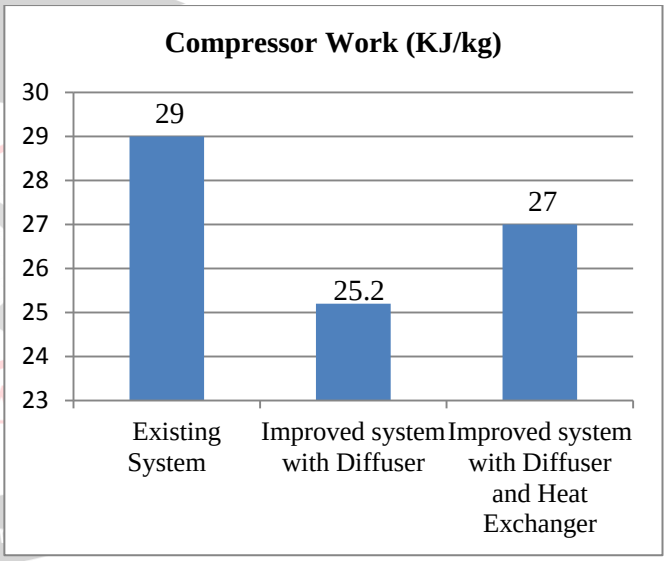
IV. RESULT AND DISCUSSION

The aim of this project is to improve the COP of the existing VCR system by inducting some modifications in it. So, Graphs are shown in this section to analyze the effect of inducting diffuser and heat exchanger.

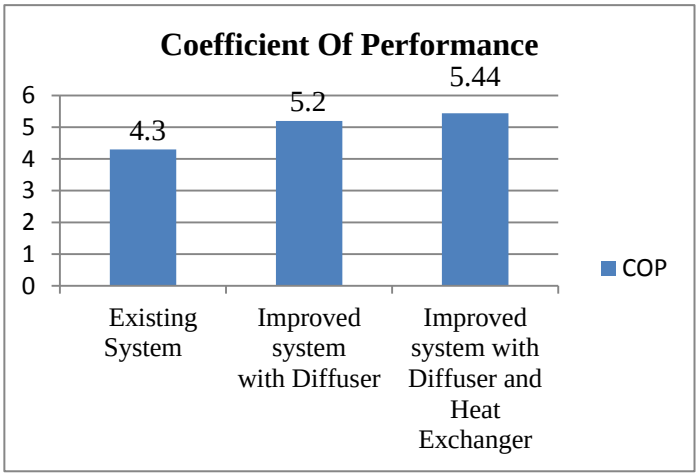
Graph: 01



Graph: 02



Graph: 03



- For the Conventional VCR system, work done by the compressor in the normal VCR system is 29 KJ/Kg and

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the power consumption is found to be 0.81KW. The COP is found to be 4.3 (Table no.1).

- For the modified VCR system with the diffuser at condenser inlet, the cop is found to be 5.2 which shows an increase in cop (Graph 03) and work done by the compressor is found to be 25.2 KJ/Kg which is lower than previous system(Graph 02). Thus Introducing diffuser reduces the compressor work and increases the COP. The power consumption by this VCR system is 0.67KW.
- For the modified VCR system with the diffuser at the condenser coil inlet and heat exchanger at condenser outlet, the Refrigerating effect is found to be 147 KJ/kg, the largest among all the three set ups which shows the effect of inducting heat exchanger (Graph 01). The cop is found to be 5.44 (Graph 03). The power consumption by this modified VCR system is 0.84KW.

Comparing both Conventional and modified VCR system with diffuser and Heat Exchanger, it is found that COP of the system increases by approximately 1.14.

Hence it is recommended to place a diffuser before the condenser inlet and heat exchanger at condenser outlet. This gives an increase in discharge pressure, reducing the compressor work and refrigerating effect simultaneously and also reduces the compressor work and power consumption for the refrigerator.

V. CONCLUSION AND FUTURE SCOPE

V.I CONCLUSION:

I have compared the performance of Existing Vapour compression refrigeration system with Modified VCR System in this experiment. After completing the experiment, I have found that the performance of vapour compression refrigeration system with diffuser at condenser inlet and Heat exchanger at condenser outlet is much better than the Existing VCR system.

The following conclusions have drawn from this research work as follows:-

- For the same refrigerating effect, Diffuser reduces the compressor work due to which COP of the VCR system increases.
- Use of Heat exchanger increases the Refrigeration effect. This can be used to reduce the size of the evaporator.
- Superheating in the Evaporator reduces the chances of going liquid refrigerant particles to compressor, which increases the life of the compressor.
- As the temperature of the refrigerating compartment reduces, the COP of the system starts reducing after a certain temperature.

V.II FUTURE SCOPE:

The present work on the vapor compression refrigeration system which has been carried out in the Heat engine laboratory at BIT, Sindri (Jharkhand) has provided efficient novel refrigeration system. Many operation and design parameters have been considered in this research. However, there are still many other areas that can be investigated. Recommended future studies are as follows:

- For different application areas, the cycle may be analyzed for different temperatures, pressures and different types of refrigerant.
  A research can be done on finding the optimum size of the diffuser by varying the shape and size so that it gives its best results.
- A research can be done on the design of Liquid line-suction line Heat Exchanger so that it exchanges maximum heat with each other.

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