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Performance of a new two-stage multi-intercooling transcritical CO_2 ejector refrigeration cycle

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ABSTRACT

In this study, a new two-stage multi-intercooling transcritical CO_2 refrigeration cycle with ejector-expansion device (MIERC) is investigated. At this studied cycle, the vapor compression line includes two intercoolers, the first with external coolant (air or water) and the second one with cycle refrigerant. The overall performance of the new cycle was compared with that of the conventional ejector refrigeration cycle (CERC) and the internal heat exchanger ejector refrigeration cycle (IHEEC). It was found that the new cycle has the maximum amount of COP and IHEEC has the minimum one. The maximum COP value of the new cycle in the surveyed high-side pressure interval is 15.3% and 19.6% higher than those of CERC and IHEEC respectively. The effect of main cycle parameters such as compressor high-side pressure (discharge pressure), intermediate pressure, gas cooler outlet temperature and evaporator temperature on COP of cycle were studied and results presented here.

1. Introduction

The American Alexander Twining was the first researcher who suggested the use of carbon dioxide as a refrigerant for vapor compression systems in his patent in 1850. The first carbon dioxide system which is called ice machine was built by Thaddeus S. C. Lowe in about 1869 in Jackson, Mississippi [1]. Nowadays this refrigerant, has gained much more attention owing to its no toxicity, no flammability, low cost and no hazard to the environment [2].

In 1990, ejector was used as an expander in vapor compression refrigeration cycles. Using this component as an expansion device instead of conventional expansion valve, reduces the losses during expansion process and makes a rise in the capacity of refrigeration cycle. Kornhauser theoretically investigated the thermodynamic performance of the ejector-expansion refrigeration cycle using R-12 as the refrigerant and found a COP improvement of up to 21% over the standard cycle under standard operating conditions [3]. Use of ejector in transcritical CO_2 cycle not only improves the COP, also simplifies the process of controlling the gas cooler pressure in the CO_2 cycle by changing the throat area of the ejector nozzle [4]. Improving COP by adding ejector led to use it in cycles with other refrigerants [3,4]. Through comparative study, Deng et al. showed that the ejector improves the maximum COP by up to 18.6% compared with the internal heat exchanger system and by 22.0% compared with the conventional system with greatly reducing the throttling losses [5]. Yari and Sirousazar proposed a new refrigeration cycle with an ejector, internal heat exchanger and intercooler. They showed that the COP and second law efficiency values of the new ejector compression cycle are on average 8.6% and 8.15% higher than that of the conventional ejector-vapor compression refrigeration cycle with R125 as refrigerant [6].

In this study, a new two-stage multi-intercooling transcritical CO_2 refrigeration cycle with ejector-expansion device is investigated. At this cycle, both the vapor compression and intercooling processes are done at two stages. After first stage of compression, the refrigerant is sent to intercoolers. At intercooler 1 the refrigerant is cooled with an external coolant and then is sent to intercooler 2 at which a portion of saturated vapor coming out of the vapor–liquid separator is used to improve the cooling process. The overall performance of the new two-stage multi-intercooling transcritical CO_2 ejector refrigeration cycle (MIERC) is then compared with those of the conventional ejector refrigeration cycle (CERC) and the internal heat exchanger ejector refrigeration cycle (IHEEC). The conventional ejector refrigeration cycle (CERC) which is depicted in Fig. 1, is the cycle once was discussed by Deng et al. and includes one compressor, so it doesn't have any intercooler [5]. In the internal heat exchanger ejector refrigeration cycle (IHEEC), a heat exchanger is stuck in the cycle which will exchange heat

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