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Vapor compression refrigeration system with diffuser at condenser inlet

R. T. Saudagar[1], Dr. U. S. Wankhede[2]
[1]*IV Semester M. Tech. Heat Power Engineering, Mechanical Engineering Department, G. H. Raisoni College of Engineering Nagpur-440016, Maharashtra state, India.*
[2]*Professor, Mechanical Engineering Department, G. H. Raisoni College of Engineering Nagpur-440016, Maharashtra state, India.*

Abstract—*Aim of this paper is to review the literature on advances in vapor compression refrigeration system to improve coefficient of performance of system and after comparative study suggest a new area of research. To improve the coefficient of performance, it is required that compressor work should decrease and refrigerating effect should increase. It was found through the literature that advances in the design of compressor reduced the compressor work where in capillary tube increased the refrigerating effect. Modifications in condenser are meant to increase degree of sub-cooling of refrigerant which increased refrigerating effect. The minimization of the hunting behavior of evaporator at the onset of superheat using balanced point approach was reviewed as advances in evaporator. 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.*

Keywords— *Vapor compression refrigeration system, Diffuser, Condenser.*

I. INTRODUCTION

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) [14]. Generally, domestic and industrial refrigerator, air conditioning system, heat pump and water cooler designed base on vapor compression refrigeration cycle.

In vapor compression refrigeration system condenser is used to remove heat from high pressure vapor 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 vapor compression refrigeration system is air cooled condenser, which may be naturally or forced air cooled. Heat transfer occurs from the refrigerant to the cooling fluid i. e., outside air. High pressure liquid refrigerant flows through an expansion device to obtain low pressure refrigerant. Low pressure refrigerant flows through the evaporator. The two phase refrigerant in the evaporator enters into heat exchange relationship with secondary fluid to regulate the temperature of the secondary fluid that is circulated to regulate it, of an area inside the structure. Liquid refrigerant in the evaporator absorbs latent heat and get converted into vapor refrigerant which returned to compressor. Compressor raised the pressure and temperature of the vapor refrigerant and discharged into the condenser to complete the cycle [13]. 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 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 [14]. 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 increases. In air cooled condenser for constant air temperature, temperature difference between hot and cold fluid will be increases. So, amount of heat rejected from condenser will be increases. 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 a 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.

II. MODIFICATION AND ADVANCES IN COMPRESSOR FOR REFRIGERATION SYSTEM

Many programs to develop new compressors are underway. Important advances in refrigeration compressor are summarized by Spauschus (1987). According to this study advances in refrigeration compressor are Rolling piston-stationary vane type compressor, Screw type, Scroll type, Trochoidal type compressor.

One of the types of compressor used in vapor compression refrigeration system is hermetically sealed reciprocating compressor. According to variations of motor/compressor this lead to the configurations as Open motor - hermetic compressor, Open motor - semi-hermetic compressor, Hermetic motor - hermetic compressor and Hermetic motor - semi-hermetic compressor. An open compressor has a motor drive which is outside of the refrigeration system, and provides drive to the compressor by means of an input shaft with suitable gland seals. In hermetic and most semi-hermetic compressors, the compressor and motor driving the compressor are integrated, and operate within the refrigerant system. The motor is hermetic and is designed to operate, and be cooled by, the refrigerant being compressed [12].

III. MODIFICATION AND ADVANCES IN CONDENSER AND EVAPORATOR FOR REFRIGERATION SYSTEM

Advances in condenser to increase coefficient of performance means to increase degree of sub-cooling. To do this, Yu et al. (2005) 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.

Adegoke et al. (2006) investigated the minimization of the hunting behaviour of evaporators at the onset of superheat using balanced point approach. A design model based on balanced points between the operational components of vapor compression refrigeration systems was used to interpret the result obtained from the constructed rig. Test data was used to assess the quality of the computer simulation results. The simulated and the experimental performance results were compared and the results obtained from the experimental investigations were justified adequately for the developed design. From the experimental investigations, it could be concluded that the balancing of the operational components enhanced the performance of the evaporator. With the system balancing, the hunting of the evaporator was reduced to the minimum. It was noted that, as the degree of superheating increased, the system performance reduced. Higher degree of superheating should not be allowed for optimum performance of any vapor compression refrigeration system. Analysis and experimental investigation showed that model results were comparable to the experimental ones. Finally, from the experimental investigations it could be concluded that the balancing of the operational components enhanced the performance of the evaporator.

Bolaji (2010) studied experimentally, effects of sub cooling on the performance of R-12 alternatives in a domestic refrigeration system. R-32, R-152a, R-143a, R-134a ozone friendly refrigerants were used as alternative to R-12. The performance parameter of the system working with alternative refrigerant were evaluated and compared with those of R-12. The sub-cooling heat exchanger was used for transferring heat from high pressure liquid refrigerant to low pressure vapor refrigerant. The results obtained were showed that an increased in sub cooling effectiveness reduced compressor work input and increased the system refrigeration capacity. As the degree of sub-cooling increased, the pressure ratio reduced while both the refrigerant mass flow rate and coefficient of performance increased. By comparing the performance of all four refrigerants, it was found that R-134a can use as alternative for R-12.

Adegoke et al. (2007) carried out experimentation for two vapor compression refrigeration systems. These two systems were tagged Rig A was constructed from a design model; while Rig B was assembled from equivalent components available in the market. Both Rigs were of equal capacities. It was showed that, the effect of imbalance between the major components of the refrigeration systems made the system to degrade the available energy. In the comparison of the two Rigs used in this study, it was concluded that Rig A performed better than Rig B because of the fact that the design model used was based on balanced points. It has been identified that as a result of imbalance between the components of Rig B, any change in the environmental condition affects negatively on the system performance. The running cost could be reduced by basing the component design on balance points not encouraging superheating and limiting sub-cooling to between 3^0C and 5^0C.

IV. MODIFICATION AND ADVANCES IN CAPILLARY TUBE FOR REFRIGERATION CYCLE

Akintunde (2007) investigated the effect of pitch of both helical and serpentine coiled capillary tube on the performance of vapor compression refrigeration system and compared the effect of helical coiled capillary tubes with those of serpentine capillary tubes using R-134a as the working refrigerant. Result obtained were showed that in case of helical coiled capillary tube, there was no significant increase in both mass flow rate and coefficient of performance with increase in pitch. If the coiled diameter increased, there was significant increase in both refrigerant mass flow rate and coefficient of performance. In case of serpentine capillary tube, as the pitch increases both refrigerant mass flow rate and coefficient of performance increased.

Akintunde (2004B) reported the performance of R-12 and R-134a in capillary tubes for refrigeration systems. In this work fifty eight capillary tubes of different geometries (50 straight and 8 coiled) made of copper tubes were used. The straight tubes were of ten different lengths and different internal diameters, while the coiled tubes were with different coiled diameters but of the same internal diameter. The results also indicated that mass flow rate decreased with the coil diameter.

V. DEVELOPMENT OF NEW REFRIGERATION CYCLES

Yari et al. (2007) developed a new configuration of the ejector-vapor compression refrigeration cycle, which used an internal heat exchanger and intercooler to enhance the performance of the cycle. On the basis of first and second laws of thermodynamics theoretical analysis on the performance characteristics was carried out. The effects of the evaporative and condenser temperatures on the coefficient of performance, second law efficiency, exergy destruction rate and entrainment ratio were investigated. 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-vapor compression refrigeration cycle compare to the conventional ejector-vapor compression refrigeration cycle with R125. It was also found that there was increase of 21% in the coefficient of performance of the new ejector-vapor compression cycle compare to the conventional vapor compression system.

Selvaraju et al. (2004) analyzed an ejector with environment friendly refrigerants. Vapor 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. Investigations were carried out for analyzing the performance of the system and its components with few selected organic and inorganic refrigerants. 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.

Bergander (2005) investigated new regenerative cycle for vapor compression refrigeration which described a novel approach to the Rankine vapor compression cycle for cooling and refrigeration. Generally expansion valve, capillary tube and other throttling valves are used in vapor compression refrigeration system to lower the pressure of liquid refrigerant and low pressure refrigerant delivers to the evaporator. Specific innovation was two phase ejector applied as second step of compression, which results reduction in mechanical work required for compressor for the process of compression of gas at the expense of available kinetic energy of gas in the ejector. Injected liquid phase into accelerated flow of the vapor phase and separated working medium to high and low density phases achieved gain in efficiency. In this, compression ratio was lowered by decreasing discharge pressure from the compressor, not by increasing suction pressure. Results obtained were showed that pressure on the ejector increased by 15-16% and prototype achieved energy saving of 16%.

Akintunde (2011) obtained the validation of a design model for vapor compression refrigeration system developed by Akintunde (2004). This model was used to design a vapor compression refrigeration system. The experimental set-up was made up of a compressor- reciprocating type, 0.746 kW capacity, using R134a as working fluid, with cylinder stroke volume of 32.7 cm2, evaporator and condenser, bare coil tube-in-tube serpentine copper coil. The analysis showed that the model results were comparable to the actual system from both quantitative and qualitative points of view. Under the same operational conditions, maximum absolute deviations of the variable parameters – mass flow rate, coefficient of performance and circulating water temperature were within the range of 16%.

VI. CONCLUSION

High velocity refrigerant has various serious affect on vapor compression refrigeration system such as liquid hump, undesirable splashing of the liquid refrigerant in the condenser, starving in evaporator and damage to the condenser tubes by vibration, pitting and erosion. Way to reduce high velocity of refrigerant is the conversion of some amount of kinetic energy into pressure energy without work consumption. Diffuser is such a device which can do the same.

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