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CFD ANALYSIS OF OIL DISCHARGE RATE IN ROTARY COMPRESSOR

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ABSTRACT

Oil discharge rate in rotary compressor has a significant influence on heat transfer performance of condenser and evaporator in air conditioning system. In order to find out the influence which caused by the structure of rotary compressor on the oil discharge rate, the flow field of rotary compressor has been calculated by VOF method and the lubricant distribution in rotary compressor can be obtained. At the same time, Oil discharge rate in rotary compressor at different operating conditions has been calculated in this paper.

1. INTRODUCTION

The lubricating oil plays an important role in a hermetic rotary compressor as it provides lubrication to the moving parts and fills in the sealed parts to reduce gas leakage; also it remove heat generated from mechanical friction of sliding parts and gas compression, motor, etc; when excessive oil is discharged from the compressor with the gas flow, the performance of air conditioning system will debase as the heat transfer coefficients of condenser and evaporator decline. More seriously it may affect the reliability of the compressor. Usually, an oil separator device is used in the air conditioner not only to avoid excessive oil will discharge into the condenser and evaporator but also ensure the oil supply for compressor. While for common house conditioner the oil separator device is not used. So it is necessary to control the oil discharge rate of rotary compressor.

Haitao Hu et al. (2008) discussed the local heat transfer coefficients of R410A-oil mixture decrease with the increase of local oil concentration when the local oil concentrations are higher than 8%.

Antonio et al. (2008) studied the oil pumping system of the reciprocating compressor with the simulation method ;Kamal Sharma et al. (2010) discussed the way of reduce oil circulation ratio in the rotary compressor by using CFD analysis; Yusheng Hu et al. (2011) studied the shaft oil feed system of rotary compressor by using VOF method, the average error between the simulation and the experimentation is less than 10%.

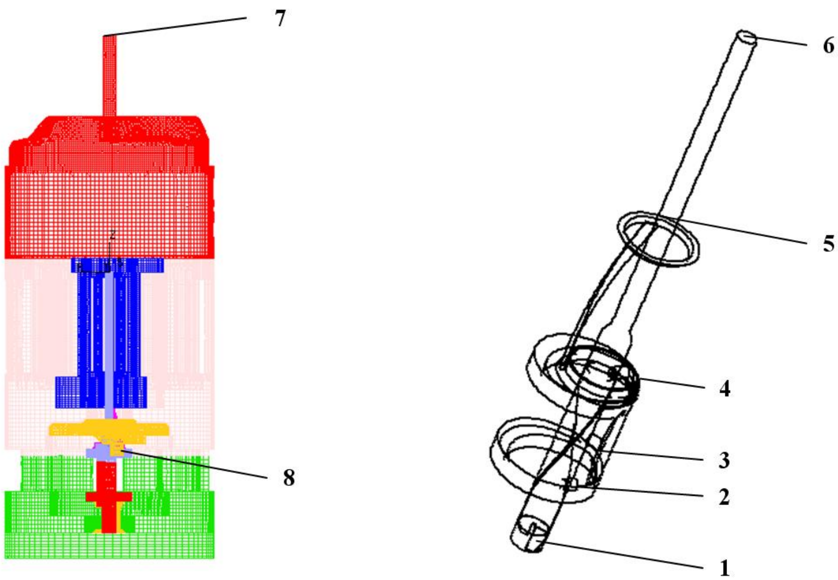
This paper using STAR-CD, a general purpose CFD software to study the oil distribution in the rotary compressor and compare the influence on oil discharge rate out of rotary compressor of different operating conditions.

2. MODEL AND BOUNDARY

The shaft oil feed system in rotary compressor pump oil into the axes hole of crankshaft under the force of pressure drop and the centrifugal force caused by rotation of the crankshaft. The amount of oil and the height of pump oil are enhanced when the crankshaft fix a spiral plate on the inlet of crankshaft. The oil flow into each bearing groove, the clearance between roller and each bearing through the radial holes ((1).(2). (3) in figure 1) which locates in crankshaft. At last one part of the oil return to the oil pool, another will discharge out of the rotary compressor with the gas flow.

2.1 Calculation Model Descriptions

Figure 1 shows the mesh model of rotary compressor which contains oil pool, the shaft oil feed system, muffler, rotor components, gap between stator and rotor, the stator packet gap, flow holes of stator, the chamber up and down of the motor, exhaust pipe. The shaft oil feed system and rotor components use structuring grids, other parts use trim grids. The total mesh number is approximately 380,000. Crankshaft and rotor components are set to moving mesh and the rest parts are set to stationary mesh. Both moving and stationary meshes are treated through attach boundary. Using event file to connect the adjacent attach boundary and invoke .cgrd file which controls the moving mesh.



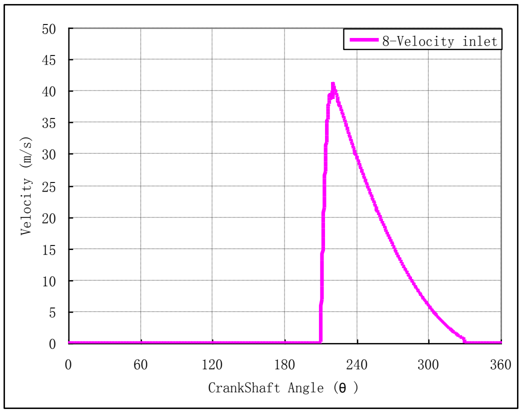
(1). Crankshaft inlet (2). Lower journal bearing hole (3). Roller hole (4). Upper journal hole
(5). Spiral groove outlet (6). Crankshaft outlet (7). Compressor outlet (8). Muffler inlet

Fig 1: Rotary compressor model

2.2 Calculation Schemes and Boundary conditions

The numerical simulation adopts the VOF model, The turbulent model use K-Epsilon/RNG model. Standard wall function is adopted in the near wall treatment. The physical properties of oil which is used as the heavy fluid and R410A which is used as light fluid are constant. Operating frequency of the rotary compressor is 60HZ. As figure 1 shows: (1)—(6) are internal faces termed to monitoring the transformation of the flow field. (7) is the compressor outlet, (8) is the inlet of the muffler. This paper have four calculation schemes to compare the oil discharge rate of rotary compressor when compressor works at different conditions.

Scheme 1: The rotary compressor works in the atmospheric environment, no gas discharged from the muffler, The compressor outlet (7) use pressure boundary and the pressure is 0.1Mpa.
Scheme 2: The muffler inlet (8) use velocity boundary as figure 2 shows, the volume fraction of oil in the fluids accounted for 1%; the compressor outlet (7) use pressure boundary and the pressure is 3.43Mpa.
Scheme 3: The muffler inlet and the compressor outlet both use pressure boundary as figure 3 shows, the volume fraction of oil in the inlet fluids accounted for 1%.
Scheme 4: The muffler inlet and the compressor outlet both use pressure boundary as figure 3 shows, the inlet fluid is defined as pure R410A.



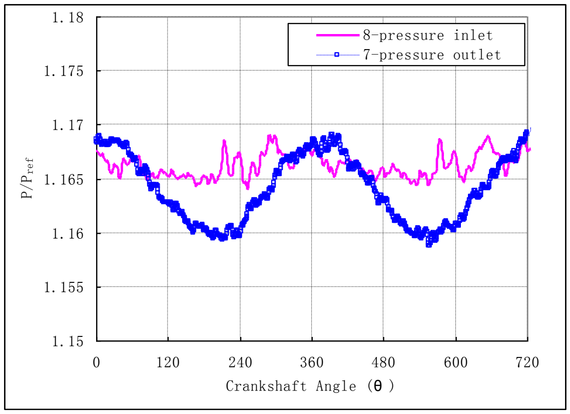


Fig 2: Velocity boundary of muffle inlet

Fig 3: Pressure boundaries

3. CFD ANALYSIS

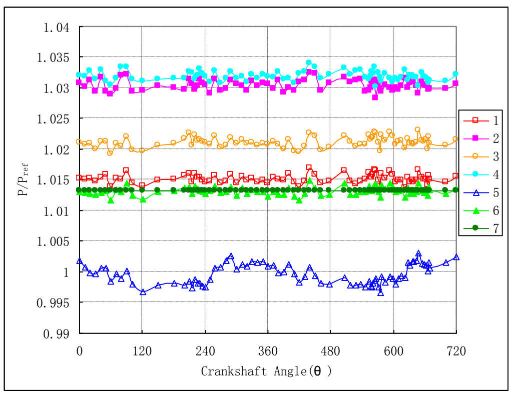
3.1 Pressure Analysis

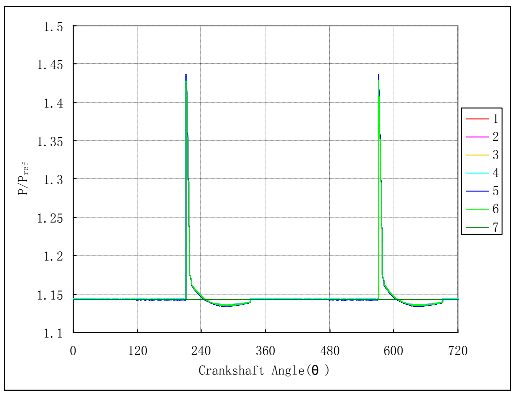
As figure 4 shows, in scheme 1, pressure at the of spiral groove outlet (5) has a periodic fluctuation which caused by the movement of main balance block, and it is the lowest in all of the monitoring surfaces. Pressure of other monitoring surfaces have not change significantly. Among the three radial holes of crankshaft, pressure of the upper journal hole is the highest, followed by the lower journal hole, pressure of the roller hole is lower about 1000 pa than other two radial holes. This may be caused by the structural of the shaft oil feed system. The roller hole is connect with the gap which between the roller and the journal bearings through the groove which located in the eccentric part of crankshaft. So the resistance of the roller hole for fluid is smaller than the upper journal hole and the lower journal hole.

When the inlet of muffler use velocity boundary in scheme 2, the pressure of all the monitoring face suddenly increase as the inlet velocity speed on the rise. and then down as the inlet velocity speed drop. Pressure of the roller hole is the lowest among the three radial holes of the crankshaft.

Scheme 3 and scheme 4 use the same pressure boundaries at the muffler inlet and compressor outlet. The different is that the volume fraction of oil in the fluids of inlet flow accounted for 1% in scheme 3. as the results shows ,The pressure from high to low in order is: upper journal hole, lower journal hole, roller hole, crankshaft inlet, crankshaft outlet, spiral groove outlet. The pressure transformation of each monitoring face is caused by the pressure inlet boundary and pressure outlet boundary of calculation model.

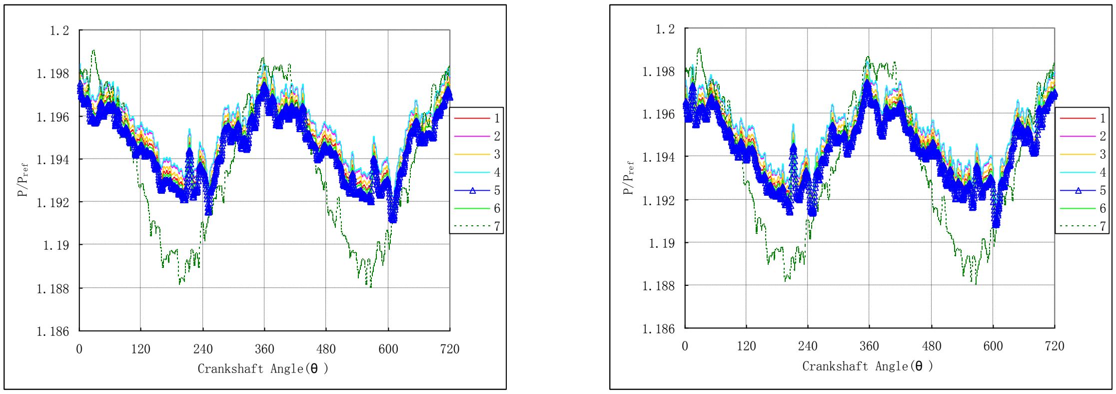
Except scheme2, in other three schemes, the relative pressure of each monitoring face is similar. The boundaries of calculation model is very important to flow field.





(a) Scheme 1

(b) Scheme2



(c) Scheme 3 (d) Scheme4

Fig 4: Pressure transformation curves

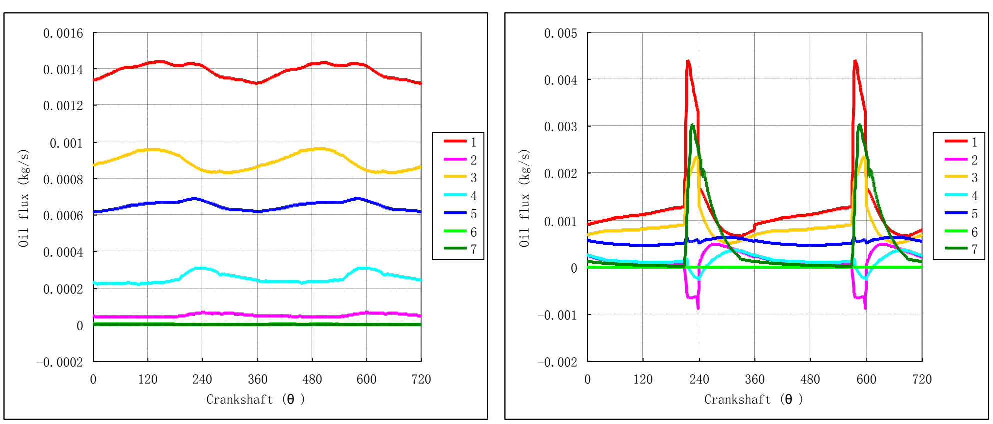
3.2 Oil flux Analysis

As figure 5 shows, in scheme 1, scheme 3 and scheme 4, the amount of oil out of the monitoring face from big to small in order is: roller hole, spiral groove outlet, upper journal hole, lower journal hole. There has no oil discharge out of the compressor. In scheme 2, when the gas begin discharge, the oil flow rate increase suddenly, during the moment of gas discharge rate increase, back flow appears in the lower journal hole and upper journal hole; the amount of oil out of roller hole still is the biggest, next is the spiral groove out;

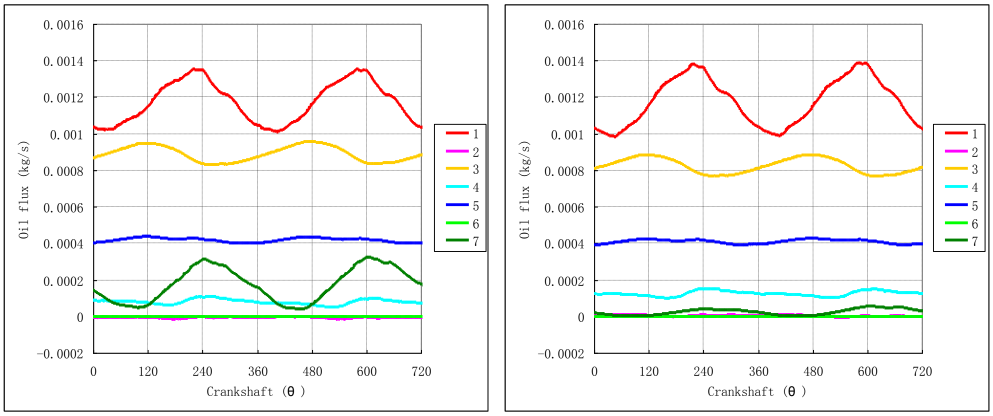
Statistics of average oil flux and OCR has list in table 1. OCR (abbreviation of Oil Circulation Ratio) which is defined by the formula (1) is used to denote the oil discharge rate of rotary compressor. From the comparison of table 1, the difference of total average pump oil among the four calculation schemes is not very obviously. To oil pump system, the oil quantity output of the roller hole is always the biggest. Followed is the spiral groove out, the oil quantity output of the upper journal hole and the lower journal hole is very small, almost no oil output of the crankshaft end.

The oil volume fraction of the inlet flow is same in scheme 2 and scheme 3, while OCR in scheme 2 is bigger than scheme 3 as they use different calculation boundaries.

OCR in scheme 3 is bigger than scheme 4 as they use the same calculation boundaries while the oil volume fraction of the inlet flow is bigger than scheme 4. The OCR of this rotary compressor at experiment is 0.61% which is intervene the OCR in scheme 3 and scheme 4. So the oil volume fraction of gas discharge out of the muffler is an important factor to oil discharge rate in rotary compressor.



(a) Scheme 1 (b) Scheme2



(c) Scheme 3 (d) Scheme4

Fig 5: Oil flux transformation curves

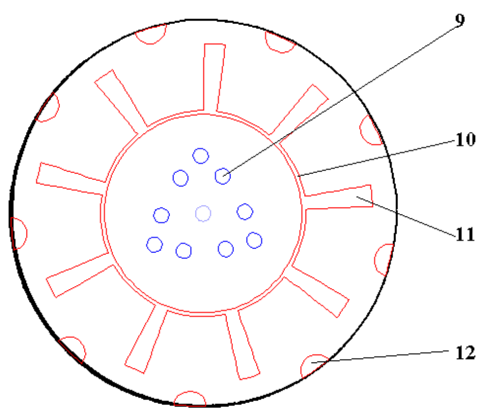
Table 1. Statistics of average oil flux and OCR (unit: g/s)

	1	2	3	4	5	6	7	8	OCR
Scheme 1	**1.48**	**0.048**	**0.875**	**0.236**	**0.61**	**0**	**0**	**0**	**0.00%**
Scheme 2	**1.17**	**0.143**	**0.87**	**0.126**	**0.514**	**-0.007**	**1.46**	**0.52**	**2.85%**
Scheme 3	**1.19**	**-0.006**	**0.878**	**0.093**	**0.418**	**0**	**1.2**	**0.16**	**0.63%**
Scheme 4	**1.18**	**0.003**	**0.824**	**0.125**	**0.41**	**0**	**0**	**0.024**	**0.018%**

$$OCR = \frac{g_{oil}}{g_{R410A} + g_{oil}} \times 100\% \tag{1}$$

g_{oil}: the oil mass discharged out of the compressor; g_{R410A}: the R410A mass discharged out of the compressor.

Figure 7 shows the oil flux transient curves of monitoring faces (9-12) which are illuminated in figure 6. Backflow appear in the rotor flow holes all the time and fluctuate slightly; in the other flow holes the fluids have obviously periodic fluctuate. The amount of oil flux from high to small in order is: stack gap, stator flow holes, gap between rotor and stator, rotor flow holes.



(9). Rotor flow holes (10). Gap between rotor and stator (11). Stack gap (12). Stator flow holes

Fig 6: Motor flow holes

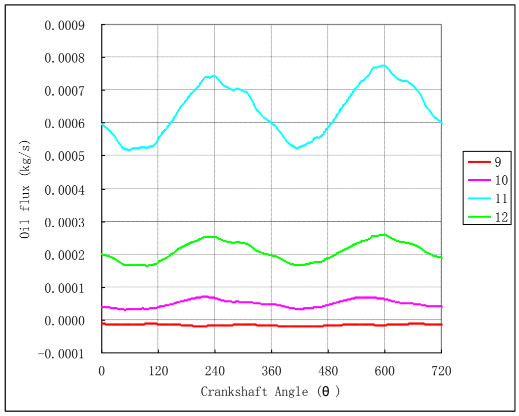
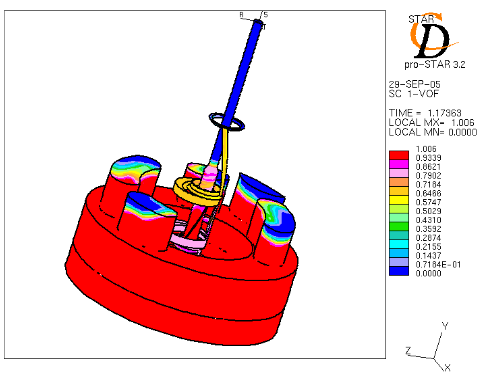


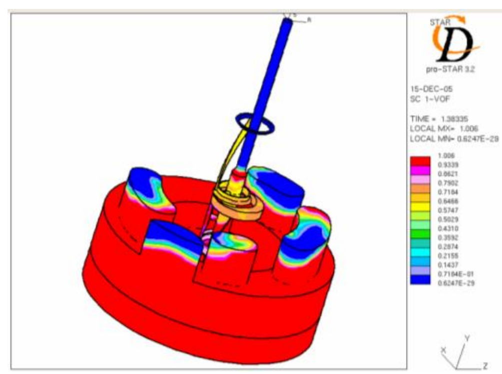
Fig 7: Oil flux transient curves of motor flow hole (scheme 3)

3.3 Oil pumping height

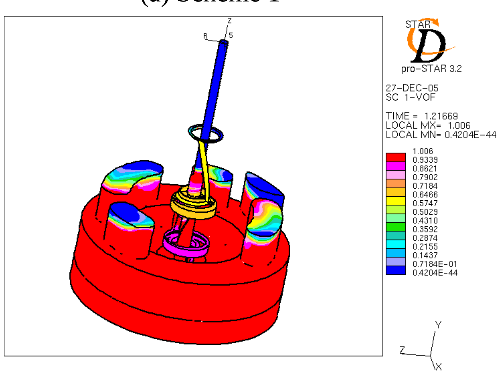
Oil pumping height of four schemes are showed in figure 8. In a word, operating environment has puniness effect on the shaft oil feed system as the pump oil height of four schemes are only slightly higher than the crankshaft neck.



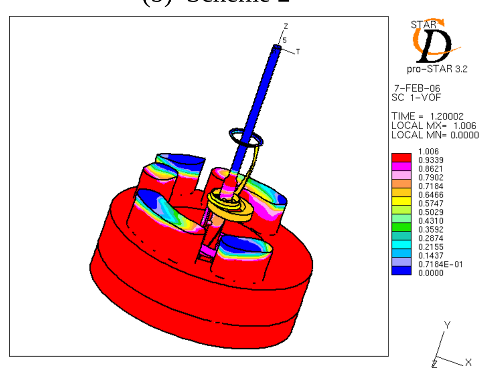
(a) Scheme 1



(b) Scheme 2



(c) Scheme 3



(d) Scheme4

Fig 8:Oil pumping height

4. CONCLUSIONS

Oil distribution in rotary compressor and oil discharge rate are calculated in this paper, the calculation take no account of the solubility of R410A. The following conclusions are made on the rotary compressor:
(1) Pressure at the upper journal hole and the lower journal hole are higher than pressure at the roller hole; pressure at the spiral groove out is the lowest among the monitoring faces of the shaft oil feed system.
(2) The amount of oil out of the roller hole is the largest among the monitoring faces of the shaft oil feed system, followed by the spiral groove out, only a little of oil out of the lower journal hole and upper journal hole, almost no oil out of the crankshaft end.
(3) The oil volume fraction of inlet flow is an important factor to oil discharge rate out of the rotary compressor and has little influence on the shaft oil feed system.
(4) For the motor flow holes of rotary compressor in this paper, the oil mainly distribute in the stack gap, the following is stator flow holes and the gap between rotor and stator.

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