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Influencing Factors Study of the Variable Speed Scroll Compressor with EVI Technology

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ABSTRACT

Heating capacity of general air-condition system at low ambient temperature has been heavily attenuated. To solve the problem stated, the variable speed Scroll compressor with enhanced vapor injection (EVI) becomes the focus of the study in recent years. Influencing factors of the capacity and energy efficiency of the scroll compressor with EVI technology have been introduced in paper, including the area of Supplementary channel, the parameters of orbiting and fixed scroll profile, the position and number of Supplementary inlet. The different scheme of prototype is tested and the effect of the scheme is compared and analyzed. With the vapor injected into compress chambers, the Gas forces of working chambers change, and the characteristics of gas force about the scroll compressor with EVI Technology have also been analyzed.

1. INTRODUCTION

Heating mode is bounded by the Qinling Mountains In winter of china, centralized heating has been adopted by using coal, heavy oil and natural gas as the heat source in north of the Qinling Mountains. People hope to use new energy as a heat source because of increasingly severe environmental problems. South of the Qinling Mountains, including Jiangsu, Zhejiang, Hunan and Hubei areas currently adopt heaters and other equipment group, which cannot meet the needs of most people. Ordinary heating capacity of heat pump system at low ambient temperature has been heavily attenuated by the characteristics of the refrigerant, and reliability is also affected.

A variable speed Scroll compressor with EVI can solve the problems, which greatly enhance cooling capacity in winter by increasing mass flux of refrigerant. There is enough oil and gas to lubricate the pump when gas is injected into the scroll, so the compressed gas inside Compression chamber can be cooled to reduce the temperature of the exhaust gas and improve the reliability of the compressor. Therefore, Scroll compressor with EVI becomes the focus of the study in recent years. HuiXia Zhao（2005）has established theoretical model of supplement gas process and compared the heating capacity and energy efficiency of the different position of supplementary inlet by theoretical calculation.

In this paper, we analyze and summarize the factors of the scroll compressor with EVI, and then Gas forces of working chambers are compared by switching vapor injection channel at the end of the article.

2. ENHANCED VAPOR INJECTION PROGRESS

There is symmetric and asymmetric scroll profile for scroll compressor. Compared with symmetrical profile, asymmetric profile can reduce suction superheat and exhaust pressure loss, and easily use a single supplementary channel. At a word, the compressor with using Asymmetric profile has excellent efficiency, simple Structure and high reliability. As shown in figure 1, with the movement of orbiting scroll which is driven by the crank shaft, the scroll wrap of orbiting scroll covers the supplementary inlet when orbiting scroll rotate to the position in figure 2(a), and the orbiting scroll continues to rotate to the position in figure 2(b), gas is Injected to the inner chamber, orbiting scroll wrap covering the inlet again at the position in figure(c), the outer chamber Inject gas at the end, a cycle ends.

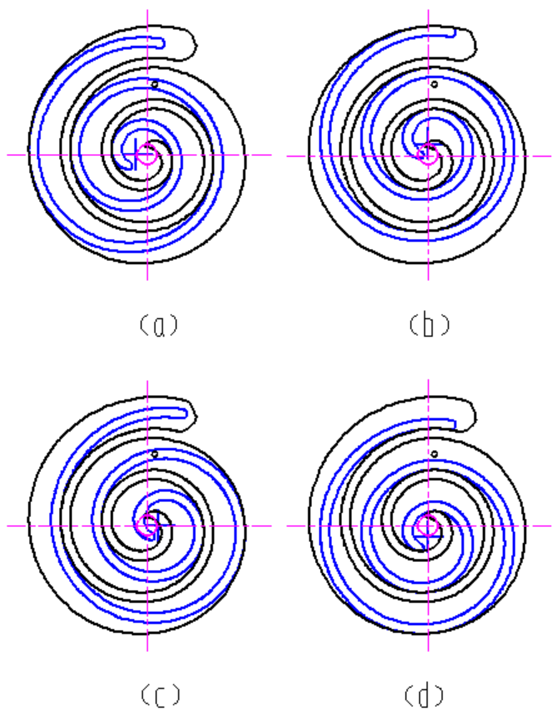


Figure 1: The vapor inject process

Economy of heat pump system which Uses Scroll compressor with EVI has two options which including flash-tank and sub cooler. The principle of heat pump system with flash-tank is introduced as an example, and the pressure enthalpy diagram is shown in Figure 2.liquid (point 9) becomes a gas-liquid mixture (point 10) into the flash-tank through the expansion valve .In the flash-tank, vapor in the upper part is sucked into supplementary inlet, Sub cooled liquid is throttled to the evaporation pressure Pe again and enters the evaporator. Low pressure gas (point 1) enters the compressor through the suction port, and is compressed to a certain pressure (point 2), which is mixed with gas through supplementary inlet in the compression chamber, and is discharged through further compression (point 7).

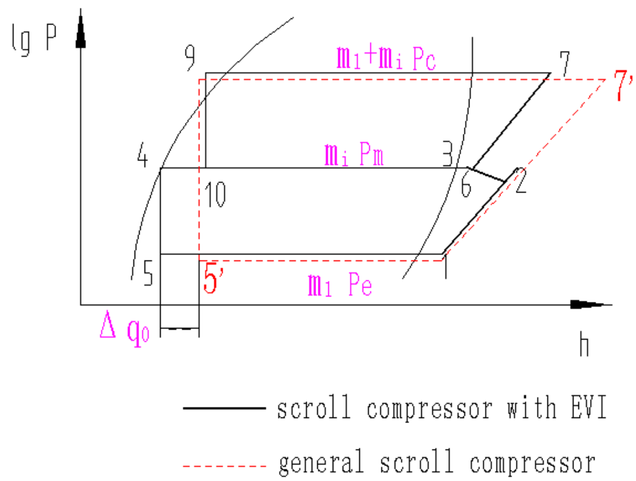


Figure 2: the pressure-enthalpy diagram of heat pump system with flash-tank

Cooling capacity is determined by enthalpy difference between points 1 and point 5 and mass flux of refrigerant which enters the evaporator. When the intermediate pressure is lower, the enthalpy difference is the greater between two points. If the pressure is too low, it will affect mass flux of refrigerant which enters the evaporator. Therefore, the optimal intermediate pressure value exists. To increase refrigerant mass flow of gas which enters condenser can enhance the heat capacity.

3. ANALYSIS OF INFLUENCING FACTORS

3.1 Supplementary channel

Reducing pressure loss of supplementary channel will help enhance the mass flux of supplementary gas, and increase heat capacity. Geometry model of supplementary channel is shown in Figure 3, the author uses CFD software to study the pressure loss of supplementary channel, and the pressure distribution is shown in Figure 4. The resistance loss mainly locates at both ends of the supplementary inlet, because the cross-section area suddenly changes, which resulting in local resistance losses. The effect of the diameter of supplementary channel is relatively small. It should focus on reducing losses here. We choose two different areas of radial channels to test, and the diameter is 5 mm and 7 mm. test results of the two programs are very similar, experimental and simulation results are consistent.

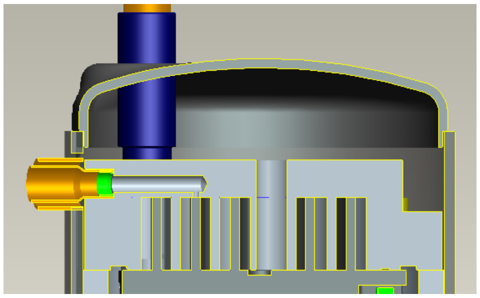


Figure 3: geometry model

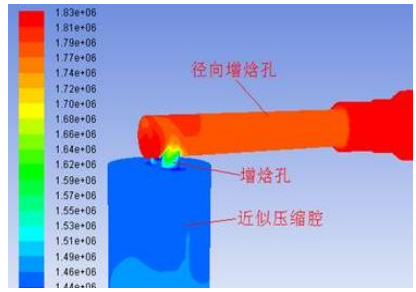


Figure 4: pressure cloud

3.2 Parametric of scroll profile

As the compressor with EVI, we need to consider how to choose the various parameters or equations, so that the volume of the intermediate compression chamber is large, and pressure is small. The rate of volume is determined by different parametric of scroll profile. For the same displacement, the compression chamber pressure is different with different parametric which including the pitch, wall thickness and wrap height. Therefore, in view of the above analysis, we designed two different parameters. By comparison, compression chamber pressure in option 1 is lower than option 2, so profile parameter chooses option 1, the result is shown in figure 5.

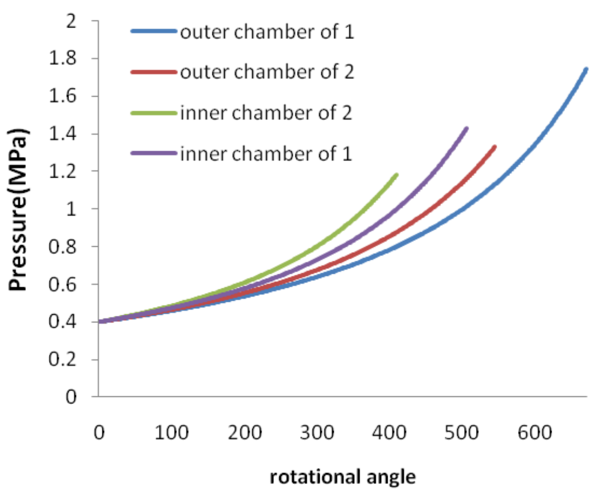


Figure 5: the curves of pressure according to the crank shaft

3.3 The position of supplementary inlet

Different position haves the greatest impact on pressure in the compression chamber. When position of supplementary inlet is near the suction finished chamber, pressure of the compression chamber is the lowest. We design the some different position of supplementary inlet, the paper chooses only two options as an example to analyze data. The starting step 0° is defined as the moment when the outermost or inner chambers are sealed off. The first scheme supplementary inlet is away from the closed position, and the second scheme is near the closed position, the angle of the crank shaft of the first program is 102-277 when vapor inject, the second one is 1-174.

Compared without EVI, the increases of cooling capacity and efficiency with EVI are distinctly shown in fig.7. Cooling capacity of the first scheme is improved between 3% -14% except IPLV50%, the effect in Cryogenic conditions is best, and the improved mount achieves 23%; Cooling capacity of the second scheme is improved 5%-26%, and cooling efficiency of the first one is improved between 5%-15.85%.

Compared the first scheme , the increase curve of cooling capacity and efficiency of the second scheme with EVI is shown in figure 8, Cooling capacity and efficiency of the second one is higher than 2%-12% and 0.6%-11.08% than first respectively. So the effect the second program is better than the first one.

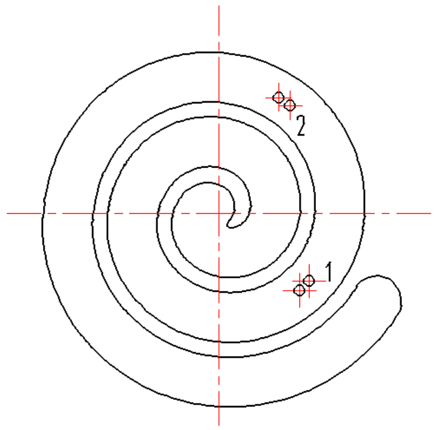
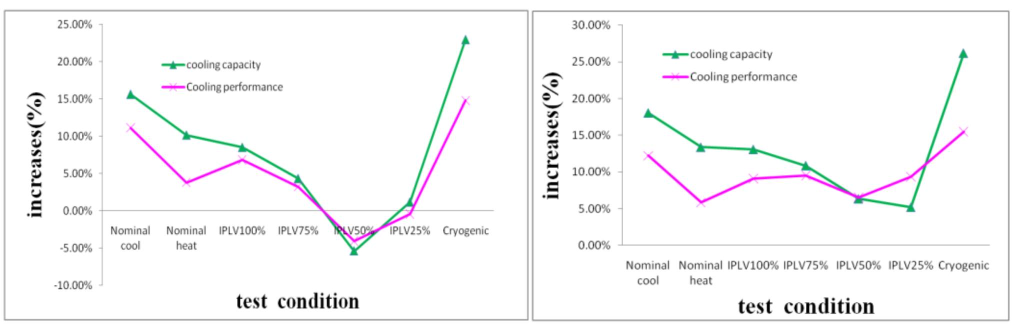


Figure 6: the position of supplementary inlet



（a） （b）

Figure 7: increases of cooling capacity and cooling efficiency with EVI:

(a) the first scheme, (b) the second scheme,

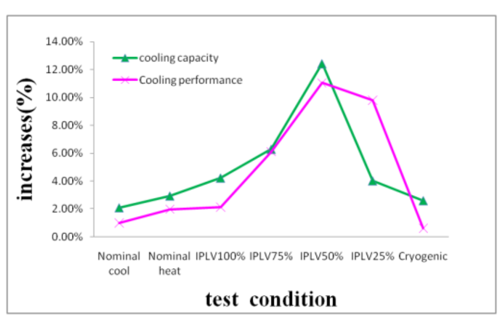
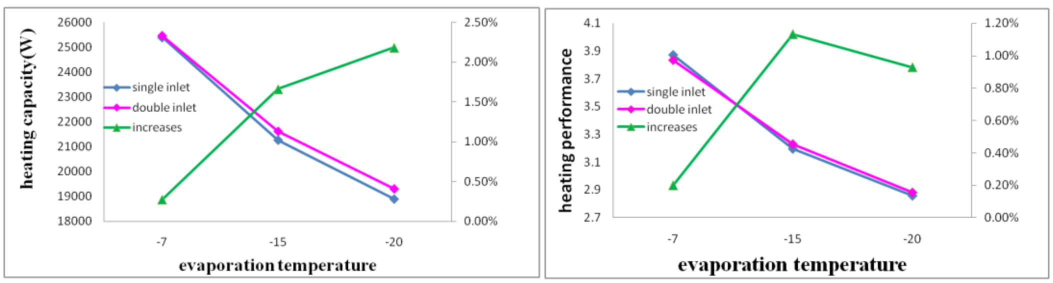


Figure 8: increases of cooling capacity and cooling efficiency between the second and first scheme

As can be seen from the above test data, improvement effect of cooling capacity and energy efficiency is remarkable including a light load conditions. Effect of the second program near the closed position is better.

3.4 Number of Supplementary inlet

In order to seal the compression chamber, enthalpy diameter of the hole is limited by the thickness of the wrap, and cannot be too large. We can only increase the number of Supplementary inlet to reduce fluid resistance loss, the author designed two programs, including single and double holes. On the basis of the same position, the three low temperature conditions, the evaporation temperature is respectively -7, -15 and -20 degrees centigrade. Heating capacity and efficiency is tested in the compressor efficiency test rig with flash evaporator. The results of the comparison are shown in figure 9. At the three low-temperature conditions, heating capacity and energy efficiency of the compressor which adopt double holes have been enhanced in contrast with single hole.



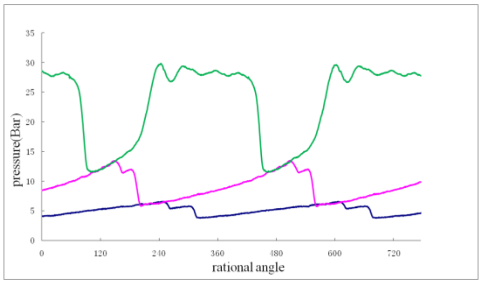
（a） （b）

Figure 9: comparison of single inlet and double inlet: (a) heating capacity, (b) heating efficiency

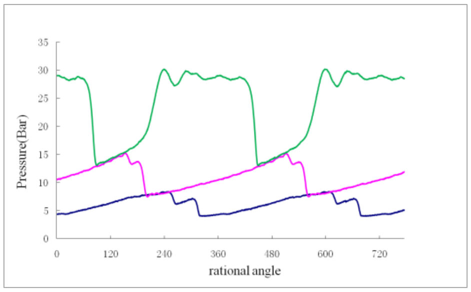
4. ANALYSIS OF GAS FORCE

Orbiting scroll of scroll compressor is floating, seal of the pump is controlled by back pressure force of orbiting scroll and pressure of the compression chamber. Change of pressure in compression chamber will affect the stability and movement of orbiting scroll. If back pressure force is too small, the leakage of the scroll pump have important influence on capacity and energy efficiency, and the back plate of orbiting scroll can wear. If back pressure force is too big it will increase the clamping force between orbiting scroll and fixed scroll, increasing power consumption. So measurement of pressure of compression chamber is essential for efficiency and reliability of the compressor.

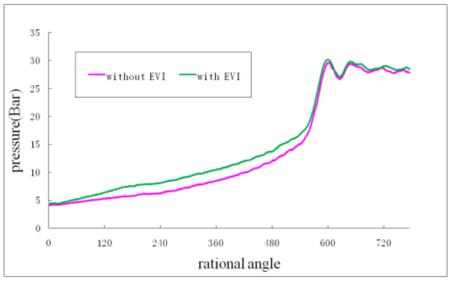
In order to measure pressure in the compression chamber, four piezoelectric pressure sensors were arranged in different position of the fixed scroll. The pressure can be monitored throughout the compression process, while the



（a）



（b）



（c）

Figure 10: Variation Curve of Pressure in compression chamber:
(a) without EVI,(b) with EVI，(c)comparison result

Crank angle also is monitored by displacement sensor. The curve of pressure in compression chamber with crank angle is exported. For all operating conditions the pressure shows similar pattern. As an example, pressure at low temperature condition has been analyzed. Variation curve of pressure is shown in figure 10.

When vapor is injected, pressure in the compression chamber becomes higher. Pressure compression chamber at the end of vapor inject is slightly less than the intermediate pressure, and the pressure of the compression chamber depending on the intermediate pressure. Therefore, with conventional compressor, sealing problems should be different for scroll compressor with EVI.

5. CONCLUSIONS

Based on theoretical analysis and experimental validate, the influencing factors of capacity and energy efficiency of the scroll compressor with EVI technology have been analyzed. We can summarize the following:

- Different profile parameters will affect the structure and effect of scroll compressor with EVI. Asymmetric profile is adapted by scroll compressor with EVI.
- Profile parameter is designed to reduce pressure of the compression chamber. The optimal position of supplementary inlet is near position of suction finished. Supplementary channel is designed rationally according to the volume of fixed scroll. Effect of double supplementary inlets is superior to the single one.
- Pressure in compression chamber at the end of vapor inject is slightly less than the intermediate pressure, and the pressure of the compression chamber depending on the intermediate pressure.

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Huixia Zhao.(2005).Theoretical Analysis and Experimental Study On Heat Pump System With Flash-Tank Coupled with Scroll Compressor. *Beijing University of Technology*.