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Performance improvement of air source heat pump using gas-injected rotary compressor through port on blade

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ABSTRACT

Gas injection has been a crucial technology to avoid the serious degradation of air source heat pumps in low ambient temperature. A novel injection structure on the blade for rotary compressors has been put forward in previous research to overcome the drawback of traditional injection structures. Based on a verified numerical model, the thermodynamic performance of an air source heat pump with the new gas-injected rotary compressor is investigated. The results indicate that, compared to the air source heat pump with the regular single-stage rotary compressor, the proposed injection structure can enhance heating capacity and COP of the air source heat pump by 23.1–28.2% and 4.5–8.1%, respectively.

Amélioration des performances d'une pompe à chaleur aérothermique fonctionnant avec un compresseur rotatif à injection de gaz via un port à ailettes

Mots clés : Injection de vapeur ; Compresseur rotatif ; Pompe à chaleur aérothermique ; Économiseur du réservoir de vaporisation instantanée

1. Introduction

Air source heat pumps (ASHP) have been widely used for space heating in domestic and light commercial buildings as a high-efficiency and renewable heating source (Hepbasli and Kalinci, 2009). However, the thermodynamic performance of ASHP, including COP and heating capacity, will drastically degrade as outdoor temperature decreases, which has become a major barrier for expanding the utilization of ASHP in cold regions. To overcome the performance degradation and enhance system reliability in low temperature ambient, various technologies, including variable speed compressors (Adhikari et al., 2012), additional heat sources (Banister and Collins, 2015; Lv et al.,

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2015; Omojaro and Breitkopf, 2013), two-stage compression (Baek et al., 2014), vapor injection technology (Ko et al., 2013), and so on, have been developed correspondingly. Among these methods, vapor injection technology has attracted much attention and has been considered as an effective and economic method to enhance performance and improve reliability, as it can increase the heating capacity and decrease the discharge temperature effectively. Vapor injection technology has been comprehensively investigated and is widely used in the ASHP with scroll compressors (Heo et al., 2011; Ma and Chai, 2003; Wang et al., 2009a, 2009b; Winandy and Lebrun, 2002; Xu and Ma, 2001), screw compressors (Wu et al., 2004) and twin-cylinder rotary compressors (Xu and Ma, 2014).

However, vapor injection technology is not well developed and applied in single-cylinder rotary compressors. The main reason for this can be attributed to the limited performance improvement. Actually, this limited performance improvement of gas injection on single-cylinder rotary compressors can be ascribed to the unavoidable back-flowing of injected refrigerant and limited injection area.

At present, there are two types of vapor injection structures that have been used for single rotary compressors (Jia et al., 2015; Yan et al., 2016). The first is called cylinder injection, in which the injection port is opened on the cylinder and keeps as close as possible to the discharge port. However, when the rolling piston rotates from the injection port to the suction port, the injection port and the suction port both will open to the suction chamber simultaneously. Therefore, the middle pressure injection refrigerant will flow into the low-pressure suction tube through the suction chamber. This back-flowing will largely decrease the real suction volume of the compressor from the evaporator and, consequently, the heat absorbed by the evaporator. Meanwhile, in order to decrease the amount of injection refrigerant gas flowing back to the suction tube, the injection area is artificially limited.

The other vapor injection structure is called end-face injection. The injection refrigerant gas is injected into the working pocket through an injection port on the end sheet. In end-face injection, the rolling piston serves as a controller of the injection, which means that the injection will start only when the rolling piston does not cover the injection hole. Obviously, the position of the injection hole is critical for the compressor performance. In current design (Yan et al., 2016), end-face injection would also face the back-flowing of injected refrigerant and the constrained injection area as cylinder injection. Studies (Jia et al., 2015) about end-face injection have indicated that it exhibited better performance as the less back-flowing. Yan et al. (2016) found that end-face injection can improve the heating capacity by 5.6–14.4% in low ambient temperature. However, the COP of an end-face injected system showed advance only when the ambient temperature was lower than −15 °C.

In contrast, gas injection on the ASHP with a twin-cylinder rotary compressor can enhance the heating capacity and COP by 20–25% and 0–10%, respectively (Heo et al., 2010). ASHP with a gas injected rotary compressor therefore shows a much weaker performance improvement compared to ASHP with a twin-cylinder rotary compressor. In other words, back-flowing of the injected refrigerant dramatically eliminate the merits of vapor injection technology, and seriously restrict further application of injection technology in single-cylinder rotary compressors.

However, single rotary compressors have many merits compared to twin-cylinder rotary compressors, such as simpler structure, lower cost and better reliability. Optimizing the injection structure and enhancing the injection performance of single-cylinder rotary compressors have great value. Accordingly, a novel injection structure on the blade for a single rotary compressor has been proposed (Liu et al., 2016). Initial research has indicated that the proposed injection structure can

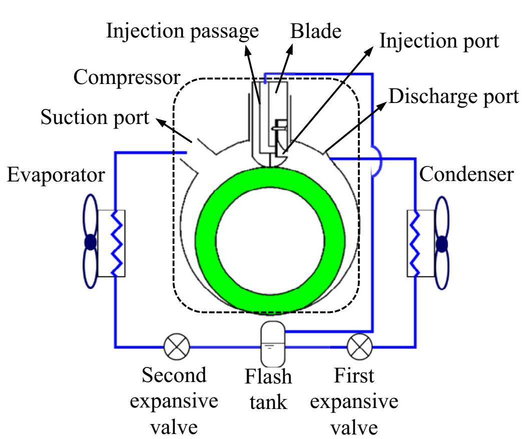

Fig. 1 – ASHP with blade injected rotary compressors.

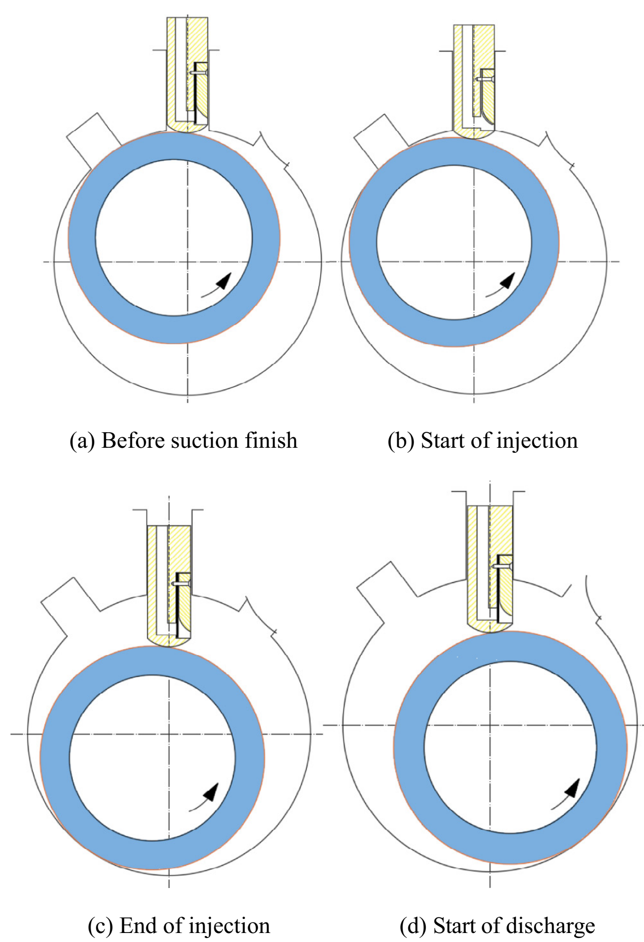

Fig. 2 – Working process of the rotary compressor with blade injection.