Experimental Research on Effect of Heat Source on Performance of Transcritical CO_2 System

Yingfu Liu[1, a], Tongzhen Jia[1, b], Guangya Jin[2, c]

[1] Baoding Electric Power VOC. & TECH. College, 1278 North Lekai Street,

Baoding 071051, Hebei, China

[2] North China Electric Power University, 619 North Yonghua Street,

Baoding 071003, Hebei, China

[a]liuyingfu2008@163.com, [b]135290966@qq.com, [c]rongyz@163.com

Keywords: Transcritical CO_2 system, Coefficient of performance, Heat source, Experimental research.

Abstract. In this paper, the transcritical CO_2 system is experimental studied, influence of heat source on system performance is analyzed. The experimental results show that the cooling water flow has no obvious effect on the system performance and it may be owed to the limitations of this experimental device. The cooling water temperature has a great impact on the system performance, COP_h decreases about 21.7%, COP_c decreases about 26.6% from the maximum value when the cooling water temperature range from 25℃ to 35℃. The chilled water flow and temperature has a little impact on heating coefficient of performance, while it has a great impact on the cooling coefficient of performance. When COP_h and COP_c get the extreme value with the increase of chilled water flow, COP_h decreases about 2.61%, COP_c increases about 29%. COP_h increases about 7.5%, COP_c increases about 55.1% when the chilled water temperature ranges from 7℃ to 17℃.

Introduction

Natural refrigerants are increasingly becoming the refrigerant of choice to replace the environmentally harmful CFCs and HCFCs, and the application of natural refrigerant CO_2 is of great significance to reduce the greenhouse effect and ozone depletion. The former IIR chairman G. Lorentzen [1] is the first to advance the CO_2 transcritical cycle, and think that CO_2 is "the most prospects refrigerant of the 21st century". CO_2 has its unique advantages [2] as a refrigerant such as environmental safety, favorable thermodynamic properties, and non-flammability.

In recent years, several researchers [3–6] have investigated the transcritical CO_2 system. But the coefficient of performance of the transcritical system is not high because of their lower critical temperature (31℃). Therefore, the key to promote the transcritical CO_2 cycle is to improve the system performance. It is required to investigate the performance improvement of the transcritical CO_2 system. In the paper, the transcritical CO_2 system is experimental investigated, and influence of cooling water and chilled water on the heat output (Q_h), refrigerating capacity (Q_c), compressor work (W), heating coefficient of performance (COP_h) and cooling coefficient of performance (COP_c) is analyzed, which could provide a basis for the optimization of transcritical CO_2 refrigeration cycle.

Experimental Apparatus

Fig. 1 shows a schematic diagram of the experimental apparatus, which consists of three loops: transcritical CO_2 refrigeration system, cooling water system and chilled water system. The transcritical CO_2 refrigeration system as the core part of the system consists of a compressor, a gas cooler, a pre-evaporator, an evaporator, a throttle valve, an internal heat exchanger, a gas-liquid separator and an oil separator. A manual throttle valve is used. The piston-type compressor has theoretical displacement of $3.5m^3/h$.

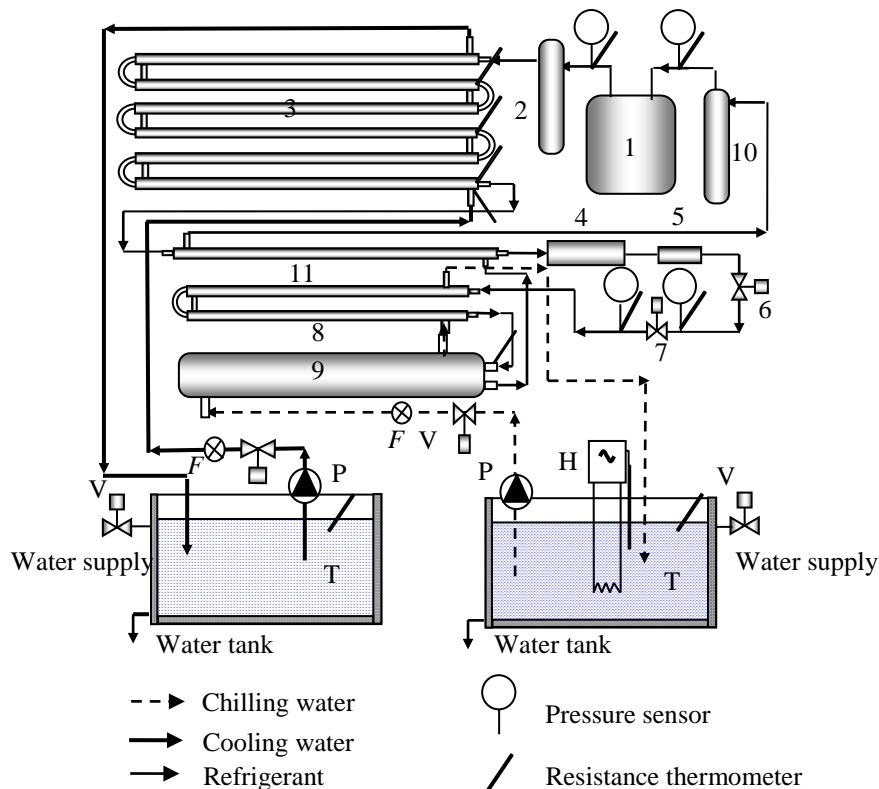Fig. 1 Schematic diagram of the experimental apparatus

1-Compressor   2-Oil separator   3-Gas cooler   4-Reservoir   5-Drier-filter   6-Magnet valve   7-Throttle valve

8-Pre-evaporator   9- Evaporator   10-Gas-liquid separator   11-Internal heat exchanger

F-Rotermeter   V-Control valve   P-Water pump   H-Heater   T-Water tank

The data collection including the pressure, temperature of refrigerant, chilled water and cooling water temperature, power and current of compressor and the heater. The temperature was measured using WZP-BW-type platinum resistance thermometer, the calibration of measurement error is ±0.1 ℃. Silicon-proliferation BP800-type pressure sensor with accuracy of 0.5‰ was used to measure the pressure. Rotameter was used to measure the flow of cooling water and chilled water, and its error is less than 3%.

Analysis of Experimental Results

Influence of Cooling Water on System Performance

Fig.2 shows the variation of heat output (Q_h), refrigerating capacity (Q_c), compressor work (W) , heating coefficient of performance (COP_h) and cooling coefficient of performance (COP_c) with cooling water flow (W_1). It shows that heat output, refrigerating capacity and compressor work changed slightly with the increase of cooling water flow, which cause the heating coefficient of

performance and cooling coefficient of performance changed a little. The cooling water flow has no obvious effect on the system performance may be owed to the limitations of this experimental device.

Fig.3 shows the variation of heat output (Q_h), refrigerating capacity (Q_c), compressor work (W), heating coefficient of performance (COP_h) and cooling coefficient of performance (COP_c) with cooling water temperature (T_1). It shows that heat output decreases slowly with the increase of cooling water temperature, while refrigerating capacity first increases slowly and then decreases with the increase of cooling water temperature, and the compressor work has a linear increase with the increase of cooling water temperature. System performance corresponding to changes of heat output, refrigerating capacity and compressor work, heating coefficient of performance showing the trend of decreases, and cooling coefficient of performance showing the trend of first increases and then decreases. When the cooling water temperature range from 25℃ to 35℃, COP_h decreases about 21.7%, COP_c decreases about 26.6% from the maximum value. The cooling water temperature has a great impact on the system performance.
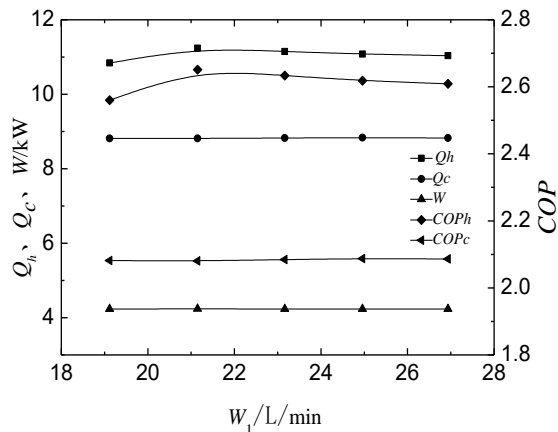

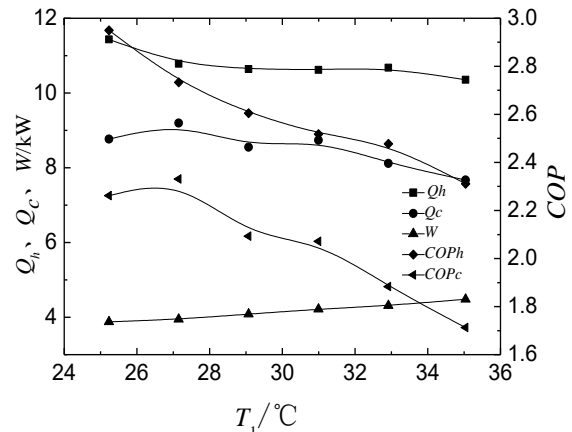Fig.2. Variation of Q_h, Q_c, W, COP_h
and COP_c with cooling water flow

Fig.3. Variation of Q_h, Q_c, W, COP_h and
COP_c with cooling water temperature

Influence of Chilled Water on System Performance

Fig.4 shows the variation of heat output (Q_h), refrigerating capacity (Q_c), compressor work (W), heating coefficient of performance (COP_h) and cooling coefficient of performance (COP_c) with chilled water flow (W_2). It shows that heat output first decreases slowly and then increases, while refrigerating capacity first increases fast and then decreases slowly with the increase of chilled water flow, and the compressor work changed slightly. Heating coefficient of performance first decreases and then increases with the increase of chilled water flow, but cooling coefficient of performance first increases fast and then decreases slowly. The chilled water flow has a little impact on heating coefficient of performance, while it has a great impact on the cooling coefficient of performance. When they get the extreme value with the increase of chilled water flow, COP_h decreases about 2.61%, COP_c increases about 29%.

Fig.5 shows the variation of heat output (Q_h), refrigerating capacity (Q_c), compressor work (W), heating coefficient of performance (COP_h) and cooling coefficient of performance (COP_c) with chilled water temperature (T_2). It shows that heat output first increases slowly and then almost does not change, while refrigerating capacity has a obviously increase with the increase of chilled water temperature, and the compressor work has a little increase. System performance corresponding to changes of heat output, refrigerating capacity and compressor work, heating coefficient of

performance showing the trend of first increases slowly and then decreases slowly, and cooling coefficient of performance showing the trend of increases fast. When the chilled water temperature ranges from 7℃ to 17℃, COP_h increases about 7.5%, COP_c increases about 55.1%. The chilled water temperature has a great impact on the cooling coefficient of performance.
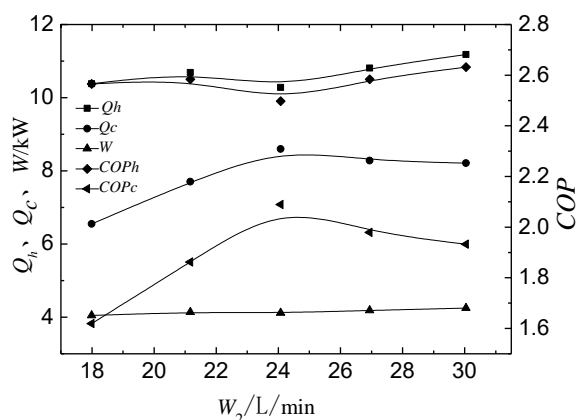

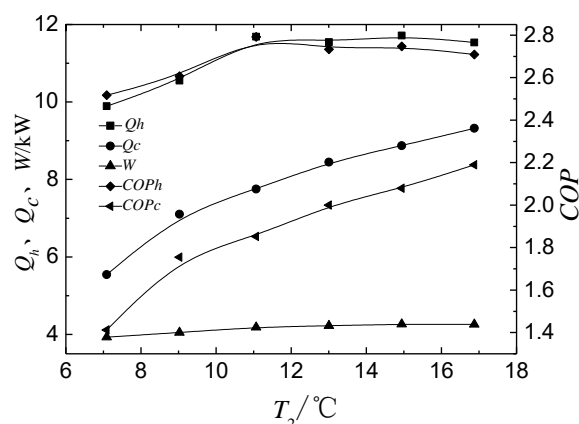Fig.4. Variation of Q_h, Q_c, W, COP_h and COP_c with chilled water flow

Fig.5. Variation of Q_h, Q_c, W, COP_h and COP_c with chilled water temperature

Conclusions

In this paper, the transcritical CO_2 system is experimental studied, influence of heat source on system performance is analyzed. The experimental results show that the cooling water flow has no obvious effect on the system performance which may be owed to the limitations of this experimental device. The cooling water temperature has a great impact on the system performance, COP_h decreases about 21.7%, COP_c decreases about 26.6% from the maximum value when the cooling water temperature range from 25℃ to 35℃. The chilled water flow and temperature has a little impact on heating coefficient of performance, while it has a great impact on the cooling coefficient of performance. When COP_c gets the maxmium value with increase of chilled water flow it increases about 29%, and when the chilled water temperature ranges from 7℃ to 17℃, COP_c increases about 55.1%.

References

[1] G. Lorentzen. Revival of carbon dioxide as a refrigerant. International Journal of Refrigeration, 1994, 17(5):292-301.

[2] Andy Pearson. Carbon dioxide-new uses for an old refrigerant. International Journal of Refrigeration, 2005, 28, 1140-1148.

[3] E.A. Groll, J.H. Kim. Review of recent advances toward transcritical CO_2 cycle technology. HVAC & R Research, 2007, 13 (3): 499-520.

[4] Ramon Cabelloa, Daniel Sancheza, Jorge Patinoa, Rodrigo Llopisa, Enrique Torrellab. Experimental analysis of energy performance of modified single-stage CO_2 transcritical vapour compression cycles based on vapour injection in the suction line. Applied Thermal Engineering, Vol. 47 , 86-94, 2012.

[5] Eunsung Shina, Chasik Parkb, Honghyun Choc. Theoretical analysis of performance of a two-stage compression CO_2 cycle with two different evaporating temperatures. International Journal of Refrigeration, Vol. 47, 164-175, 2014.

[6] Jahar Sarkar. Review on Cycle Modifications of Transcritical CO_2 Refrigeration and Heat Pump Systems. Journal of Advanced Research in Mechanical Engineering, 2010, 1(1): 22-29.