Review Paper on Transcritical Refrigeration Systems with Carbon Dioxide (CO_2)

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Abstract- *The synthetic refrigerant such as hydro chlorofluorocarbons (HCFCs) has been used over a long period as working fluids inthe vapour compression plants. They have been replaced by some alternatives due to ozone depletion factor and global warming potential (GWP). The need for alternative as refrigerating agents has encouraged the carbon dioxide refrigeration process to lower global impact. So the CO_2 refrigeration cycle could prove to be viable because of zero ozone depletion property and negligible GWP. Even though it is viable but it has limitation too. The cycle has expansion losses higher than the conventional method; hence various cycle improvements are needed to increase efficiency. The transcritical carbon cycle needs modification such as uses of multi-staging, internal heat exchanger, expansion turbine, ejector and vortex tube to enhances the performances. In this we shall understand the advantages of transcritical CO_2 refrigeration cycle over the existing refrigeration cycle. An increase of coefficient of performance was found by using heat exchanger in this refrigeration cycle. The paper shows various cycle modifications that could enhance the performance of the process.*

Keywords- transcritical cycle, multi staging, performance, economization, expansion, vortex tube

I. INTRODUCTION

CO_2 is more environment friendly as it has zero Ozone-Depleting Potential and very low direct Global Warming Potential. The CO_2refrigerants also has favourable properties like higher values of density, latent heat, specific heat, thermal conductivity and volumetric cooling capacity, and lower value of viscosity. The CO_2 being non –flammable and non – toxic having various application could be used as better future for refrigeration system. Use of Carbon dioxide as a refrigerant could be used in replacing the artificial and harmful refrigerants in many applications of daily life. However the major disadvantage is that cycle has lower COP than conventional refrigeration system because of huge expansion loss.Working at high pressure and transcritical condition has forced to redesign the compressor of Carbon dioxide refrigeration process. Thus various modifications are needed to improve its efficiency, and make it advantageous. However, CO_2refrigerant has high operating pressure because of its low critical temperature (31.1 °C) and high critical pressure(73.8 bars). In a CO_2refrigeration system when heat is rejected to ambient air at the temperatures or above 31.1 °C, i.e. the critical temperature of CO_2, the refrigeration cycle is said to operate in a transcritical mode. For many refrigeration applications, the ambient temperature will exceed a level of 25°C, making it practically impossible to reject heat by condensing carbon dioxide. However, Carbon dioxide can indeed be used as a refrigerant for those applications where heat rejection is achieved other than condensation process.

II. TRANSCRITICAL CYCLE PROCESS

In Transcritical cycle the heat rejection takes place at temperature and pressure above the critical point, in fluid region often referred to as a gas state. For the transcritical cycle process, the heat rejection is therefore called gas cooling and subsequently the heat exchanger used is called a gas cooler.

The transcritical cycle process begins with a one-stage compression and the temperature rises up to130°C. The heat rejection process occurs at constant pressure above the critical point. The temperature during this process varies continuously from the inlet to the outlet point. The expansion process occurs at constant specific enthalpy. The inlet condition is supercritical (above the critical point) and the outlet is two-phase (mixture of liquid and vapour).The evaporation process occurs at constant pressure and constant temperature. The outlet condition (compressor inlet condition) is slightly superheated. In transcritical process, the heat rejection process does not involve condensing but only cooling of a gas, hence the temperature of the refrigerant will change continuously throughout the entire heat rejection process. So the temperature and pressure becomes independent.

III. CYCLE MODIFICATION

1) INTERNAL HEAT EXCHANGE:-

The simplest method of modification is the addition of internal heat exchanger between the suction line and the gas cooler discharge line that enhance the performance of the system. The saturated vapour is superheated in the internal heat exchanger and then compressed in the compressor. The supercritical carbon dioxide is cooled in the gas cooler by rejecting heat to the external fluid. Carbon dioxide at high pressure is further cooled in the internal heat exchanger, then expanded through expansion device.

The state of the refrigerant changes as it evaporates by absorbing heat. The use of internal heatex changer may be profitable at higher refrigerant temperature at the gas cooler exit. With the increase in internal heat exchanger length the optimum discharge pressures,which give maximum heating capacity and COP, decreases. COP of the transcritical CO2 cycle with internal heat exchanger is slightly improved up to 10% in residential application.

2) EXPANSION WITH WORK RECOVERY:-

Another modification to reduce the expansion losses and improve COP is the use of a work producing device (expander). Enthalpy decreases in expansion process and hence the net work requirement reduces and cooling effect increases, which will improve the COP of the cycle. COP improves by about 18% when an expander of 80% isentropic efficiency is used in the cycle. Different types of expansion valves can be used (automatic, thermostatic, and electronic). The valve senses the inlet pressure (the gas cooler pressure) and opens and closes according to a set-point for inlet pressure. They can be manually adjustable.

3) MULTISTAGE CYCLE:-

The performance of transcritical CO_2 cycle can be improved by introducing multistage compression with intercooling. The experimental investigations on the multistage transcritical CO_2 cycles showed the significant performance improvement over the basic single stage cycle. Several types of configurations such as flash gas removal, flash gas inter-cooling, and compression inter-cooling for a multistage transcritical CO_2cycle can be applied to improve the system performance depending on the requirement. Experimental study with two-stage compression with inter-cooling showed up to 25% increase in the coefficient of performance. Another study showed transcritical CO_2 cycle with expander improves COP By 9% by introducing two stage compressions.

4) VORTEX TUBE EXPANSION CYCLE:-

In vortex tube expansion transcritical CO_2 system saturated liquid from the gas cooler goes through the vortex tube nozzle. In the vortex tube, the liquid expands to the evaporation pressure into three fractions: Saturated liquid which is collected in a ring inside the vortex tube, saturated vapour and superheated gas. The superheated gas is cooled in the heat exchanger and mixed with the gas coming from the evaporator before entering the compressor. The efficiency of vortex tube should be above 0.38for the improvement of COP. The use of vortex tube is more effective for higher temperature lift and lower optimum discharge pressure over the basic cycle.

5) PARALLEL COMPRESSION ECONOMIZATION:-

The performance of transcritical CO_2 refrigeration cycle can be also improved by using parallel compression economization. In this refrigeration system the liquid and vapour are separated in economizer after expansion through primary expansion valve. The liquid is again expanded through another expansion valve and heat is extracted. In the compressor, refrigerant vapour is compressed to supercritical discharge pressure in two separate non-mixing streams; one coming from an economiser and the other coming from the main evaporator. Then both the supercritical fluids are mixed and passed to the gas cooler for heat rejection to the external fluid. By parallel compression, both refrigeration effect and compressor work increases, and the increase in compressor work is less than increase in refrigeration effect, hence COP increases, and also brings down the optimum discharge pressure.

IV. CONCLUSION

Various reviews on the use of Transcritical CO_2 refrigeration cycle modification with the use of internal heat exchanger, work recovery expansion, vortex tube, multi-staging, parallel compression economization and their detailed comparisons are done. Thus CO_2 vapour compression cycle can be achieved by replacing the expansion device with a work recovery expander or by using multi-staging. Working with the use of heat exchanger under varying temperature conditions at the gas cooler inlet has been viable. Using the internal heat exchanger the COP is 10% better than conventional system. However, the cost of modifications is really high. The recent research concentrates mostly on ejector expansion cycle due to various advantages. We can say that transcritical CO_2 cycle can be modified for their future advantages as residential applications.

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