International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Enhancement of Cop of Vapour Compression Refrigeration System by using Diffusers

G.Naga Raju, K.Dilip Kumar, T.Srinivasa Rao

Abstract: This experimental investigation exemplifies the design and testing of four diffusers at compressor inlet and condenser inlet in the vapour compression refrigeration system with the help of R134a refrigerant .The Four diffusers with divergence angle of 10°,12°, 14° and 16° are designed for same inlet and outlet diameters. Diffusers are testing at compressor inlet first. The diffusers are used with inlet diameter equal to discharging tube diameter of evaporator and outlet diameter is equal to suction tube diameter of the compressor. One of the diffuser gives the better performance, it will fixed at compressor inlet. Then diffusers are testing at condenser inlet, diffuser inlet diameter equal to discharging tube diameter of compressor and outlet diameter equal to condenser inlet diameter The system is analyzes using the first and second laws of thermodynamics, to determine the refrigerating effect, the compressor work input, coefficient of performance(COP). During the experimental test,the coefficient of performance (COP) of the system without diffuser and with diffuser optimized at compressor inlet and condenser inlet are find out. At compressor inlet 14° divergence angle of diffuser given the maximum cop (2.46). Percentage of increase in cop is approximately 6%. At condenser inlet 12° divergence angle of diffuser given the maximum cop (2.59).Percentage of increase in cop is approximately 3%.

Index Terms: Diffuser, Refrigeration effect, Compressor work, coefficient of performance, Diffuser work.

I. INTRODUCTION

In vapour compression refrigeration system, the refrigerant under goes phase changes from liquid to vapor and then vapor to liquid in a closed cycle by absorbing the heat in the evaporator and reject the heat at condenser. The coefficient of performance (cop), which is a ratio of heat transfer rate at the evaporator to the power input to the compressor in the refrigeration system. The coefficient of performance can be increased either by decreasing the compressor work or by increasing the refrigeration effect. Different type of methods have been tried out for improving the cop of the vapour compression refrigeration system, as reported in literature. S. Saboor et al.,[1] have studied and reported the use of diffuser at condenser inlet in vapour compression refrigeration system. It is performance most advantageous to providing the diffuser at condenser inlet in all the approaches. The refrigeration system performance can be enhanced with the help of diffuser.

Revised Manuscript Received on 30 July 2019.
***** Correspondence Author
G.Naga Raju*, M.Tech student, Department of Mechanical Engineering, Lakireddy Balireddy College of Engineering, Mylavaram, India.
K.Dilip Kumar, Professor, Department of Mechanical Engineering, Lakireddy balireddy college of engineering, Mylavaram, India.
T.Srinivasa Rao, Professor, Department of Mechanical Engineering, Vasireddy Venkatadri Institute of Technology, Guntur, Indian.

The cop of system increases by 6.2% and compressor work is reduced by 6.15%. Nurul Seraj et al.,[2] have studied to enhanced the coefficient of performance, it is to require either increasing the refrigeration effect or decreasing the compressor work.

In this analysis by using diffuser power consumption is less for same refrigerating effect so performance is improved. In this experiment design of diffuser is very important. To design the diffuser of increasing cross-section area profile with 15 degrees divergence angle. The cop increased by 9.009% in refrigeration system when diffuser is introduced at condenser inlet.

Vivek Kumar et al.,[3] have developed a new configuration by inducting 1.Diffuser in between the condenser inlet and compressor,2.Heat exchanger at condenser outlet. By using these two to evaluate the different parameters like coefficient of performance, refrigerating effect and compressor work of this system with the help of R134a refrigerant.Compared these parameters with convectional system the cop of modified system increased by approximately 1.14.

M.Yari et al.,[4]to developed a new configuration of the ejector-vapour compression refrigeration cycle, which used an internal heat exchanger and intercooler to enhance the overall performance of the refrigeration cycle. On the basis of first and second laws of thermodynamics theoretical analysis on the overall performance characteristics was find out. The results of the evaporative and condenser temperatures on the coefficient of performance, 2nd law efficiency, exergy destruction rate and entrainment ratio had been investigated. The results obtained showed that there were increases of 8.6% and 8.15% in coefficient of performance and second law efficiency values respectively of this new ejector-vapour compression refrigeration cycle compared to the conventional ejector-vapour compression refrigeration cycle with R125. It was also determined that there has been increase of 21% in the coefficient of performance of the new ejector-vapour compression cycle compared to the traditional vapour compression refrigeration cycle.

P.G.Lohote et al.,[5] have studied the performance of different condenser by changing the pressure and change in cop of refrigeration system. When changing the convectional condenser by micro channel heat exchanger the pressure changes there are change in rate of heat transfer. This will helps to control the heat losses occurring in the condenser section. So that system of different condenser is gives the batter cop than the convectional system.

M. Yohan et al.,[6] in this paper carried the experimental investigation on refrigeration system by using the nozzle at evaporator inlet. Nozzle is a device, it converts the pressure energy into kinetic energy without any input.

This concept to reduce the flooding effect on the compressor during the no load conditions and increases the coefficient of performance the system. With the help of nozzle only vapor refrigerant will enter into the compressor and protect it from damages.

C. Lokesh et al.,[7] to study the experimental data to analyze the performance of the refrigeration system with and without nozzle at condenser outlet. Due to the nozzle further reduction of pressure of refrigerant before entering into the evaporator. This improves the refrigerating effect and cop of the refrigeration system.

Dhanasi et al.,[8] to improve the coefficient of performance of domestic refrigerator with two refrigerants and wrinkle condenser. Initially he carried the experiment with two refrigerants (R-134a &R-600a) and convectional condenser, evaluated the performance. Further carried the experiment with wrinkle shaped condenser and evaluated the performance. The wrinkle shaped condenser gives the maximum cop than the other refrigeration systems.

A.Selvaraju et al.,[9] have studied to analyzed an ejector with environmental friendly refrigerants. The vapour ejector refrigeration system is a heat operated system using the low grade energies like solar energy, waste heat from industries, and it also operated at generator temperature as low as 650c. Investigation is carried out for analyzing the performance of the system with few selected refrigerants (R134a, R152a, R290, R600 and R700) only.R134a refrigerant given the batter performance and higher critical entrainment ratio than other refrigerants.

A. Ramesh et al.,[10] to carried out the experimental investigation on vapour compression refrigeration system by incorporating the nozzle at the outlet of condenser. Additionally pressure drop in the nozzle, which helps to achieve higher performance of the system. The nozzle angle is increases from 10° to 14°, the cop increases and decreases. The 14° convergent angle nozzle getting the higher cop of 3.16%. The refrigerating effect increased by 7.16% and reduction in compressor work by 2.6%.

None of the literature review has studied the effect of diffusers at compressor inlet, it rises the some pressure and temperature of refrigerant before enter the compressor. It reduces the compressor work. Due to reduction of the compressor work, system performance will increases.Diffuser at condenser inlet, it smoothly decelerates the incoming refrigerant float attaining minimum stagnation pressure losses and maximizes static pressure recovery. Due to pressure recovery, for same refrigerating effect, compressor has to do less work. Which will improvees the system efficiency.

In this work, diffusers are incorporated at compressor inlet by changing one by one and then at condenser inlet. In vapour compression refrigeration system, Compressor increases the pressure and temperature of the vapor refrigerant by compressing the refrigerant and discharges it into the condenser and condenser is used to remove the heat from high pressure vapor refrigerant and converts it into high pressure liquid refrigerant. The refrigerant flows inside the coils of condenser and the cooling fluid flows over the condenser coils. Condenser used in domestic vapour compression refrigeration system is air cooled condenser, which may be natural air cooled or forced air cooled. Heat transfer from the refrigerant to the cooling fluid. High pressure liquid refrigerant flows through an expansion valve (capillary tube) changes or converts to low pressure refrigerant. Low pressure refrigerant flows through the evaporator. Liquid refrigerant in the evaporator absorbs latent heat and converted into vapor refrigerant which returns to compressor complete the cycle. In the present cycle, initially testing the four diffusers at compressor inlet. Diffuser rises pressure and temperature of refrigerant before enter the compressor. It reduces the compressor work. Due to this reduction of the compressor work, system performance will increases. One of the diffuser gives maximum cop, which will fixed at compressor inlet.Again testing the four diffusers at condenser inlet. Diffuser at condenser inlet, it smoothly decelerates the incoming refrigerant. Achieve the minimum stagnation pressure losses and maximizes static pressure recovery. Due to pressure recovery, for same refrigerating effect, compressor has to do less work. It improves the system efficiency.

II. EXPERIMENTAL SET-UP AND METHODOLOGY

A. Manufacturing of diffuser

Diffuser is a passive device, it will increases the pressure energy by converting the available kinetic energy at the inlets. The velocity of refrigerant is subsonic in vapor compression refrigeration system and the diffuser can be manufactured with the following dimensions. The diagrams of diffusers as shown below in figure2.

Length of diffuser (L) = 9 mm
Entrance outer diameter(d_1) = 10 mm
Entrance inner diameter (d_2) = 6 mm
Exit outer diameter (D_1) = 14 mm
Exit inner diameter (D_2) = 10mm
Divergence anglesof four diffusers (θ) =10°,12°,14°,16°

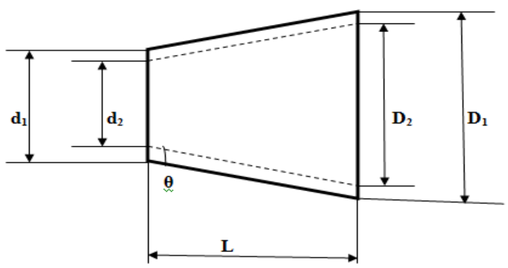

Fig.1 Diffuser line diagram

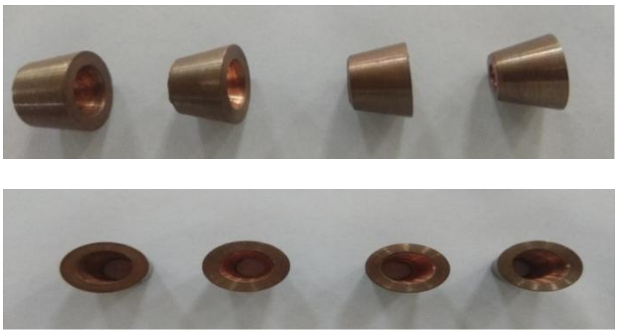

Fig.2: Diffusers

B. Experimental set-up with diffuser at compressor inlet

An experimental setup of vapour compression refrigeration system is built with diffuser at compressor inlet to investigating the performance of the system with R-134a refrigerant. The schematic diagram of vapour compression refrigeration system with diffuser at compressor inlet as shown in below figure3. It consists of a compressor, condenser, expansion valve (capillary tube) and evaporator. The compressor is a hermitically sealed reciprocating type of compressor. The condenser (air cooled) and evaporator both are copper single tubes. In single tube condenser, the refrigerant flows through inner side of tube and air flows outside the tube. The refrigerant flows into the evaporator through expansion valve. In single tube evaporator, the refrigerant flows through the inner tube and water is outside the tube. For minimizing the heat losses, the tube is insulated. Pressure gauges at inlet and outlet of the diffuser, condenser and after the expansion valve are used to note down the pressure values. The system instrumented with five temperature sensors to measure the temperatures at inlet and outlet of the every component. Initially experiment is carried without diffuser and readings are noted. After then experiment is repeated with four diffusers by changing one by one at compressor inlet and readings are noted. During a process refrigerant flows through diffuser, pressure and temperature of refrigerant increases. Due to this difference in pressure and temperature of refrigerant flows through compressor. Hence, some compression work is reduced and cop will increases.

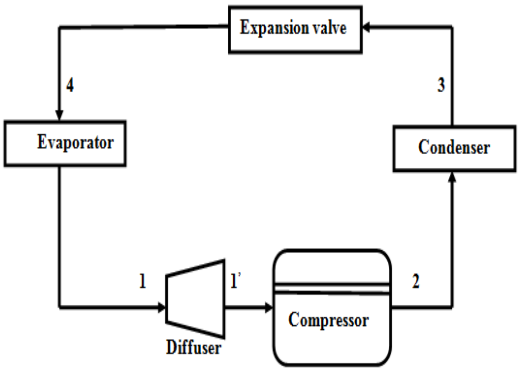

Fig.3 Line diagram of experimental setup

Fig.4 Diffuser at compressor inlet

C. Experimental set-up with diffuser at condenser inlet

The schematic diagram of vapour compression refrigeration system with diffuser at condenser inlet shown in figure 5. In above set-up one of the diffuser (14°) gives the maximum cop, it will fixed at compressor inlet. Now again testing the four diffusers at condenser inlet same as above. Initially experiment carried without diffuser and readings are noted. Then experiment will repeated with four diffuser by changing one by one and the readings (pressure & temperature) are noted. Diffuser at condenser inlet, it smoothly decelerates the incoming refrigerant float attaining minimum stagnation pressure losses and maximum static pressure recovery. Due to pressure recovery, for same refrigerating effect, compressor has to do less work. It increases the performance of the system and also increases the rate of heat transfer in condenser.

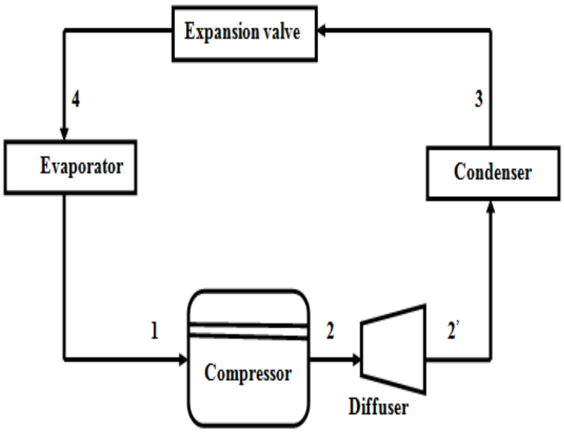

Fig.5 Line diagram of experimental setup

Fig.6 Diffuser at condenser inlet

III. RESULTS AND DISCUSSIONS

A. Diffuser at compressor inlet

Table 1 summarizes pressure and temperature readings of refrigerant at various state points as shown in the figure 3 .Table 2 summarizes refrigerating effect, reduction in compressor work and coefficient of performance without and with diffuser conditions.

Table1: Pressure and temperature of refrigerant at various state points when diffuser placed at compressor inlet

State points	Position	Pressure(bar)					Temperature(°C)				
		Without Diffuser	With diffuser				Without Diffuser	With diffuser			
			10°	12°	14°	16°		10°	12°	14°	16°
1	Compressor Inlet	0.41	0.27	0.55	0.68	0.34	32	31.2	33.6	34.5	31. 0
2	Condenser Inlet	11.72	11.72	11.72	11.72	11.72	40.6	40.6	40. 6	40.6	40.6
3	Compressor outlet	11.72	11.72	11.72	11.72	11.72	37.6	37.6	37.6	37.6	37.6
4	Evaporator Inlet	0.41	0.41	0.41	0.41	0.41	4.3	4.3	4.3	4.3	4.3

B. Calculations:

From the **p-h** chart of **R-134a** refrigerant, the following values can be obtained

h_1 = 433 kj/kg

h_1' = 437 kj/kg

h_2 = 510 kj/kg

$h_3 = h_4 = h_{f3}$ = 253 kj/kg

Compressor work (W.D) = $h_2 - h_1$ = 510 – 433

= 77 kj/kg

Refrigeration effect = $h_1 – h_4$ = 433 - 253

=180 kj/kg

Diffuser work = $h_1' - h_1$ = 437 - 433

= 4 kj/kg

Reduction in compressor work = $(h_2 - h_1) – (h_1' - h_1)$

= 77- 4

= 73 kj/kg

$$COP_{\text{without diffuser}} = \frac{\text{Refrigerating effect}}{\text{Compressorwork}}$$

= 180 / 77

= 2.33

$$COP_{\text{with diffuser}} = \frac{\text{Refrigerating effect}}{\text{Reduction in compressor work}}$$

= 180 /73

= 2.46

Table 2: Refrigerating effect, compressor work and cop for without and with diffuser condition at compressor inlet

Parameters →		Refrigerating effect (kj/kg)	Reduction in Compressor Work (kj/kg)	COP
With out Diffuser		180	77	2.33
	10°	180	79	2.27
With diffuser	12°	180	74	2.43
	14°	180	73	2.46
	16°	180	78	2.30

C. Effect of divergence angles on pressure

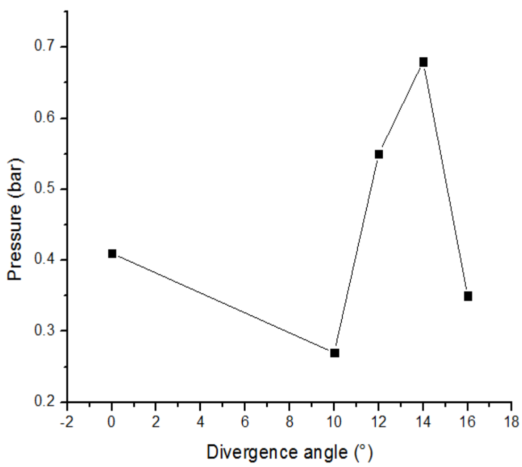

Fig.7 Variation of pressure with diverging angle

Figure 7 shows the effect of divergence angles on the diffuser pressure. It is find out that, initially the pressure at 0.41 bar without any diffuser(zero degrees). When using the 10° divergence angle of diffuser pressure is decreases to 0.27 bar and then starts to increases 0.55 bar at 12° and 0.69 bar at 14° divergence angle. Then pressure decreases up to 0.34 bar when using the 16° diffuser. At 14° divergence angle the system given by maximum pressure.

D. Effect of divergence angles on temperature

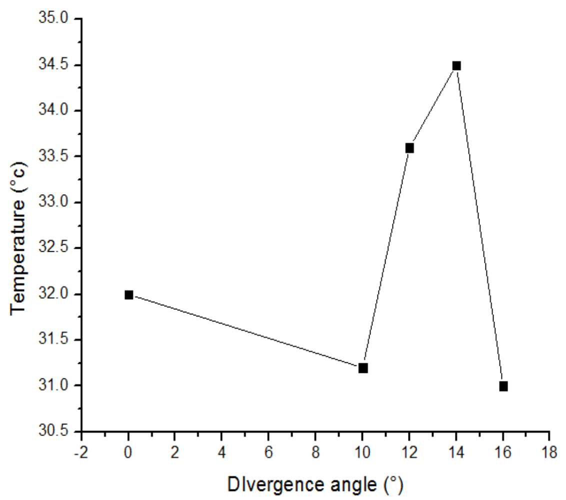

Fig.8 Variation of temperature with diverging angle

Figure 8 shows the variation of temperature with divergence angle. Initially temperature at 32° without using the diffuser. When using diffusers, the temperature decreasing first at 10° divergence angle and then increases up to certain temperature (34.5°). This is the maximum temperature at 14° divergence angle of diffuser. Further decreases when using 16° divergence angle.

E. Effect of divergence angles on cop

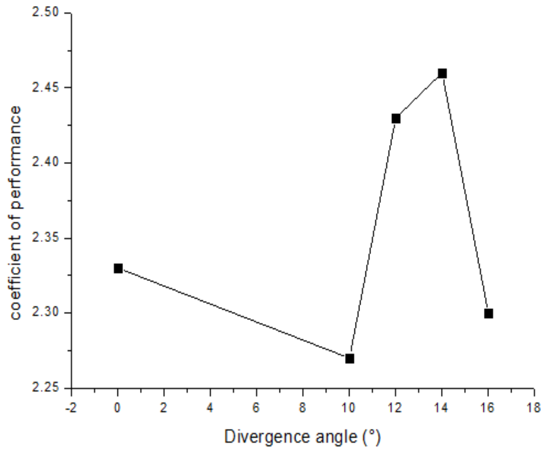

Fig.9 Variation of cop with diverging angle

Figure 9 shows the variation of cop with respect to divergence angles. It is observed that maximum gain in COP at diffuser with divergence angle 14°at pressure of 0.68 bar. Applying first law thermodynamics to diffuser. It was observed that increase in enthalpy proportional to kinetic energy of the refrigerant. The rise in enthalpy is without consumption of power from system. Hence, the compression work is reduced for some refrigerating effect, COP of the system is increased. During a process through diffuser, pressure and temperature of refrigerant increases. Due to this variation in pressure and temperature of refrigerant flows through compressor. Hence, some compression work is reduced.

F. Diffuser at condenser inlet

Table 3 summarizes pressure and temperature readings of refrigerant at various state points as shown in the figure 5 .Table 4 summarizes refrigerating effect, reduction in compressor work and coefficient of performance without and with diffuser conditions.

Table 3: Pressure and temperature of refrigerant at various state points when diffuser placed at condenser inlet

State points	Position	Pressure (bar)					Temperature (°C)				
		Without Diffuser	With diffuser				Without Diffuser	With diffuser			
			10°	12°	14°	16°		10°	12°	14°	16°
1	Compressor inlet	0.68	0.68	0.68	0.68	0.68	32	34.5	34.5	34.5	34.5
2	Condenser Inlet	11.72	11.72	11.93	11.79	11.72	40.6	40.6	41.9	41.3	40.6
3	Condenser outlet	11.72	11.72	11.72	11.72	11.72	37.6	37.6	37.6	37.6	37.6
4	Evaporator inlet	0.41	0.41	0.41	0.41	0.41	4.3	4.3	4.3	4.3	4.3

G. Calculations:

From the **p-h** chart of **R-134a** refrigerant, the following values can be obtained

h_1 = 437 kj/kg

h_2 = 510 kj/kg

h_2' = 512 kj/kg

$h_3 = h_4 = h_{f3}$ = 253 kj/kg

Compressor work (W.D) = $h_2 - h_1$ = 510 - 437

= 73 kj/kg

Refrigeration effect = $h_1 - h_4$ = 437 - 253

= 184 kj/kg

Diffuser work = $h_2' - h_2$ = 512 - 510

= 2 kj/kg

Reduction in compressor work = $(h_2 - h_1) - (h_2' - h_2)$

= 73– 2

= 71 kj/kg

$$COP_{\text{without diffuser}} = \frac{\text{Refrigerating effect}}{\text{Compressor work}}$$

= 184 / 73

= 2.52

$$COP_{\text{with diffuser}} = \frac{\text{Refrigerating effect}}{\text{Reduction in compressor work}}$$

= 184 / 71

= 2.59

Table 4: Refrigerating effect, compressor work and cop for without and with diffuser condition at condenser inlet

Parameters →		Refrigerating effect (kj/kg)	Reduction in Compressor Work (kj/kg)	Cop
With out Diffuser		184	73	2.52
With diffuser	10°	184	73	2.52
	12°	184	71	2.59
	14°	184	72	2.55
	16°	184	73	2.52

H. Effect of divergence angles on pressure

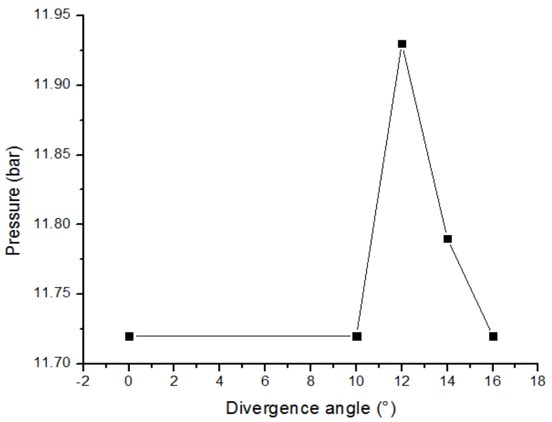

Fig.10 Variation of pressure with diverging angle

Figure 10 represents the effect of divergence angles of diffusers on the pressure. It is found that, initially the pressure at 11.72 bar without any diffuser. The pressure is same up to 10° divergence angle and then increases to 11.93 bar at 12° divergence angle. This is the maximum pressure. Then increases the divergence angle pressure decreases up to 11.72 bar.

I. Effect of divergence angles on temperature

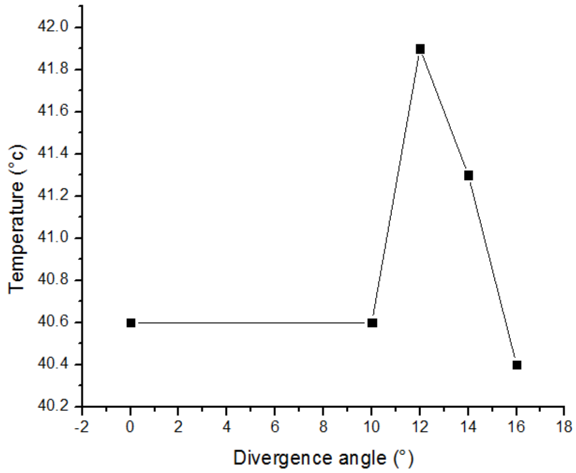

Fig.11 Variation of temperature with diverging angle

Figure 8 shows the variation of temperature with respect to divergence angle. Initially temperature at 40.6° without using the diffuser. When using diffusers, the temperature increasing and decreasing thereafter. At 12° divergence angle given the higher temperature.

J. Effect of divergence angles on cop

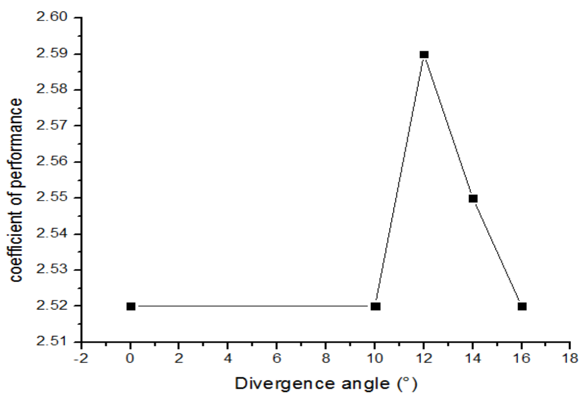

Fig.12 Variation of cop with diverging angle

Figure 12 shows the variation of cop with respect to divergence angles. It is observed that maximum gain in COP at diffuser with divergence angle 12°at pressure of 11.93 bar. Applying first law thermodynamics to diffuser. It is observed that increase in enthalpy proportional to kinetic energy of the refrigerant. The increase in enthalpy is without consumption of power from system.

Hence, the compression work is reduced for same refrigerating effect, COP of the system is increased. During a process through diffuser, pressure and temperature of refrigerant increases. Due to this variation in pressure and temperature of refrigerant flows through condenser. Hence, the rate of heat transfer increases in condenser.

IV. CONCLUSION

Experimental investigation has been carried out to study the effect of diffusers at compressor inlet and condenser inlet on vapour compression refrigeration system. The four diffusers are tested with divergence angles of 10°, 12°, 14° and 16°.

1. Diffuser at compressor inlet, diffuser with divergence angle 14° given the maximum cop (2.46) as compared to other diffusers. The pressure increases from 0.41 to 0.68 bar and the compressor work reduced by 6%. Percentage of increase in COP is approximately 6%.
2. Diffuser at condenser inlet, diffuser with divergence angle 12° given the maximum cop (2.59) as compared to other diffusers. The diffuser increases the pressure from 11.72 to 11.93 psi and the compressor work reduced by 3%. Percentage of increase in COP is approximately 3%. The rate of heat rejection in condenser is increased when diffuser placed at condenser inlet.
3. When there are using the both diffusers at a time in vapour compression refrigeration system, 14° diffuser at compressor inlet and 12° diffuser at condenser inlet. Then increases more COP than the individual using of diffuser. Percentage of increase in COP is approximately 12%.

REFERENCES

1. S. Saboor, M. Yohan and G. kiran Kumar, Proc. of the 5th International Conference on Advances in Mechanical Engineering (ICAME-2011), June 06-08, 2011 S.V. National Institute of Technology, Surat – 395 007, Gujarat, India.
2. Nural Seraj and S. C. Roy, www.ijraset.com Volume 5 Issue VI, June 2017IC Value: 45.98 ISSN: 2321-9653.
3. Vivek Kumar and S.C.Roy,International Journal for Research in Engineering Application & Management (IJREAM) ISSN: 2454-9150Vol-04, Issue-07, Oct 2018.
4. M Yari and M Sirousazar, Performance analysis of the ejector-vapour compression refrigeration cycle, Part A: Journal of Power and Energy, Vol. 221, No. 8, December 2007, pp. 1089-1098.
5. P. G. Lohate and K. P. Kolhe,JETIR1604042, April 2016, Volume 3, Issue 4 JETIR (ISSN-2349-5162).
6. M. Yohan and G. Prasanthi, ENGINEERING TODAY MONTHLY JOURNAL 133 MAY 2011 VOLUME XIII ISSUE 5 ISSN:0974-8377.
7. C. Lokesh Lecturer and K. Jaya Sudheer Kumar, International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585 Volume 4, Issue 12, December-2018.
8. Dhanasi Sabari and G. Prasanthi, INTERNATIONAL JOURNAL OF ENGINEERING & RESEARCH TECHNOLOGY [Sabari * et al. , 6(11): November, 2017] IC™ Value: 3.00 ISSN:2277-9655 Impact Factor: 4.116 CODEN: IJESS7
9. A. Selvaraju, A. Mani, Analysis of an ejector with environment friendly refrigerants, Applied Thermal Engineering, 2004, pp. 1-12.
10. [10] B. Sandhya Rani and A. Ramesh,International Journal of Mechanical Engineering and Technology (IJMET) Volume 7, Issue 6, November–December 2016, pp.642–659, Article ID: IJMET_07_06_064.

AUTHORS PROFILE

G.Naga Raju, M.Tech student, Department of Mechanical Engineering, Lakireddy Balireddy College of Engineering, Mylavaram, India. Email:**nagarajug329@gmail.com**

K.Dilip Kumar, Professor, Department of Mechanical Engineering, Lakireddy balireddy college of engineering, Mylavaram, India. Email:**dilipkumar99@gmail.com**

T.Srinivasa Rao, Professor, Department of Mechanical Engineering, Vasireddy Venkatadri Institute of Technology, Guntur, Indian. Email:**sr.tanneeru@gmail.com**