ISSN (ONLINE): 2321-3051

INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING

To study the effect of Sub-cooling and Diffuser on the Coefficient of Performance of Vapour Compression Refrigeration System

Neeraj Upadhyay

Student, Department of Mechanical Engineering, S.R.M.G.P.C, Lucknow, India

Author correspondence: Neeraj Upadhyay,56-Vaishali Enclave, Sector-9, Indira Nagar, Lucknow, Uttar Pradesh, India-226016, +919450339916, neeraj.upadhyay2203@gmail.com

ABSTRACT:

This paper presents the concept of effect of Sub-cooling and Diffuser on the Coefficient of Performance of Vapour Compression Refrigeration System mainly carried out to improve the coefficient of performance of system. To improve the coefficient of performance, it is required that compressor work should decrease and refrigerating effect should increase. The purpose of a compressor in vapor compression system is to elevate the pressure of the refrigerant, but refrigerant leaves the compressor with comparatively high velocity which may cause splashing of liquid refrigerant in the condenser, liquid hump and damage to condenser by erosion. It is needed to convert this kinetic energy to pressure energy for this purpose diffuser can be used. By using diffuser , power consumption is less for same refrigerating effect so performance is improved. The size of the condenser can also be reduced due to more heat transfer. So cost of the condenser will be reduced.

Keywords: Sub-cooling, Diffuser, Compressor, Condenser.

1. INTRODUCTION

Refrigeration may be defined as lowering the temperature of an enclosed space by removing heat from that space and transferring it elsewhere. The most frequently used refrigeration cycle is the vapor compression refrigeration cycle. Ideal vapor compression refrigeration cycle results, by eliminating impracticalities associated with reversed Carnot cycle such as vaporizing the refrigerant completely before compression, replacing turbine with throttling device (expansion valve or capillary tube). Generally, domestic and industrial refrigerator, air conditioning system, heat pump and water cooler designed based on vapor compression refrigeration cycle.

Yari et al. [1] developed a new configuration of the ejector-vapour compression refrigeration cycle, which used an internal heat exchanger and intercooler to enhance the performance of the cycle. Results obtained showed that there were increase of 8.6% and 8.15% in coefficient of performance and second law efficiency values respectively of the new ejector-vapour compression refrigeration cycle as compared to the conventional ejector-vapour compression refrigeration cycle with R125. It was also found that there was increase of 21% in the coefficient of performance of the new ejector-vapour compression cycle compare to the conventional vapour compression system.

Selvaraju et al. [2] analyzed an ejector with environment friendly refrigerants. Vapour ejector refrigeration is a heat-operated system utilizing low-grade energy such as solar energy, waste heat from industrial processes, etc., and it could satisfactorily be operated at generator temperature as low as 650C. Results obtained were showed that among the working fluids selected, R134a given a better performance and higher critical entrainment ratio in comparison with other refrigerants.

Jianlin Yu, Hua Zhao, Yanzhong Li [3] Presented a novel auto cascade refrigeration cycle (NARC) with an ejector. In the NARC, the ejector is used to recover some available work to increase the compressor suction pressure. The NARC enables the compressor to operate at lower pressure ratio, which in turn improves the cycle performance.

N.D. Banker, P. Dutta, M. Prasad and K. Srinivasan [4] present the results of an investigation on the efficacy of hybrid compression process for refrigerant HFC R134a in cooling applications. The conventional mechanical compression is supplemented by thermal compression using a string of adsorption compressors. It is shown that almost 40% energy saving is realizable by carrying out a part of the compression in a thermal compressor compared to the case when the entire compression is carried out in a single-stage mechanical compressor. The hybrid compression is feasible even when low grade heat is available. Some performance indicators are defined and evaluated for various configurations.

Advances in condenser to increase coefficient of performance means to increase degree of sub-cooling , F. W. Yu and K. T. Chan [5] described use of direct evaporative coolers to improve the energy efficiency of air-cooled condenser. This evaporative cooler is installed in front of air-cooled condenser to pre-cool outdoor air before entering the condenser. Results were predicted that the use of the evaporative cooler results in an increase in the refrigeration effect.

Present work deals with the improvement of vapor compression refrigeration system by using sub-cooling and diffuser at inlet of condenser. In this work, diffuser is installed at condenser inlet. In vapour compression refrigeration system, condenser is used to remove heat from high pressure vapour refrigerant and converts it into high pressure liquid refrigerant. The refrigerant flows inside the coils of condenser and cooling fluid flows over the condenser coils. Condenser used in domestic vapour compression refrigeration system is air cooled condenser, which may be naturally or forced aircooled. Heat transfer occurs from the refrigerant to the cooling fluid. High pressure liquid refrigerant flows through an expansion device to obtain low pressure refrigerant. Low pressure refrigerant flows through the evaporator. Liquid refrigerant in the evaporator absorbs latent heat and get converted into vapour refrigerant which returns to compressor. Compressor raises the pressure and temperature of the vapour refrigerant and discharges it into the condenser to complete the cycle[6,7]. In the present cycle, the vapor refrigerant leaves the compressor with comparatively high velocity. This high velocity refrigerant directly impinges on the tubing of condenser which may cause damage to it by vibration, pitting or erosion. It results in undesirable splashing of refrigerant in the condenser coil. It also results a phenomenon called as “liquid hump”. Liquid hump refers to a rise in the level of the condensed refrigerant liquid in the central portion of the condenser as compared to the level at the ends of the condenser. It reduces the effective heat transfer surface area which can reduce condenser efficiency. Diffuser is the static device. It raises the pressure of flowing fluid by converting its kinetic energy. In vapor compression refrigeration system, to avoid the problems of high velocity refrigerant one of the way is to use diffuser at condenser inlet. It smoothly decelerates the incoming refrigerant flow achieving minimum stagnation pressure losses and maximizes static pressure recovery[8]. Due to pressure recovery, at same refrigerating effect compressor has to do less work. Hence, power consumption of the compressor will be reduced which results improvement in system efficiency. As the refrigerant flow passes through the diffuser, pressure as well as temperature will be increased. In air cooled condenser for constant air temperature, temperature difference between hot and cold fluid will be increased. So, amount of heat rejected from condenser will be increased. To remove the same amount of heat less heat transfer area will be required. Using the diffuser at condenser inlet will provides an opportunity to use smaller condenser to achieve the same system efficiency. Use of diffuser will also provide an advantage of reducing the effect of starvation in vapor compression refrigeration systems[9].

The cross-sectional area of diffuser should reduce in the flow direction for supersonic flows and should increase for subsonic flows [8]. The velocity of refrigerant leaving the compressor is sub-sonic. Hence, cross-sectional area of diffuser should be increasing.

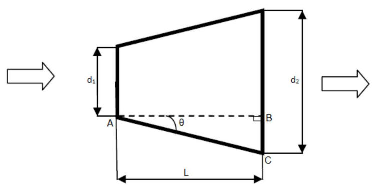

Figure1: Geometry of diffuser

Diffuser's inlet and outlet diameters were designed. To design length of diffuser equation is developed from Figure.

$$L = AB = \frac{(d_{2-d_1})/2}{\tan\theta} \quad \ldots\ldots\ldots (1)$$

2. METHODOLOGY

The schematic diagram of the vapour compression refrigeration system with diffuser at condenser inlet is shown in figure 2. The system consists of two flow lines one is simple VCRS flow line without diffuser and other is flow line with diffuser. Two pressure gauges are installed at diffuser outlet and at simple flow line to measure the pressure of the refrigerant at diffuser outlet and pressure in simple VCRS flow line. Thus we can calculate the pressure with and without diffuser. A fan is introduced to condenser for the subcooling effect. The both lines can be opened or closed with the help of flow control valves. A constant refrigeration effect is maintained throughout the experiment. The experiment is performed by taking readings with and without diffuser and compared with each other.

P-h diagram has been shown in figure 3.

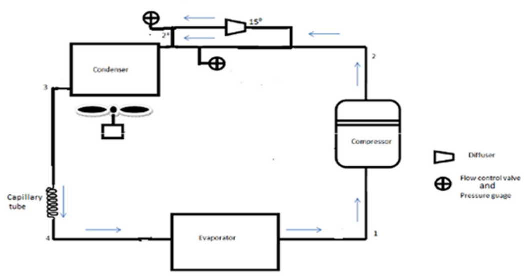

Figure 2 : Schematic of vapour compression refrigeration system with diffuser at condenser inlet

Vol.2 Issue.6,
June 2014.
Pgs: 40-44

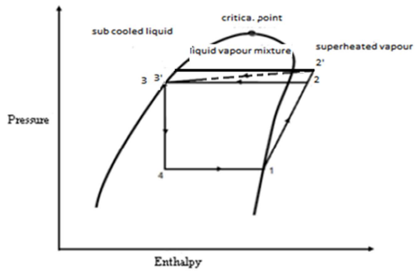

Figure 3: Pressure-Enthalpy chart

Figure 3 shows the pressure enthalpy chart of the system. The path 1-2-3-4 shows the VCR cycle without diffuser and path 1-2'-3'-4 shows the VCR cycle with diffuser at condenser inlet.

COP = net refrigerating effect / workdone

= (h1- h4)/(h2- h1)

COP (when diffuser is not used) = net refrigerating effect / workdone

= (h1- h4)/(h2'- h1)

After the use of diffuser the pressure will decrease from point 2' to 2.

So the cop will become:

COP (when diffuser is used) = (h1 – h4) / (h2 – h1)

so the COP will increase by the factor = { (h1 – h4) / (h2 – h1)} – {(h1 – h4) / (h2' – h1)}

3. RESULT AND DISCUSSION

By sub-cooling enthalpy of vaporization of refrigerant increases, so refrigerating effect increase thus COP increases. By using diffuser after compressor high velocity is converted into pressure. Some part of required pressure increases in diffuser and some amount of pressure increases in compressor so compressor work decreases or power consumption decreases. Thus performance or COP increases.

4. CONCLUSION

COP of Vapor Compression Cycle is increased by lowering the power consumption /work input or increasing the refrigerating effect. By using sub-cooling and using diffuser at condenser inlet refrigerating effect increases and power consumption or work input decreases. Thus performance of cycle is improved. High velocity refrigerant has various serious effect on vapor compression refrigeration system such as liquid hump, undesirable splashing of the liquid refrigerant in the condenser and damage to the condenser tubes by vibration, pitting and erosion. Diffuser is such a device to reduce high velocity of refrigerant is the conversion of some amount of kinetic energy into pressure energy without work consumption. Condenser tubes will be saved from vibration, pitting and erosion. It will save from the phenomenon of liquid hump. The heat transfer will increase due to increase in pressure and temperature. Hence, there will be reduction in size and cost of the condenser.

5. REFERENCES

[1] 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

[2] A. Selvaraju, A. Mani, Analysis of an ejector with environment friendly refrigerants, Applied Thermal Engineering, 2004, pp. 1-12

[3] Jianlin Yu, Hua Zhao and Yanzhong Li, "Application of an ejector in auto cascade refrigeration cycle for the performance improvement", International journal of refrigeration, vol.31, 2008, pp.279-286.

[4] N.D. Banker, P. Dutta, M. Prasad and K. Srinivasan, "Performance studies on mechanical+ adsorption hybrid compression refrigeration cycles with HFC 134a", International journal of refrigeration, vol.31, 2008, pp.1398-1406.

[5] F. W. Yu and K. T. Chan, "Application of Direct Evaporative Coolers for Improving the Energy Efficiency of Air-Cooled Chillers", A.S.M.E., Vol. 127, August 2005, pp. 430-433.

[6] P N Ananthanarayanan. Basic Refrigeration and Air Conditioning. Tata McGraw-Hill, 2005.

[7] R. J. Dossat and T. J. Horan. Principles of Refrigeration, Prentice-Hall International Inc., New Jersey, USA, 2002.

[8] Yunus A. Cengel and Michael A. Boles. Thermodynamics An Engineering Approach. Tata McGraw-Hill, 2003.

[9] C. O. Adegoke and M. A. Akintunde, An Experimental Study of Hunting in Evapourators, A.U. J.T., Vol. 10, No. 1, Jul.-2006, pp. 45-51.