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Seasonal Applicability of Refrigerant Release Technology in Room Air Conditioner

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ABSTRACT

The refrigerant release technology relieves even eliminates the over-compression loss of scroll compressor by bypassing the refrigerant in the compression chamber to the suction pipe under small system pressure ratio conditions. Because the room air conditioner works in mild conditions at most of the time, its seasonal energy performance is expected to be effectively improved by the refrigerant release technology. Accordingly, the effect of refrigerant release on the seasonal performance of the room air conditioner is analyzed and the applicability is evaluated in this paper. The results show that, for the fixed speed air conditioner, the refrigerant release technology decreases 14%~24% and 20%~23% seasonal energy consumption for residential and office building, respectively. The refrigerant release technology has good applicability for the room air conditioner.

1. INTRODUCTION

The room air conditioner is widely used in residential and office buildings for both cooling and heating. Compared to the chiller in large public building, the room air conditioner is air-sourced and its working conditions are heavily affected by the environment. As a result, the working condition of the room air conditioner will vary in a much larger range, which leads to the system compression ratio (SCR, equals to $P_{condenser}/P_{evaporator}$) varying in a large range. Figure 1 shows the simulated SCR distribution of a room air conditioner in the whole cooling season at different cities. The big (red) point indicates the SCR under the rated condition. Therefore, the air conditioner will work in pretty small SCR conditions at most of the time, far away from the design point. The same situation can be found in heating season.

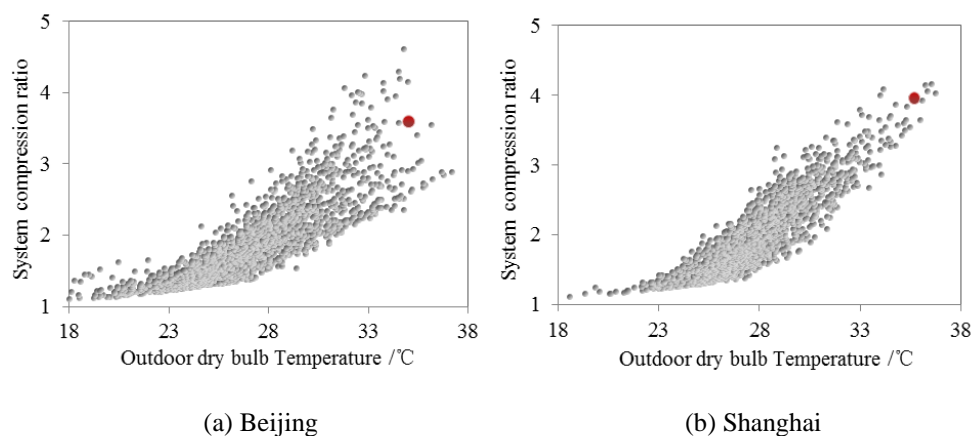


Figure 1: Distribution of system compression ratio in the whole cooling season

The scroll compressor is the mainstream compressor for the room air conditioner due to its high efficiency under the design condition. However, the inherent feature of fixed inner volume ratio (equals to $V_{suction}/V_{discharge}$) causes large degradation of the scroll compressor's indicated efficiency when the inner compression ratio (ICR, equals to $P_{discharge}/P_{suction}$) mismatches with the SCR under the off-design condition, which is confirmed as the maximum barrier for pursuing high seasonal energy performance. Some investigations have been conducted to enhance the inner compression efficiency. Gas refrigerant injection has been proven effective for decreasing the under compression loss and improving the indicated efficiency of the scroll compressor under large SCR conditions (Winandy and Lebrun, 2002; Park *et al.*, 2002; Ma *et al.*, 2003; Beeton and Pham, 2003; Wang, *et al.*, 2008). For small SCR conditions, the configuration of multi discharge ports with reed valve has been utilized by some compressor manufactures to overcome the over-compression loss. However, the utilization of the reed valve will decrease the efficiency of the scroll compressor under normal conditions. Besides, the refrigerant release technology is expected as a solution to decrease the over compression loss and enhance the inner compression efficiency more effectively (Shibamoto *et al.*, 2003; Shin *et al.*, 2005, 2008; Wang *et al.*, 2012).

However, most of the previous research are focused on the single or several design points. The effects of refrigerant release on the seasonal performance of room air conditioner is still unknown. So, this investigation is conducted to discover the seasonal adaptability of this technology.

2. FUNDAMENTAL PRINCIPLE OF REFRIGERANT RELEASE

Figure 2 presents the schematic diagram of a refrigeration system using scroll compressor with refrigerant release. The system configuration can be divided into two parts: the main cycle and the bypass cycle. The main cycle is constituted by a scroll compressor with refrigerant bypass ports, a condenser, an expansion valve and an evaporator orderly. The bypass cycle includes a check valve and a control valve. One end of the bypass tube is connected with the bypass port of the compressor and the other is connected with the suction pipe or the outlet pipe of the evaporator.

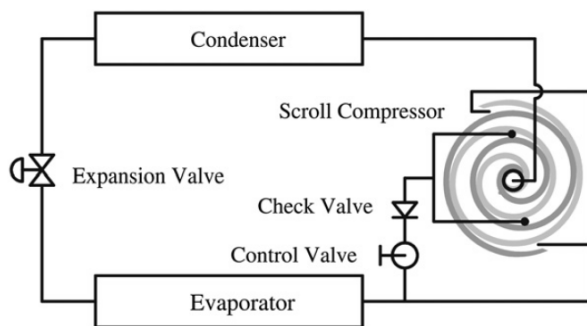


Figure 2: Schematic of air conditioner using scroll compressor with refrigerant release

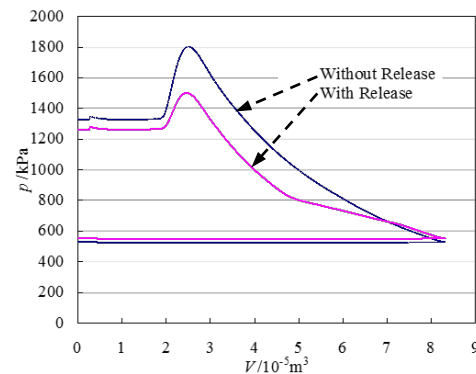


Figure 3: Simulated p-V diagram of scroll compressor with and without refrigerant release

When the system compression ratio is not smaller than the one the compressor provided, the control valve in the bypass cycle turns off and the bypass cycle is out of work. Once the system runs under over compression, the bypass cycle is put into effect. The control valve opens and a part of the refrigerant is released through the bypass channel back to the inlet of the compressor. As a result, the effective compression length of the scroll compressor is shortened, the inner compression ratio is reduced, and the over-compression loss is relieved (Figure 3). Furthermore, the refrigerant through the condenser and evaporator is decreased, which lowers the heating and cooling capacity of the system.

3. METHODOLOGY

The study is carried out in following steps:

Firstly, using a building load simulation software, DeST, the annual cooling and heating loads of these buildings located in different climate zones are calculated. Beijing, Shanghai and Guangzhou in China are chosen as the typical locations to represent the different climates from cold to warm. Moreover, both a residential building and an office building are calculated in order to evaluate the impact of building type on the adaptability.

Secondly, based on a numerical models of room air conditioners with and without refrigerant release function, the hourly energy consumption of these two kinds of air conditioners in the whole season are calculated. The model used in this research has been proposed in previous research (Wang *et al.*, 2012) and has been verified.

Finally, the energy consumption of air conditioners with and without refrigerant release are compared and the applicability of refrigerant release technology in room air conditioner is evaluated.

4. RESULTS AND ANALYSIS

Figure 4 shows the operating hours of the air conditioner in releasing mode and in non-releasing mode for the air conditioner with refrigerant release function. Generally speaking, there are a large number of hours to operate the air conditioner in refrigerant release mode and it is not affected by the climate or the building type. Because the space heating is provided by district heating system in Beijing. The air conditioner in Beijing will not run in winter. So the heating performance of air conditioner in Beijing is not evaluated.

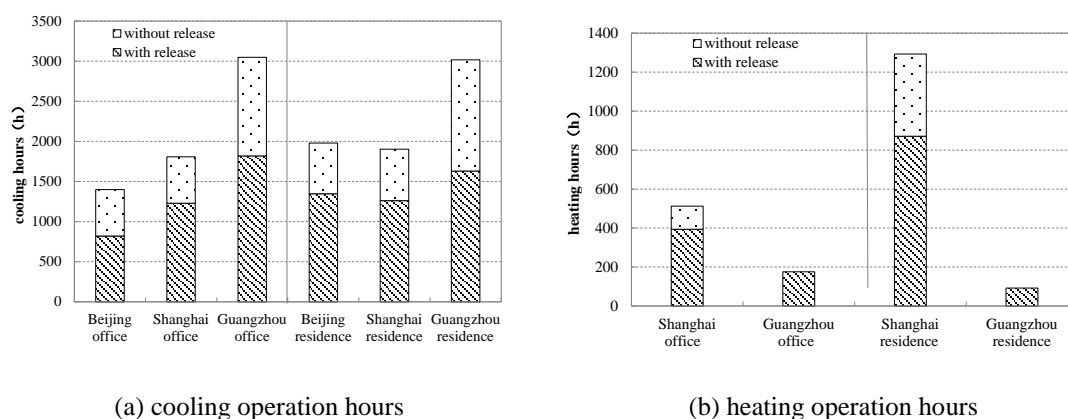


Figure 4: Operation hours of the air conditioner in different buildings

Figure 5 (a) and (b) present the seasonal energy consumptions of air conditioner with and without refrigerant release function in different buildings. Generally, the power consumption of air conditioner with refrigerant release is lower than that without refrigerant release, not matter in cooling season or heating season. The reasons are like that: on one hand, the refrigerant release reduces the over-compression loss; on the other hand, refrigerant release can reduce the system capacity, which largely decreases the on-off starting loss. Another phenomena also should be noticed: the energy consumption of residential buildings are much lower than the office building, which can be ascribed to the quite energy-saving operating habit of the occupants. Most of them just turn on the air conditioners when they come back from work and turn off the air conditioner when the room temperature drops to a relative comfort range.

Figure 5 (c) and (d) illuminate the seasonal energy saving amount and energy saving rate of different buildings. The energy saving ratio in cooling season can reach 17% ~ 24%. The air conditioner in Guangzhou gets the biggest energy saving amount but the relative lower energy saving ratio, which can be attributed to the higher outdoor temperature and longer operating time in hot area. The energy saving ratio in winter can reach 17% ~ 31%. Compared to the cooling season, the energy saving amount in heating season is quite less, that's because the shorter operating time during winter, especially in Guangzhou.

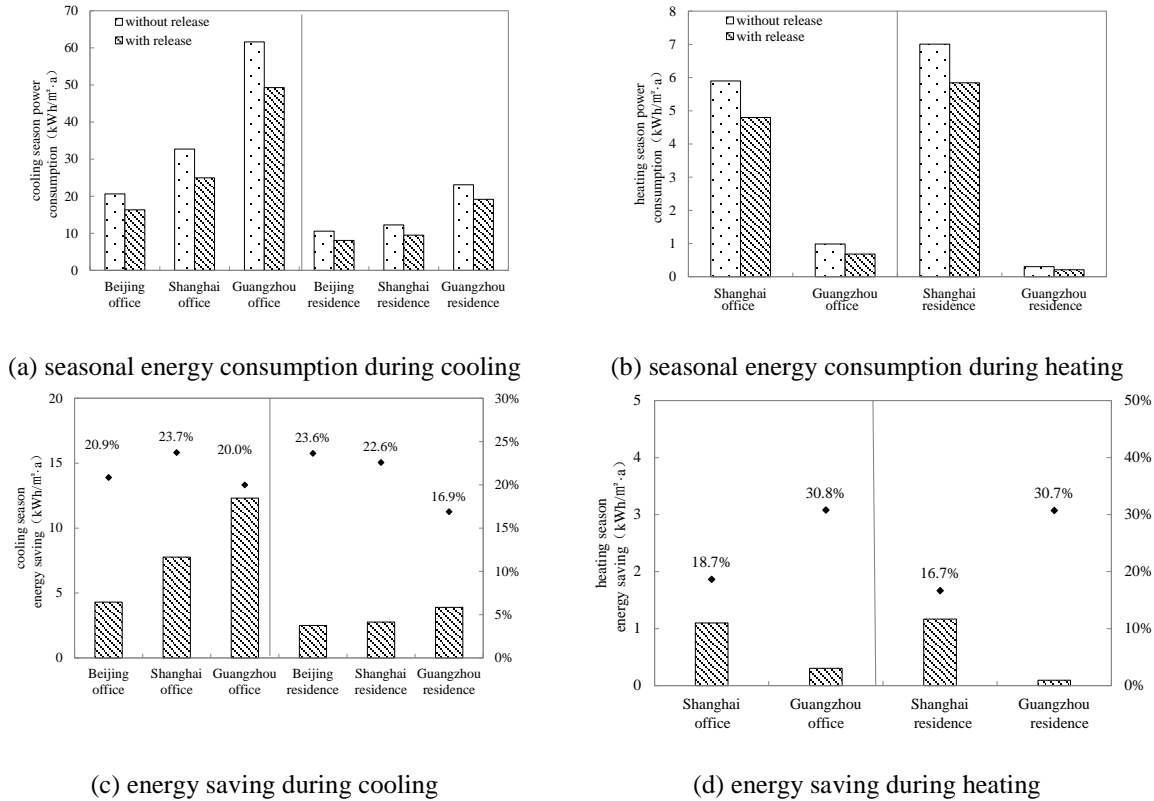


Figure 5: Seasonal energy consumption of air conditioner with and without refrigerant release

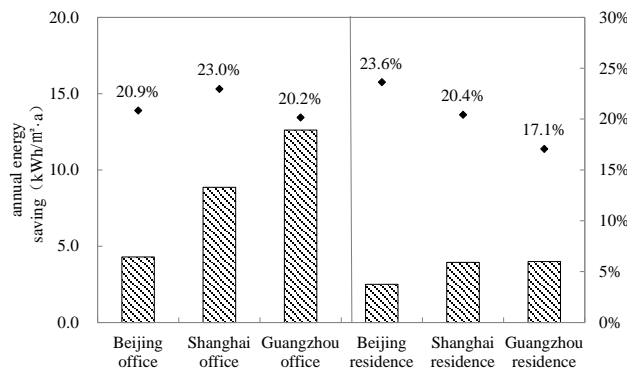


Figure 6: Annual energy saving ratio

Combined the cooling performance and heating performance, the annual energy performance of the air conditioner with refrigerant release can be acquired (Figure 6). The total energy saving ratio can reach 20% ~ 23% for office buildings in different locations. For residential buildings, the whole year energy saving ratio is between 17% ~ 24%. So the refrigerant release technology can effectively reduce the system annual energy consumption, and improve the annual energy efficiency for all kinds of buildings no matter where they are.

5. CONCLUSIONS

The inherent feature of fixed inner volume ratio of scroll compressor causes large degradation of the compressor indicated efficiency when the inner compression ratio mismatches with the system compression ratio under off-

design condition. The refrigerant release has been proven an effective method to decrease the over compression loss and enhance the compressor and air conditioner efficiency under mild environments. Through a whole year simulation, the seasonal adaptability of the refrigerant release is evaluated:

- 1) The real system compression ratio of the room air conditioners in residential buildings and office buildings are much less than the one under the rated condition;
- 2) The implement of refrigerant release can obviously decrease the power consumption of the air conditioner by decreasing the inner compression ratio and relieving over compression loss, and realize 14%~24% and 20%~23% seasonal energy saving for residential and office building, respectively;
- 3) The refrigerant release technology has good seasonal applicability for the room air conditioner and should be considered as an effective method to enhance the seasonal performance of air conditioner.

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