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Numerical Study on the Oil Pump System of Rotary Compressor

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SIMULATION ON THE OIL PUMP SYSTEM OF ROTARY COMPRESSOR

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ABSTRACT

Oil pump lubrication system is an essential part of compressor to ensure the normal operation. During the process of compressor running, lubricant system can form oil film on surface of moving parts to decrease friction and reduce abrasion and occlusion. In order to meet the lubrication requirements, we must design pump oil structure reasonable. However, oil lubricating and circulating process is a complex and dynamic process, only if through experimental study to understand the characteristics of each components in oil lubrication system is very difficult.

Therefore, in this article, we use commercial software CFD to research the best pump structure. In order to study the pump oil performance, we adopt the gas-liquid two-phase model to research the lubricating oil rising process and the flow of each oil hole in different speed.

1. INTRODUCTION

Pump oil system of rotary compressor is composed of oil tank, oil pump, radial hole, shaft hole, the shaft undercuts, bearing on the spiral tank, as well as a number of leak paths, shown in Figure 1. One end of the crankshaft is immersed in the oil. The oil rises along the crankshaft center hole, and enters into the radial hole of the crankshaft when the crankshaft rotating. This oil arrives the lubrication surface by the centrifugal force to form a film lubricated bearings, and the superfluous lubricant oil flows back to the oil pool.

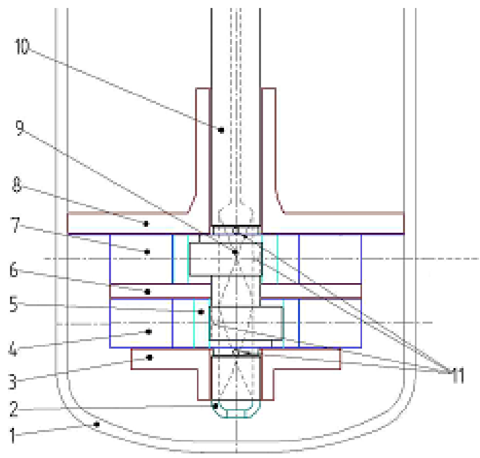


Figure 1: Pump oil sysytem

1: compressor housing 2: dust collector 3: under cylinder head 4:under cylinder 5:piston
6 :up cylinder 7:up cylinder head 8: rotating woods 9: crankcase 10 oil hole

Oil pump lubrication system is an essential part of compressor to ensure the normal operation. During the process of running, the lubrication system have the following function: forming the oil film on the moving parts to reduce friction, reducing wear and tear of moving parts, taking away the heat generated by friction and debris when the lubricating oil flows, improving the working conditions of the friction surface; The oil film can absorb the sound to reduce noise.

Pump oil lubrication cycle is a complex physical dynamic process. When the compressor motor start running, the crankshaft rotating in a high speed, due to centrifugal force, lubricating oil rising along the crankshaft internal wall to overcome gravity and surface tension, and finally arriving at each hole of the bearing for lubrication. When the running is stability ,the height and shape of the oil surface is affected by centrifugal force, gravity, surface tension, the interaction of decision. In order to meet the lubrication requirements, we must design the pump oil reasonably. However, pump oil lubrication cycle is a complex physical dynamic process. If we want to know the characteristics of each component, only through trial study has some difficulties.

In recent years, the rapid development of computational fluid dynamics (CFD) provides an important hole in Engineering Fluid Mechanics technology research. In 2004, Trane engineers simulated the scroll compressor pump oil system by CFD, and got the detailed process of pumping oil (Michael M. CUI. ,2004). In 2008, Xi'an Jiaotong University, simulated the rotating-cylinder compressor oil system to solve practical engineering problems (Zhanli Zhai,2008).

we apply commercial software CFD in this article to design the best pump structure .We adopt The gas-liquid two-phase model to study the oil pump performance and research the lubricating oil in the crank wall rising process and the flow of each oil hole in different speed. In order to compare the performance the best applicable conditions of two kinds of crankshaft structure, we adopt the gas-liquid two-phase separation model to simulate the compressor pump oil by CFD .

2. NUMERICAL SIMULATION OF COMPRESSOR PUMP OIL SYSTEM

2.1 The flow equation

Lubricating oil rose along the center hole of the crankshaft, and ultimately achieve a stable surface as the crankshaft rotating, it is a free liquid surface problems. The flow field is described by the continuity equation, the N-S equation, the energy equation and the gas equation of state. The turbulence model is RNG equation, and he oil act as a Newtonian fluid in CFD modle (www.adapco-online.com).

The model of the turbulent kinetic energy equation as follows:

$$\frac{\partial}{\partial t}(\rho\varepsilon)+\frac{\partial}{\partial x_j}(\rho u_j\varepsilon-\frac{\mu_{eff}}{\sigma_\varepsilon}\frac{\partial\varepsilon}{\partial x_j})=C_{\varepsilon 1}\frac{\varepsilon}{k}[\mu_t(P+C_{\varepsilon 3}P_B)-\frac{2}{3}(\mu_t\frac{\partial u_i}{\partial x_i}+\rho k)\frac{\partial u_i}{\partial x_i}] \tag{1}$$

Turbulent dissipation rate equation:

$$\frac{\partial}{\partial t}(\rho\varepsilon)+\frac{\partial}{\partial x_j}(\rho u_j\varepsilon-\frac{\mu_{eff}}{\sigma_\varepsilon}\frac{\partial\varepsilon}{\partial x_j})=C_{\varepsilon 1}\frac{\varepsilon}{k}[\mu_t(P+C_{\varepsilon 3}P_B)-\frac{2}{3}(\mu_t\frac{\partial u_i}{\partial x_i}+\rho k)\frac{\partial u_i}{\partial x_i}]-C_{\varepsilon 2}\rho\frac{\varepsilon^2}{k}-C_{\varepsilon 4}\rho\varepsilon\frac{\partial u_i}{\partial x_i}-\frac{C_\mu\eta^3(1-\eta/\eta_0)}{1+\beta\eta^3}\frac{\rho\varepsilon^2}{k} \tag{2}$$

Where

k for the turbulent kinetic energy, ε for the turbulent dissipation rate, $\mu_{eff} = \mu + \mu_t$, μ_t turbulent viscosity coefficient, $\eta \equiv S\frac{k}{\varepsilon}$, $S \equiv (2s_{ij}s_{ij})^{1/2}$.

For the other empirical parameters: the amendment for speed and the k 、ε as follows:

For the speed equation

$$U^+ = \begin{cases} y^+ & y^+ \le 11.63 \\ \frac{1}{\kappa}\ln(Ey^+) & y^+ > 11.63 \end{cases} \tag{3}$$

Where,, $U^+ = \frac{U_p C_\mu^{1/4} k_p^{1/2}}{\tau_w / \rho}$, $y^+ = \frac{\rho C_\mu^{1/4} k_p^{1/2} y_p}{\mu}$; κ for von Karman coefficient, E is Smooth coefficient for the wall; τ_w is wall shear stress ; U_p is the average speed at the point P, k_p for the turbulent kinetic energy at point P, y_p The distance to the wall for the point P ; μ for the kinematic viscosity。

Equation k of the turbulent kinetic energy for P_k 、ε is amended as follows:

$P_k \approx \tau_w \frac{\partial U}{\partial y} = \tau_w \frac{\tau_w}{\kappa \rho C_\mu^{1/4} k_p^{1/2} y_p}$ $\varepsilon_p = \frac{C_\mu^{3/4} k_p^{3/2}}{\kappa y_p}$; Without solving the ε equation.

Use the finite volume method to control equation for discrete within collocated grids, and using SIMPLE method to solving the equations. The basic idea of SIMPLE method is bring in the concept of correction, by finding the pressure correction equation that relationship of the pressure correction and velocity correction via continuity equation, finally solving the equation.

2.2 VOF Method

VOF method is tracking of the moving interface by solving the VOF function, (www.adapco-online.com). It defines a function C in the entire flow field, the function C is a ratio by the target fluid volume and the grid size in each grid . The grid have no fluid inside (C = 0) referred to "empty grid", the grid full of fluid inside (C =1) referred to "full" grid, then the grid gave some of fluid inside (0<C<1) referred to "semi-grid".

At any moment, knowing that the C values of this function on each grid, we can construct a variety of free moving interface, you can calculate the free surface slope, curvature, given a more accurate description of the free surface. VOF function have its own physical meaning, it is a fluid grid in the share of the entire volume of the grid than solving equations, to maintain its physical significance is difficult, so the equation format should be conserved . The value of each time step function passing interface from 1 to 0 or from 0 to 1, near the moving interface to form a "ribbon", only in the "tape" within VOF function 0 <C <1. To get a clear material interface, and improve resolution in solving physics equations, the "tape" must not be too wide. Is to maintain the VOF function only on a grid containing interface is greater than 0 and less than 1, on the other grid must be 1 or 0.

3. CFD SIMULATION OF OIL-PUMPING SYSYTEM

3.1 Model of pump oil

Using VOF method to simulate the process of oil rising, the grid distortion is as small as possible, the grid size is more uniform. Also hope the overall grid small changes to reduce the difference between the results of the calculation due to the grid changes when structure changing, (Zhang Huajun,2001)(Kamal Sharma,2010). So using "couple " method between the connection of various piping. Figure 2 oil-pumping system model.

The model of the fluid region contains all the lubricating oil channel except the bearing oil film . for example, We simulate the frequency conversion compressor for the speed of 900 rpm and 2850 rpm.

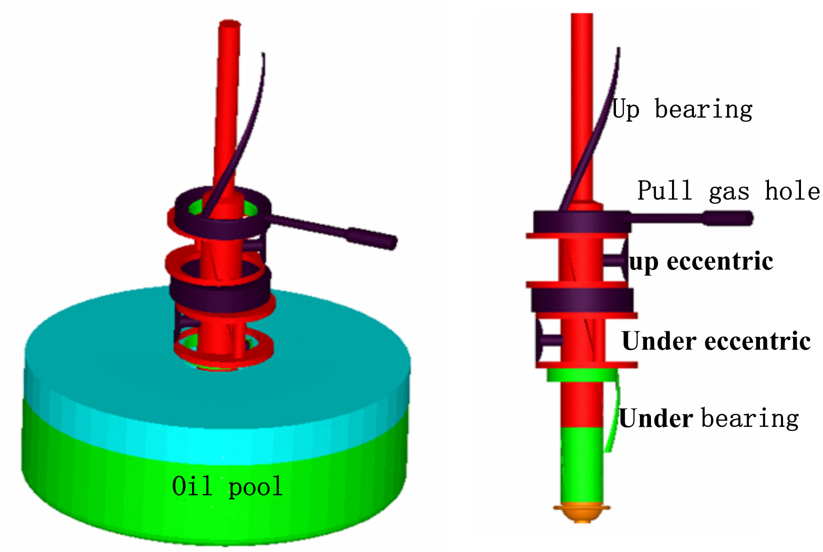


Figure 2: Oil-pumping system model

3.2 Boundary conditions are set

In the Oil-pumping modle, the crank-side hole, the oil surface, the spiral groove are set for the pressure boundary. The value of all Boundary pressure need to simulate the exhaust chamber of the compressor prior modeling calculation, tracking the crankshaft-side hole, the oil surface, the pressure of the spiral groove, the calculation model shown in Figure 3. Taking the average value of each position in a cycle, the pressure value of the oil surface spiral groove in the motor lower part is approximately equal; while the crankshaft hole side, which is the upper part of the motor, the pressure value is less than the oil surface and spiral. The greater speed the greater pressure difference of the crankshaft end hole and cross hole, the values of the boundary as shown in Figure 4 and Figure 5.

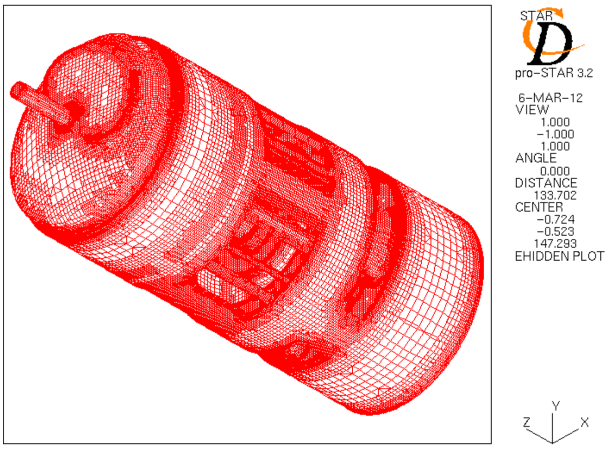


Figure 3: Boundary pressure value model

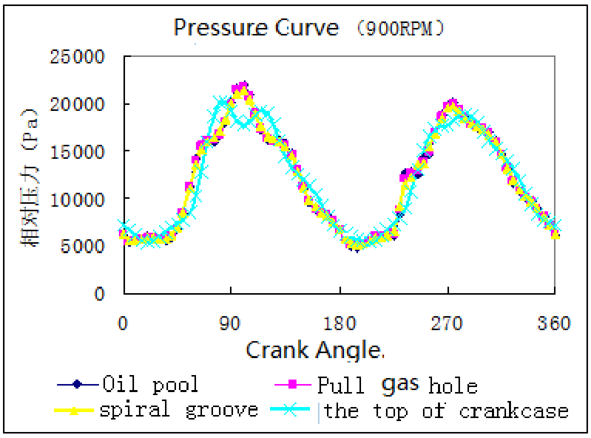


Figure 4 : Each boundary pressure curve (900RPM)

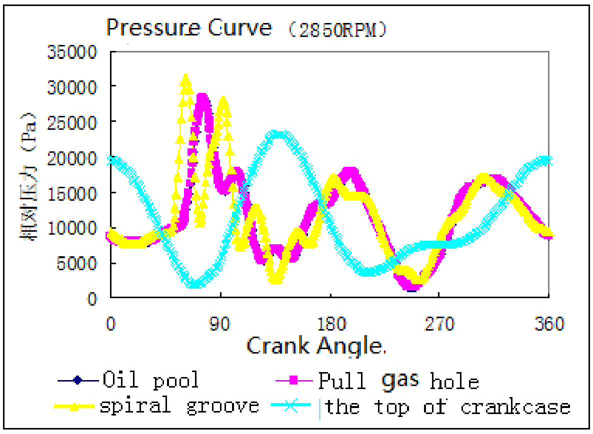
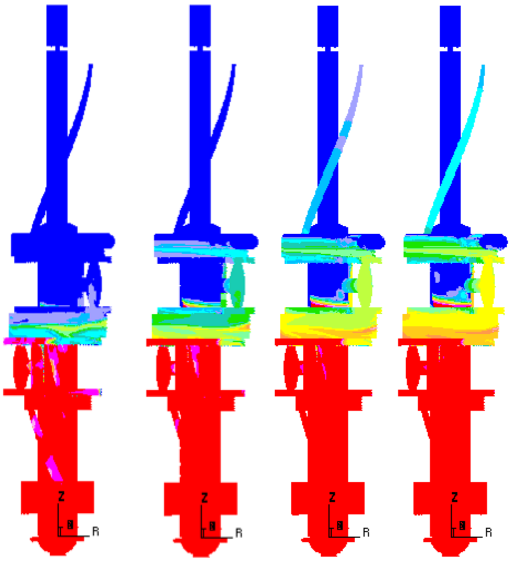


Figure 5: Boundary pressure curve (2850RPM)

4. CALCULATION RESULTS

4.1 Flow characteristics of oil-pumping system

When Crankshaft's speed is 900 rpm, we calculate 70 cycles, it means that crank turned 70 revolutions to stabilize. While Crankshaft speed at 2850rpm , the crank turned 50 rpm to achieve stability. The flow characteristics of the oil-pumping system and process in different speed is basically the same, namely, the oil pump through the dust collector, it first to reach the crankshaft out of the hole the oil, to lubricate the lower bearing, and then reach the hole in the crankshaft oil then to rise reach the eccentric bearing and then divided into two-way ,inside and outside, inside to reach the bearings and outside to reach spiral groove on bearing lubrication. Compare with 900 rpm and 2850rpm, the speed is higher, the lubricants climb faster, oil-pumping system to achieve stability in the shorter time, the shorter time the corresponding dry friction in the compressor starts. Figure 6 is the lubricant distribution map at speed 900rpm when crank turned 1.2s, 2s, 2.8s, 3.6s, we can see that the basic process of the crankshaft pump oil.



1. 2s 2s 2. 8s 3. 6s

Figure 6: Lubricating oil at different times maps

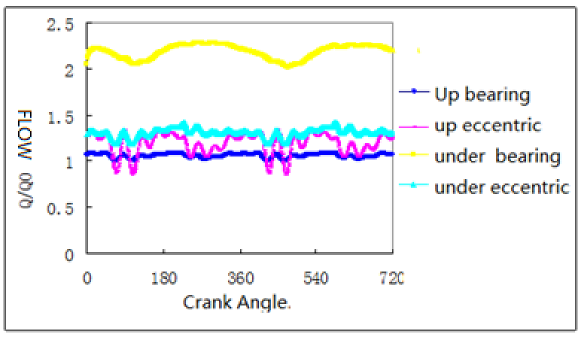
4.2 Oil quantity comparison

The performance of pump oil is decided by two factors: the centrifugation by rotating and the pressure difference of the crankshaft-side hole from the oil surface. Due to there is pressure difference in motor up and down, so the pressure in crankshaft end hole is smaller than the pressure of the oil surface of the pool, is favorable for pumping oil.

The centrifugal force and the side hole with the oil surface pressure difference in different speeds.The greater the speed, the greater centrifugal force, he greater the pressure difference, the greater the force, and the stronger the corresponding oil-pumping capacity.

Moreover, the pressure of the straight hole and the spiral groove and the oil surface of the pool is pulsation, so the flux of each hole is not a stable value.

For the four oil hole, the flux of under eccentric is the biggest, and the upper bearing second, the under bearing and the under eccentric is less in different speeds, showed as Figure 7, Figure 8.



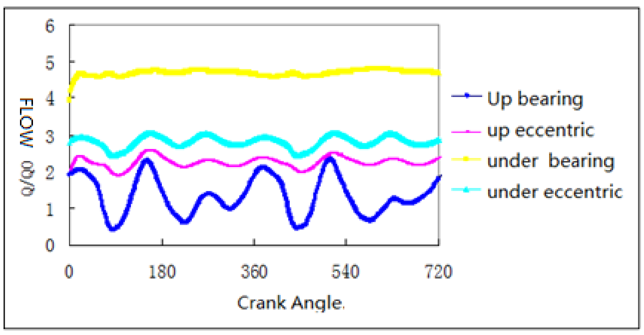


Figure 7: Out of hole flow with the angle change/900RPM **Figure 8:**Out of hole flow with the angle change/2850RPM

5. CONCLUSION

(1)The oil is pumped through the dust collector, then it first to reach the under crankshaft oil hole to lubricate the bearing, and then lubricant oil in the internal crankshaft wall continues to rise to reach the eccentric bearing and then divided into two channel, and external , internal to reach the bearings and external to reach spiral groove on bearing lubrication.

(2)The performance of pump oil is decided by two factors: the centrifugation by rotating and the pressure difference of the crankshaft-side hole from the oil surface. Due to there is pressure difference in motor up and down, so the pressure in crankshaft end hole is smaller than the pressure of the oil surface of the pool, is favorable for pumping oil.

(3)Moreover, the pressure of the straight hole and the spiral groove and the oil surface of the pool is pulsation, so the flux of each hole is not a stable value.

(4) For the four oil hole, the flux of under eccentric is the biggest, and the upper bearing second, the under bearing and the under eccentric is less in different speeds.

NOMENCLATURE

Physics Terms			**Subscript**	
t	temperature	K	i	vector ,orientation X incoordinate
p	pressure	Pa	j	vector ,orientation Y incoordinate
ρ	density	kg/m^3	ε_1	experiential coefficient 1;often1.44
k	turbulent kinetic energy	--	ε_2	experiential coefficient 2, often1.92
ε	turbulent dissipation rate	--	ε_3	experiential coefficient 3, often0,or 1
μ	viscosity	m^2/s	ε_4	experiential coefficient 4 ,often1.44
τ	shear stress	N/m^2	w	wall
y	distance in Y incoordinate	m		
C	experiential coefficient	--		
β	expand coefficient	--		

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