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THEORY OF SYNCHRONAL ROTARY COMPRESSOR

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ABSTRACT

A new synchronal rotary compressor is developed to overcome disadvantage on large friction loss and short life-span of parts of other compressors• It is made up of a bladed rotor and a cylinder ,which are synchronal• The working chamber• which are formed by the inside surface of cylinder and outside surface of bladed rotor, is connected with the intake port. The inflow is continuous in the whole cycle and flow rate is slow and the relative glide speed of the opposite surface of the working chamber is slow too. Meanwhile, the operating state is extremely steady. The operating principle• structure characteristics and geometric theory of this mechanism are analyzed and calculation formulae of displacement volume• pressure in chamber and thermodynamic properties are deduced detailedly in this paper. The experimental result shows that this mechanism possess these merits, such as simple structure• no wearing parts, easily airtight, slight friction and lower cost. So, this mechanism is fit for more fluid.

1. INTRODUCTION

Since Ramilli used revolving piston instead of reciprocating piston to realize the compress of air for the first time, there is a great leap in the development of compressor (Yu Yongzhang, 2000). The rotary compressor not only solved the problem of the equilibrium of inertia force effectively, but also abnegates its easy damage parts entirely in reciprocating compressor. But a rotary compressor brought us the problems of serious friction loss between the revolving piston and cylinder, because of prodigious relative speed. A new synchronal rotary compressor is developed to overcome the large friction loss and short life-span of parts of other compressors. It is made up of a bladed rotor and a cylinder, which are synchronal. The working chamber, which is formed by the inside surface of cylinder and outside surface of bladed rotor is connected with the intake port. The inflow is continuous in the whole cycle and the flow rate is slow, and the relative glide speed of the opposite surface of the working chamber is almost static. Thereby, the operating state is extremely steady. The operating principle, structure characteristics and geometric theory of this mechanism are analyzed, and the calculation formulae for displacement volume, chamber pressure, relative speed and thermodynamic properties are deduced.

2. WORKING PRINCIPLE AND CHARACTERISTIC OF STRUCTURE

Fig.1 shows the working processes and structure of the synchronal rotary compressor. From the fig.1, we can see that it is made up of the bladed rotor 1, cylinder 2 and slippery board 3. The center of the driving shaft and bladed rotary is superposition, the driving shaft drives the bladed rotary to do absolute rotary. The slippery board inlays the cylinder depending on centrifugal force. So the cylinder synchronal runs with the bladed rotor, furthermore the point A going into mesh with the bladed rotary is stationary. The relative glide speed of the opposite surface of the working chamber is tiny, and it overcomes the large friction loss and short life-span of parts of other compressors. Fig.1 shows that the slippery board divides the working chamber into two parts, they are intake and compress chamber separately. The fig.1 shows several working states: when $\beta = 0$, discharge is end and intake will start; when β >0, compressing process is start and intake is continuous at the same time; when β =90, the working chamber of intake and compress is equal; when $\beta = \psi$, discharge starts and compressed air discharge from the central port, ψ is discharge angle. When $\beta = 2\pi$, a working cycle is completed.

The synchronal rotary compressor has the incomparable advantages over other compressors; its flowage loss and friction loss is small, volume efficiency is higher; operation is smooth; structure is simple and the price of it is low.

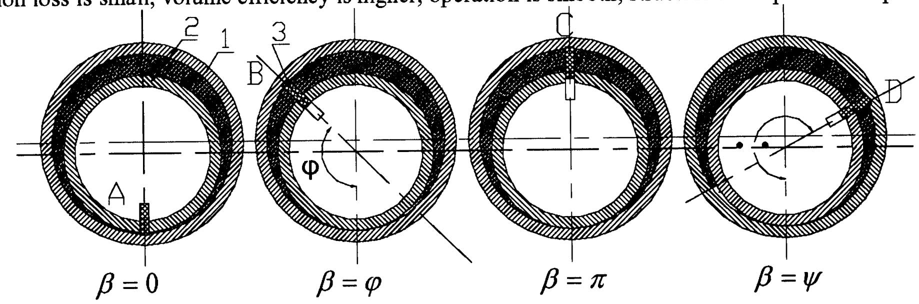

Figure1: Working and structure principle

3. CALCULATION OF DISPLACEMENT VOLUME

Fig.2 shows calculation mode of a displacement volume, in a triangle $\Delta O'AO$ (Qu ZongChang, 2003):

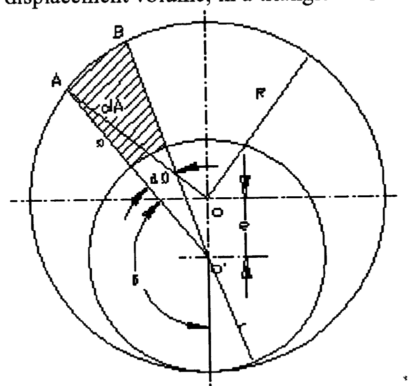

Figure 2: Calculation mode of displacement volume

$$R^2 = \rho^2 + e^2 + 2\rho e \cos\beta \tag{1}$$

Where, the length of radius vector OA is ρ and e is the eccentricity distance.

Let $\frac{r}{R} = a$, then

$$\rho = -R[(1-a)\cos\beta - \sqrt{(1-a)^2(\cos^2\beta - 1) + 1}] \tag{2}$$

The shadow differential coefficient area dA is given at arbitrarily angle β

$$dA = \frac{1}{2}(\rho^2 - r^2)d\beta \tag{3}$$

Where, R is radius of the cylinder; r is radius of the bladed rotor.

If the influence of slippery board on working volume is not considered, the area of working chamber at arbitrarily angle β is as below:

$$A(\beta)=\frac{1}{2}\int_0^{\beta}(\rho^2-r^2)d\beta$$

$$=\frac{1}{2}R^2\{[\frac{1}{2}(1-a)^2\sin 2\beta+\beta-(1-a)\sin\beta\sqrt{1-(1-a)^2\sin^2\beta}$$ (4)

$$+\arcsin[(1-a)\sin\beta]\}-a^2\beta\}$$

The displacement volume of the cylinder is as below:

$$V(\beta)=A(\beta)H$$

$$=\frac{1}{2}HR^2\{[\frac{1}{2}(1-a^2)\sin 2\beta+\beta-(1-a)\sin\beta\sqrt{1-(1-a)^2\sin^2\beta}$$ (5)

$$+\arcsin[(1-a)\sin\beta]]-a^2\beta\}$$

The length $h(\beta)$ of the slippery board in working chamber is as below:

$$h(\beta)=\rho-r$$

$$=-R[(1-a)\cos\beta-\sqrt{(1-a)^2(\cos^2\beta-1+1}]-r$$ (6)

$$=-R[(1-a)\cos\beta-\sqrt{(1-a)^2(\cos^2\beta-1+1}]-a]$$

When $\beta=2\pi$, the displacement volume is as below:

$$V_S=\pi(R^2-r^2)H$$ (7)

Where, H is the height of cylinder.

The displacement volume of the cylinder is given at arbitrarily angle β considering the influence of slippery board on working volume:

$$V(\beta)=[A(\beta)-h(\beta)]H$$

$$=\frac{1}{2}HR^2\{[\frac{1}{2}(1-a^2)\sin 2\beta+\beta-(1-a)\sin\beta\sqrt{1-(1-a)^2\sin^2\beta}$$ (8)

$$+\arcsin[(1-a)\sin\beta]]-a^2\beta-\frac{2}{R^2}\}$$

4. ROTARY SPEED CHARACTERISTIC

Fig. 3 shows the structure principle of the synchronal rotary compressor. When bladed rotor uniform revolves round on its own center o' , the cylinder also revolves round on its center o . Although the time that they revolve a circuit is the same, their revolving centers are different. So, the cylinder inevitably revolves in accelerating and decelerating, the relative speed between the cylinder and bladed rotor is a function of the rotary angle φ . It depends on the radius R , r , offset e and the radial ratio of the cylinder to the bladed rotor (a=r/R).

The bladed rotor and the cylinder revolving segmental arc are $A\hat{A}_1$ and $A\hat{A}_2$ at the same rotary angle φ , they are determined as the followings:

$$A\hat{A}_1=r\varphi$$ (9)

$$A\hat{A}_2=\int_0^{\varphi}\rho d\varphi$$ (10)

Where, φ is rotary angle φ of the bladed rotor.

The length ρ of radius vector can be obtained from the formula (2).

Revolving speed of the bladed rotor is given as below• •

$$V_1 = \frac{d(A\hat{A}_1)}{dt} = \omega \frac{d(A\hat{A}_1)}{d\varphi} = \omega r \tag{11}$$

Revolving speed of the cylinder is given as below:

$$V_2 = \frac{d(A\hat{A}_2)}{dt} = \omega \frac{d\left[\int_0^{\varphi} \rho d\varphi\right]}{d\varphi} = \omega\rho \tag{12}$$

Relative speed between the cylinder and bladed rotor is:

$$\Delta V = \omega(\rho - r) \tag{13}$$

Angles corresponding with the maximum or minimum revolving speed of the cylinder can be obtained. Differential coefficient with revolving speed of the cylinder is made as below:

$$\begin{aligned} \frac{dV}{dt} &= \omega \frac{d\rho}{d\varphi}\frac{d\varphi}{dt} = \omega^2 \frac{d\rho}{dt} \\ &= \omega^2 R[(1-a)\sin\varphi - \frac{(1-a)^2 \sin\varphi\cos\varphi}{\sqrt{(1-a)^2(\cos^2\varphi - 1) + 1}}] \end{aligned} \tag{14}$$

Let formula (6) equal to zero, it can be reduced that $\varphi = 0$ *or* $\varphi = \pi$. Revolving speed of the cylinder is maximum or minimum. It is given respectively as below:

$$\Delta V_{\max} = 2\omega(R - r) \tag{15}$$

$$\Delta V_{\min} = 0 \tag{16}$$

Fig. 4 shows the relationship of the relative speed between the cylinder and the bladed rotor with the rotary angle under different ratios of radius. It is shown in fig. 4 that the relative revolving speed is at direct ratio to angular velocity ω of driving axis and the revolving radius R of the cylinder, and the maximum relative speed is affected secondarily by the ratio of the radius. Therefore, in order to reduce the weight of the synchronal rotary compressor when designing the synchronal rotary compressor, it is better to reduce the radius R of the cylinder and to increase the ratio a of the radius as much as possible. It is also shown from fig. 4 that the rather small rotary speed of this compressor has created an excellent sealed condition for compressed gas.

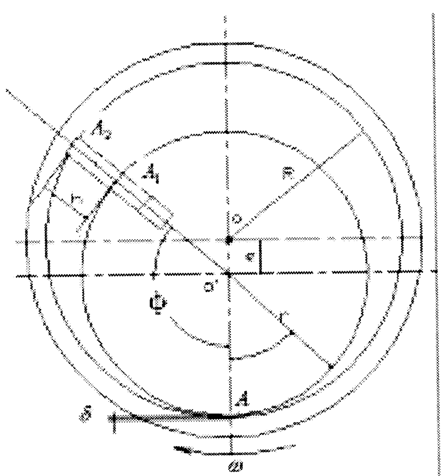

Figure3: Structure principle

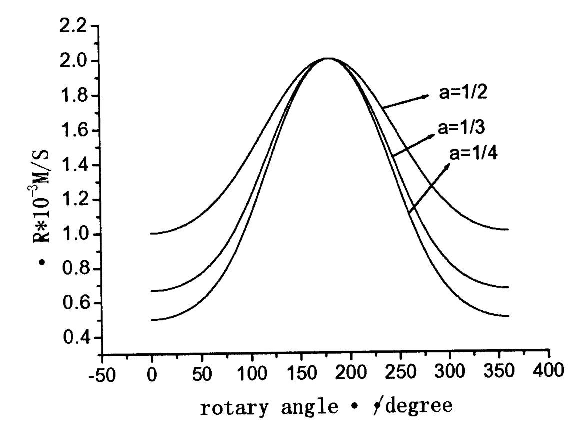

Figure4: Relative speed changing with rotary angle

5. CONCLUSIONS

A new synchronal rotary compressor is developed to overcome the large friction loss and short life-span of parts of other compressors. The operating principle, structure characteristics and geometric theory of this mechanism are analyzed, and the calculation formulae for displacement volume, chamber pressure, relative speed between the cylinder and bladed rotor and thermodynamic properties are deduced. It is the foundation of development for a synchronal rotary compressor.

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