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ABSTRACT
A rotary compressor with double cylinders, double suctions and double reservoirs is presented in this paper. The two cylinders achieve independent suction pressures and two different evaporation temperatures. Combined with the structure characteristics of the rotary compressor with two independent suction pressures and the operation characteristics of the household fresh air conditioning system, the compressor can be applied to the household fresh air conditioning system with two evaporating temperatures. By comparison, the theoretical circulation COP of the new fresh system applying the compressor with two independent suction pressures is about 23% higher than that of the fresh air conditioning system with conventional compressor. By test verification, the COP of the fresh air conditioning system with the compressor with two independent suction pressures is increased by 6.55%.

1. INTRODUCTION
Comfort, oxygen content and cleanliness have become the latest target of IAQ with the improvement of demand for IAQ(Indoor Air Quality). The market demand of household fresh air-conditioning system is becoming more and more urgent. So the industry of household fresh system is in a rapidly developing stage now in China.

The conventional household fresh system usually adopts the all-air heat recovery exchanger: Indoor return air preheats and precools the outdoor fresh air through the filter, which can achieve heat recovery. And a part of indoor return air is discharged at the same time. The all-air heat recovery exchanger can realize the fresh air supply and the heat recovery, but it can’t control the temperature and humidity of the fresh air accurately. The direct evaporation all fresh air handling unit can realize the constant control of temperature and humidity of fresh air, and it has the advantages of compact structure, convenient maintenance, obvious dehumidification effect and so on. So it has been gradually extended to the field of household fresh air-conditioning system in recent years.

The compressor with two independent suction pressures discussed in this paper has been studied in ‘the separate sensible and latent cooling system (SSLC)’. The test results show that the energy efficiency is increase by 8.40% in SSLC mode than that of the conventional mode under rated cooling conditions (Liu et al, 2016). The application in the direct evaporation all fresh air handling unit with the compressor with two independent suction pressures is mainly discussed in this paper. Combined with the structure characteristics of the rotary compressor with two independent suction pressures and the operation characteristics of the household fresh air conditioning system, some optimization designs of
air-conditioning system have been proposed to satisfy the control of temperature and humidity of fresh air. The overall energy efficiency of the air conditioning system is improved effectively in this way, and the application fields of the rotary compressor with two independent suction pressures are broadened.

2. THE STRUCTURE CHARACTERISTICS OF THE TOTARY COMPRESSOR WITH TWO INDEPENDENT SUCTION PRESSURES

Fig 1(a) shows the conventional twin rotary compressor with double suction structure and single reservoir. The refrigerant from one or two evaporators is mixed in the reservoir of the suction side of compressor, and then the refrigerant is evenly distributed into the two cylinders to be compressed. After being compressed, the refrigerant is mixed in the exhaust chamber of the compressor, then it is exhausted from the discharge pipe into the condenser of the air-conditioning system(Liu et al, 2016). A single evaporation temperature and a single condensation temperature are achieved by the conventional twin rotary compressor in air-conditioning system.

The compressor with two independent suction pressures is different from the conventional twin rotary compressor. Fig 1(b) shows its structure characteristics of two independent suction structures and two independent accumulators. The refrigerant from one or two evaporators enters the desired reservoir of the suction side independently, then the refrigerant enters the desired cylinder to be compressed. After being compressed independently, the refrigerant is mixed in the exhaust chamber of the compressor, then it is exhausted from the discharge pipe into the condenser of the air-conditioning system(Liu et al, 2016). Two independent evaporation temperatures and a single condensation temperature are achieved by the compressor with two independent suction pressures in air-conditioning system. The displacement ratio of the compressor with two independent suction pressures is determined by the cooling load ratio and the operation conditions under two different evaporation temperatures.

Fig1: Comparison of compressor structure
3. THE OPERATION CHARACTERISTICS OF THE HOUSEHOLD FRESH AIR CONDITIONING SYSTEM

Table 1: Standards comparison of room air conditioner and household fresh air conditioner

<table>
<thead>
<tr>
<th></th>
<th>Household fresh air conditioner (Fresh Air Dehumidifiers)</th>
<th>Room air conditioner</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GB 20109-2006</td>
<td>GB 7725-2004</td>
</tr>
<tr>
<td>Outdoor air (Dry bulb temperature /Wet bulb temperature)</td>
<td>Supply air (the dew point temperature)</td>
<td>Dehumidification quantity</td>
</tr>
<tr>
<td></td>
<td>ºC</td>
<td>ºC</td>
</tr>
<tr>
<td>Rated Cooling</td>
<td>35/28</td>
<td>&lt;12</td>
</tr>
<tr>
<td>Maximum Cooling</td>
<td>40/30</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Minimum Cooling</td>
<td>16/14</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>

Fig 2: Return air processing VS fresh air processing

(a) Room air conditioner     (b) Household air conditioner

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According to the comparison of standards of room air conditioner and household fresh air conditioner in Table 1, it can be seen that there are some definite requirements for supply air in GB/T 20109 – 2006 (Fresh Air Dehumidifiers). That means the outdoor air should be treated from 35°C/28°C to the state of the supply air (the dew point temperature ≤ 12°C) under the rated cooling condition shown as Fig. 2. And the dehumidification quantity of fresh air is required to be 2.3kg/ (h.KW). So the design evaporation temperature of the household fresh air conditioner under the rated cooling condition is usually lower than that of the room air conditioner. Considering the heat transfer temperature difference, the design evaporation temperature of the household fresh air conditioner is generally set to be less than 10°C, which ensures the effect of fresh air dehumidification.

However, there are no definite requirements for supply air in GB7725-2004(Room Air conditioners). There is a requirement for indoor temperature. That means the indoor return air should be controlled at 27°C/19°C under the rated cooling condition. And there is no clear requirement for dehumidification quantity. It is considered that the standard of energy efficiency is getting higher and higher in recent years, the design evaporation temperature of the room air conditioner is generally set to be above 10°C.

This comparison shows that the household fresh air conditioner needs lower evaporation temperature than the room air conditioner in order to ensure the effect of fresh air dehumidification. However, the lower evaporation temperature causes the increase of pressure ratio, so the energy efficiency of the household fresh air conditioning system is generally lower than that of the room air conditioning system.

According to the previous research (Ling et al, 2010), the compressor with two independent suction pressures achieves two different evaporation temperatures, which can effectively improve the overall energy efficiency of the air conditioning system. Combined with the structure characteristics of the rotary compressor with two independent suction pressures and the operation characteristics of the household fresh air conditioning system, it is estimated that the household fresh air conditioning system using the compressor with two independent suction pressures has a more obvious advantage than using a conventional compressor. Either of cylinders of the compressor with two independent suction pressures is responsible for precooling of fresh air, and a higher evaporation temperature can be designed. The other cylinder is responsible for the wet load of the fresh air, which achieves the dehumidification of fresh air, and a lower evaporation temperature can be designed.

4. DESIGN OF THE COOMPRESSOR WITH TWO INDEPENDENT SUCTION PRESSURES APPLIED TO HOUSEHOULD FRESH AIR CONDITIONING SYSTEM

Combined with the structure characteristics of the rotary compressor with two independent suction pressures and the operation characteristics of the household fresh air conditioning system, the refrigeration system of household fresh air conditioner is designed shown as Fig 3.
Fig3: system scheme of household fresh air conditioner

(a) Conventional compressor applied          (b) Compressor with two independent suction pressures applied

Fig3(a) shows the schematic diagram of household fresh air conditioner using the conventional compressor. The filtered outdoor fresh air is cooled and dehumidified through the indoor heat exchanger (the evaporation temperature is below 10℃). Considering the thermal comfort of the human body, the supply air to the space from the indoor heat exchanger should be reheated to 16℃ through the reheat exchanger. The exhaust air is discharged through the gaps of doors and windows or through the special exhaust pipes. The low evaporation temperature is designed because of the requirement of dehumidification. The operating pressure ratio of the compressor is usually high, and the energy efficiency of the household fresh air conditioner is low. The heat transfer loss is also very large for the high enthalpy difference heat transfer of air side.

Fig3(b) shows the schematic diagram of household fresh air conditioner using the compressor with two independent suction pressures. The filtered outdoor fresh air is precooled through the indoor heat exchanger 1 (high evaporation temperature). Then the fresh air from the indoor heat exchanger 1 is dehumidified through the indoor heat exchanger 2 (low evaporation temperature). The supply air to the space is reheated to 16℃ through the reheat exchanger at last. So the supply to the space is comfortable for human body. The exhaust air is also discharged through the gaps of doors and windows or through the special exhaust pipes. The two indoor heat exchangers undertake the sensible load (Precooling) and latent load (Dehumidification) respectively by using the compressor with two independent suction pressures. The operation pressure ratio of is much higher at the side of sensible load because of the high evaporation temperature. So the comprehensive efficiency of the household fresh air conditioner is higher than that of the system using the conventional compressor. At the same time, the cooling process and the dehumidification process of the fresh air is realized by two small enthalpy difference heat transfers. The heat transfer loss is much lower than of the system using the conventional compressor.

5. PERFORMANCE ANALYSIS THE COOMPRESSOR WITH TWO INDEPENDENT SUCTION PRESSURES APPLIED TO HOUSEHOLD FRESH AIR CONDITIONING SYSTEM

5.1 Comparison of theoretical performance of household fresh air conditioning system
According to the process of the fresh air supplying shown in Fig 3, the design conditions of the compressor applied in household fresh air conditioner under the rated cooling condition are determined shown in Table 2. The theoretical calculation results of the refrigeration cycle show that the theoretical cycle COP of the household fresh air conditioning system using the compressor with two independent suction pressures is 23.03% higher than that of the household fresh air conditioning system using the conventional compressor.

The displacement of the two cylinders of the compressor with two independent suction pressures can be adjusted according to the design requirements of the fresh air conditioning system (the ratio of sensible load and latent load) and the experimental results of the system.

### Table 2: Theoretical calculation performance of the household fresh air conditioning system

<table>
<thead>
<tr>
<th></th>
<th>Conventional compressor</th>
<th>Compressor with two independent suction pressures</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Precooling</td>
</tr>
<tr>
<td>Evaporation temperature/℃</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Condensation temperature/℃</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Displacement of compressor/(mL/r)</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Speed /(r/min)</td>
<td>3 900</td>
<td>3 900</td>
</tr>
<tr>
<td>Theoretical cooling capacity /W</td>
<td><strong>8 394</strong></td>
<td><strong>9 952</strong></td>
</tr>
<tr>
<td>Theoretical power /W</td>
<td>1 352</td>
<td>1 303</td>
</tr>
<tr>
<td>Comprehensive COP</td>
<td><strong>6.21</strong></td>
<td><strong>7.64 (↑ 23.03%)</strong></td>
</tr>
</tbody>
</table>

Note: The rated cooling condition: Outdoor air temperature 35℃/24℃, Supply air (the dew point temperature) temperature ≤ 12℃.

### 5.2 Comparison of experimental performance of household fresh air conditioning system

For the same capacity of the household fresh air conditioning system, the comparison of the experimental performance of the system using the conventional compressor and the compressor with two independent suction pressures is carried out respectively. The evaporator of the system is divided into two parts. When the household fresh air conditioning system using the conventional compressor is tested, the two parts of the evaporator are combined into a single evaporator for testing. When the household fresh air conditioning system using the compressor with two independent suction pressures is tested, the two parts of the evaporator are independent. The exits of the two independent evaporators are connected with the two independent reservoirs respectively, the two independent suction pressures of the household fresh air conditioning system are achieved.

The test results of household fresh air conditioning system using the two different types of compressors are shown in Fig 4.

According to the experimental results shown in Fig 4, the COP of the household fresh air conditioning system using the compressor with two independent suction pressures is 6.55% higher than that of the system using the conventional compressor, and the dehumidification quantity of the household fresh air conditioning system using the compressor with two independent suction pressures is increased by 10.59%.
Though the energy efficiency of the household fresh air conditioning system using the compressor with two independent suction pressures is higher than that of the system using the conventional compressor, there is a wide gap between the theoretical calculation results and the test results. The reason for the gap can be analyzed as following:

(1) These test results are only the drop-in tests, the evaporators are not optimized. The higher evaporation temperature is lower than 18°C, so the superiority is not as good as the theoretical calculations.

(2) The factors such as the system heat transfer loss, pipeline pressure loss and compressor efficiency loss are not taken into account in the theoretical calculation results, so the COP of the theoretical calculation results is obviously higher than the experimental results.

In the future optimization design, the proportion of the heat transfer area of the two evaporators in the household fresh air conditioning system and the displacement of the two cylinders of the compressor with two independent suction pressures can be optimized. The high evaporation temperature can be increased, and the COP of the household fresh air conditioning system using the compressor with two independent suction pressures will be improved obviously.

6. CONCLUSIONS

(1) The rotary compressor with double cylinders, double suctions and double reservoirs is presented in this paper. The two cylinders achieve two independent suctions, and two different evaporation temperatures can be get in household fresh air conditioning system.

(2) The compressor with two independent suction pressures is applied to the household fresh air conditioning system. The system adopts the scheme of precooling (high evaporation...
temperature), dehumidification (low evaporation temperature) and reheat, which can improve both the comfort of the indoor supply air and the whole energy efficiency of the system.

(3) The COP of the household fresh air conditioning system using the compressor with two independent suction pressures is 6.55% higher than that of the system using the conventional compressor, and the dehumidification quantity of the household fresh air conditioning system using the compressor with two independent suction pressures is increased by 10.59%. The proportion of the heat transfer area of the two evaporators in the household fresh air conditioning system and the displacement of the two cylinders of the compressor with two independent suction pressures can be optimized, and the higher COP of the system will be get.

5. REFERENCES


Fresh Air Dehumidifiers, GB/T 20109—2006[S].