International Core Journal of Engineering Volume 5 Issue 10, 2019
ISSN: 2414-1895 DOI: 10.6919/ICJE.201909_5(10).0040

Study on gas-liquid separator in transcritical CO_2 ejector refrigeration cycle

Feng Xu [1, a], Feng Xiao [2, b] and Pengfei Zhang [3,c]

[1] North China University of Science and Technology, Tangshan,063210, China;

[2]Rongshen Construction Engineering Co., Ltd, Langfang,065000, China;

3Financial Street Holdings Co., Ltd, Beijing,100032, China.

[a]hblgfx@163.com, [b]haofengxiaohao@163.com, [c]zhangpf-1986@163.com

Abstract

The influence of ejector and gas-liquid separator on the system in transcritical CO2 ejector refrigeration cycle is analyzed. Using ejector to recover expansion workus, using gas-liquid separator to separate working fluid can improve the circulation performance of the system. Compared the influence of different kinds of optimal design of gas-liquid separator on system performance.

Keywords

Transcritical CO2 ejector refrigeration cycle, ejector, gas-liquid separator.

1. Introduction

The advantages of CO2 as a refrigerating medium are reflected in its ODP value of 0 and GWP value of 1. It is environmentally friendly, natural and non-toxic and has good thermal and chemical stability, reducing the risk of combustion and explosion in the process of use. CO2 has a higher refrigerating capacity and heat transfer index per unit volume. Therefore, evaporators and condensers with smaller volume can be used in CO2 refrigeration cycle to reduce the size of equipment and compact system, which has better practicability. However, since the critical temperature of CO2 is only 31.1℃, systems using CO2 as refrigerant usually operate under trans-critical conditions. However, due to higher operating pressure and larger throttling loss, COP value of trans-critical refrigeration cycle system is lower. Designing reasonable CO2 refrigeration system, improving cycle efficiency and enhancing refrigeration effect are the research emphases.

In the process of studying the refrigeration cycle, it is found that a large amount of loss occurs in the throttling components, which reduces the cycle performance and wastes energy. Ejector with its advantages of simple structure, easy processing, no moving parts and high safety has gradually replaced throttle valve as a new type of equipment to reduce throttling loss. The main advantage of ejector is that it can increase the pressure of ejector fluid without external work, and use the kinetic energy recovered in the expansion process to increase the inlet pressure of compressor and reduce the pressure ratio, thus saving the input work of compressor. Ejector device are the main disadvantages of the energy transfer efficiency is low, this is because the ejector device in many complex heat transfer and flow problems, such as the working fluid and ejector fluid mixing will produce the specific problems, such as shock wave, phase change, return of ejector device can be poor under, caused a larger energy loss to cycle. In the study of the CO2 refrigerant cycle, the circulating components mainly include gas cooler, evaporator, ejector, gas-liquid separator and compressor.

ISSN: 2414-1895 DOI: 10.6919/ICJE.201909_5(10).0040

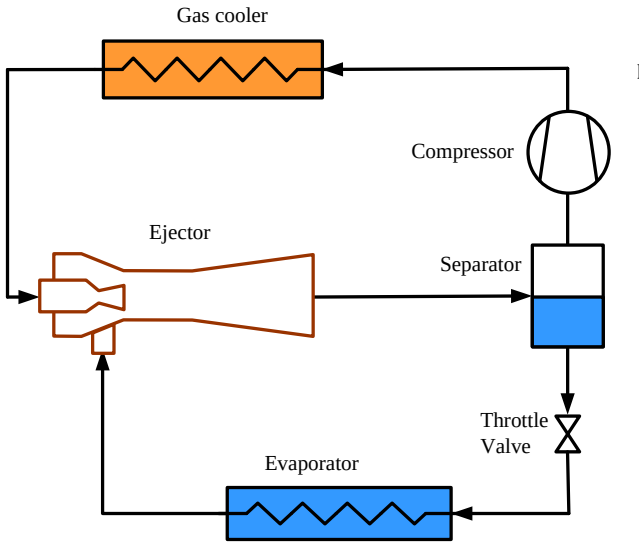

Fig. 1 The schematic of an ejector-expansion refrigeration cycle

2. Ejector refrigeration cycle

In the traditional refrigeration system, expansion valve is generally used in the throttling equipment of the refrigeration system, but expansion valve cannot recover expansion work, and about 10-20% effective energy loss exists in the throttling process. Ejector is a kind of device which can use the fluid kinetic energy released by working medium in the process of pressure reduction to save compression work of compressor. Replacing the expansion valve as ejector in the traditional refrigeration system can effectively reduce the throttle loss and improve the refrigerant gas state of the supplementary compressor, thereby significantly improving the refrigeration performance of the refrigeration system. Therefore, many scholars began to study the refrigeration cycle system with ejector.

In terms of research on trans-critical CO2 ejector cycle, ma yitai et al. [1] proposed a trans-critical CO2 cycle system with ejector and economizer in 2005. Using ejector instead of throttle valve can effectively recover expansion work and increase cooling capacity. In 2005, Li et al. [2] showed through theoretical analysis that, under typical air conditioning conditions, replacing throttle valve with ejector could increase COP by 36% with the increase of outdoor air temperature, and COP by 147% with the decrease of compressor frequency. In 2011, Sun et al. [3] conducted thermodynamic analysis on the trans-critical CO2 refrigeration system using ejector and throttle valve respectively, and found that using ejector instead of throttle valve could reduce exergy loss by 25% and increase COP value by 30%. It is also found that the ejector ejector ratio has a great influence on COP across the critical CO2 refrigeration cycle. In 2016, Bai et al. [4] conducted exergy analysis on the expansive trans-critical CO2 refrigeration system, indicating that the compressor with the most obvious exergy loss reduction was followed by ejector, evaporator and condenser. It was found that the total exergy loss of 43.44% could be avoided by improving the system composition.

3. Research status of gas-liquid separator

Ejector circulation system needs vapor liquid separator to separate the working fluid flowing out of ejector, so vapor liquid separator is an essential device, which has a great impact on the performance of circulation. The current vapor-liquid separator can be classified according to different methods of separating multiphase fluids: gravity settling type vapor-liquid separator using gravity settling separation principle, vapor-liquid separator using wire mesh separation principle, vapor-liquid separator using cyclone separation principle and vapor-liquid separator using filtration separation principle [5-7].

ISSN: 2414-1895 DOI: 10.6919/ICJE.201909_5(10).0040

In 2011, Masafumi et al. [8] studied the cross-critical CO2 ejector refrigeration cycle and found that there was a large amount of liquid refrigerant at the outlet of enterprise separator in the ejector refrigeration cycle system. Therefore, it is necessary to optimize the gas-liquid separator in the ejector refrigeration cycle. In 2014, wu tengfei [9] conducted an experimental study on the influence of gas-liquid separator on gravity liquid supply and refrigeration system, and found that structural optimization of gas-liquid separator can reduce the amount of refrigerant filling inside, thus improving the performance of the system. In 2016, Chen qiuyan [10] conducted a simulation experiment on the structure of gas-liquid separator in the overlapping system, and concluded that the location of the inlet pipe had certain influence on the separation effect of gravity settling gas-liquid separator, and the addition of a dispersion cover could also make the separation effect better. In 2017, huaiyanshuang [11] designed a new gas-liquid separator for experimental research and found that the use of the new gas-liquid separator can improve the ejector ratio of two-phase flow ejector system from 0.2-0.46 to 0.56-0.64. In 2017, hu jichao et al. [12] designed a new gas-liquid separator for R410a ejector refrigeration system. By simulating and optimizing the gas-liquid separator, the dryness of the gas phase outlet can reach 0.98 under certain working conditions. In 2018, so jin-peng et al. [13] designed a new type of vapor and liquid separator applied to the two-phase flow ejector refrigeration system, and found that compared with the original system, the cooling capacity of the main evaporator in the new system increased from 21.1%-27.8% to 82.2%-87.3%, proving that the main evaporator plays a role in improving the system performance.

4. Conclusion

Ejector can improve system performance and recover expansion work in the critical CO2 refrigeration cycle. At the same time, because refrigerant phase change in the ejector device, ejector device exports the condition of the refrigerant gas liquid two phase mixture, after the ejector device using gas liquid separator for refrigerant gas phase and liquid phase separation, according to the export of ejector refrigerant dryness to design and optimization of gas liquid separator can improve system performance.

Acknowledgements

The authors appreciate the support of Hebei Province Construction Science and Technology Research Project (2017-131), Supported by the Graduate Student Innovation Fund of North China University of Science and Technology (2019S21).

References

[1] Y.T. Ma, H.Q. Guan, J.L. Yang, et al.Ejector combined with economizer adopted in CO2 transcritical cycle refrigeration system[J].Journal of Engineering Thermophysics, 2005, (02):189-192.

[2] Li D, Groll E A. Transcritical CO2, refrigeration cycle with ejector-expansion device[J].International Journal of Refrigeration, 2005, 28(5):766-773.

[3] Sun F, Ma Y. Thermodynamic analysis of transcritical CO2, refrigeration cycle with an ejector[J].Applied Thermal Engineering, 2011, 31(6):1184-1189.

[4] Bai T, Yu J, Yan G. Advanced exergy analyses of an ejector expansion transcritical CO2, refrigeration system[J].Energy Conversion & Management, 2016, 126:850-861.

[5] G.C. Guo, M.S. Wang. Separation mechanism analysis of wire-mesh gas-liquid separator[J]. OOD &Machinery, 2010, 26(4):98-101.

[6] J. Kou. Research status and application prospect of column gas-liquid cyclone separator[J].China Petroleum Mach Nery, 2006, 34(4):71-73.

[7] J.P. Suo. Simulation and experimental study on performance of two-stage throttling transcritical CO2 ejector refrigeration system[D].Tianjin University of Commerce, 2018.

ISSN: 2414-1895 DOI: 10.6919/ICJE.201909_5(10).0040

[8] Masafumi Nakagawa, Ariel R. Marasigan, Takanori Matsukawa. Experimental analysis on the effect of internal heat exchanger in transcritical CO2 refrigeration cycle with two-phase ejector[J]. International Journal of Refrigeration, 2011, 34(7):1577-1586.

[9] T.F. Wu. Experimental study on gas-liquid separators of gravity feeding refrigeration system[D].Tianjin University of Commerce, 2014.

[10] Q.Y. Chen. Cascade refrigeration system in gravity sedimentation type gas-liquid separator simulation and the system optimization[D].Harbin University of Commerce, 2016.

[11] Y.S. Huai. Investigation on influence of gas-liquid separator on performance of two-phase flow ejector refrigeration system[D].Tianjin University of Commerce, 2017.

[12] J.C. Hu, D.D. Wang, Y.F. Wang, et al. Design and optimization of a new gas-liquid cyclone separator in ejector refrigeration system[J]. China Journal of Refrigeration Technology, 2017.

[13] J.P. Suo, X.M. Guo, Y.S. Huai.Influence of gas-liquid separator on performance of two-phase ejecotr refrigeration system[J].Cryogenics&Superconductivity, 2018,46(04):68-71.