1992

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H. Li
Xi'an Jiaotong University

Z. Shi
Xi'an Jiaotong University

G. Jin
Xi'an Jiaotong University

M. Zhu
Shanghai Tonglian Compressor Factory; P. R. China

DEVELOPMENT OF ROLLING CYLINDER RECIPROCATING COMPRESSORS

Li Hongqi, Shi Zhao, Jin Guangzi
Xi'an Jiaotong University
People's Republic of China

Zhu Mingfa
Shanghai Tonglian Compressor Factory
People's Republic of China

ABSTRACT

Considering the characteristics of rotating compressors and reciprocating ones, and the difference between them, A new type of compressor is introduced in this paper. Its working principle and structure make it not only absorb the advantages of both rotating and reciprocating compressors, but also avoid the shortcomings of them. In the paper, we present the working principle, structure and preformance prediction of this new compressor.

INTRODUCTION

As we all know, of all two types of volume compressors, A rotating compressor which often consists of fewer parts, no piston rings and valve, has compact structure and high reliability. However it is difficult to produce. For exemple, a screw compressor is small in size and simple in structure, but each of its rotors has several spiral grooves. These grooves greatly increase the difficulty of manufacturing, for a special- purpose machine tool is needed and examining the machining accuracy is also difficult. On the contrary, a reciprocating compressor can be produced easily and no special machine tool is needed, because there are not complex space curved surface. But it contains much more parts than a rotating one. The existence of easy-damaged parts, such as piston rings and valves, makes it less reliable. All these shortcomings limit the development of both two types of compressors to some extent.

For the reason mentioned above, we began to design and manufacure a new type of compressor in last year, and most of the work have been finished by now. This type of compressor works with the principle between that of a rotating compressor and a reciprocating one. We call it A Rolling Cylinder Reciprocating compressor.

STRUCTURE AND WORKING PRINCIPLE

The main structure of this new compressor is shown in Figure 1.

where:

1 — housing

2 — cylinder body

3 — piston

4 — crank shaft

5 — discharge port

6 — suction port

It mainly consists of housing, cylinder body, crank shaft, side covers and several pistons. There are two or more cylinders in one cross section of cylinder body.

When the compressor works, the cylinder body is driven by crank shaft and rotate at a high speed. The pistons rotate with the cylinder body, at the same time, transmission mechanism makes them reciprocate in the cylinders. Therefore, the volume formed by housing, cylinder and piston increases or decreases periodically with the rotating of cylinder body. There is a suction port and a discharge port at the positions specially designed of the housing. The suction and the discharge processes begin when the volume gets open into these ports respectively. There are four discharge processes per revolution for the compressor shown in Figure 1. Figure 2 and Figure 3 are the photographes of some parts of the compressor designed by us, and the test system.

The movement mechanism of the compressor is shown in Figure 4. we can easily get the geometric relations from it.

$$x=r\sin\theta$$

$$y=r\cos\theta$$

$$s=r+e\pm\sqrt{e^2+r^2+2er\cos\theta}$$

$$u=\frac{ds}{dt}=\frac{er\sin\theta}{\sqrt{e^2+r^2+2er\cos\theta}}\omega$$

$$V=\frac{\pi}{4}D^2s$$

$$\sin\theta = \sqrt{1+\lambda^2+2\lambda\cos\theta}\,\sin\alpha$$

$$\lambda = \frac{e}{r}$$

$$\omega' = \pi n/30$$

where:

x, y — coordinates of center of piston

s — displacement of piston

u — velocity of piston

V — volume

n — rotating speed of crank shaft

θ — angle of crank shaft

α — angle of cylinder

when $\lambda = 1$,

$$\theta = 2\alpha$$

$$s = 2r\left(1-\cos\frac{\theta}{2}\right)$$

$$u = \frac{ds}{dt} = r\omega'\sin\frac{\theta}{2}$$

How the displacement of piston (s) and the volum (v) vary with the angle of crank shaft (θ) is shown in Figure 5.

Figure 5 also shows the velocity of piston at different rorating angle of crank shaft.

PERFORMANCE PREDICTION

To predict the performance of this compressor, a computer modeling suitable for the closed-compression process and the discharge process is built which is based on the following assumptions:

1) The air behaves as an ideal gas.
2) Pressures and temperatures in the suction process are constant.
3) Gas leakage occures only in the driection of crank shaft axis along the clearance between the surface of cylinder body and housing.
4) The heat transfer between the air and the oil in the compression process will be negligiable.
5) There will not be any oil backflow in the discharge process when the discharge pressure is higher than the pressure in control volume.
6) Flow resistance in the suction port and the discharge port will be negligiable.

According to the first law of thermodynamics and eqution of state for

ideal gas, the pressure variation rate of the air in control volume can be written:

$$\frac{dp}{d\alpha} = -kp\left(\frac{1}{V}\frac{dV}{d\alpha} + \frac{1}{\omega m}\frac{dm}{dt}\right)$$

where:

P ——pressure of the air in control volume

k ——adiabatic exponent

ω——angle speed of cylinder body

m ——mass of the air in control volume

$\frac{dm}{dt}$——flow rate of air, including backflow, leakage and flow in discharge port etc.

Figure 6 shows the leakage paths of this compressor. From a series of original assumptions, only the air will be considered to pass through the path No. 1, the oil will leak through the others. Leakage rate of the air can be calculated with following formula:

$$\frac{dVc}{dt} = 0.26\frac{\delta^3 D\triangle P}{\eta l}$$

where:

Vc —— volume of leakage air

t —— time

δ —— value of clearance

D —— diameter of cylinder body

$\triangle$P—— pressure drop

l —— length of leakage path

η —— viscosity of the air

From the above eqution, The thermodynamic parameters of the air in control volume, the power comsumption and the performance of the compressor can be obtained. Figure 7 and Figure 8 shows the volumetric efficiency and adiabatic efficiency of this compressor. From these figures, it is obvious that since the manufacture accuracy can be as high as possible and the friction loss can be reduced as low as possible, the efficiencies will be relatively high

DISCUSSION AND CONCLUSION

This new compressor has the following advantages:

1. It consists of no more than ten parts except standard parts and has simple and compact structure, small size, light weight.

2. The discharge process is coercive. There are no easy-damaged parts, such as piston rings, valve. So it has a high reliability.

3. There is not complex space curved surface needed machining, no special-purpose machine tool is needed. So that it is easy to manufacture and test.

4. Ball bearings are widely used in this compressor except piston and cylinder. The friction loss is reduced as low as possible.

5. Leakage passages, Length of leakage lines and areas of leakage paths are much smaller than that of common rotating compressors.

From all those mentioned above, this new type of compressor has the advantages of both rotating compressors and reciprocating compressors, in the mean time, it avoids the disadvantages of them. So we can predict that it will make a good performance.

In short, this new type of compressor has great potentiality as well as a good prospect .

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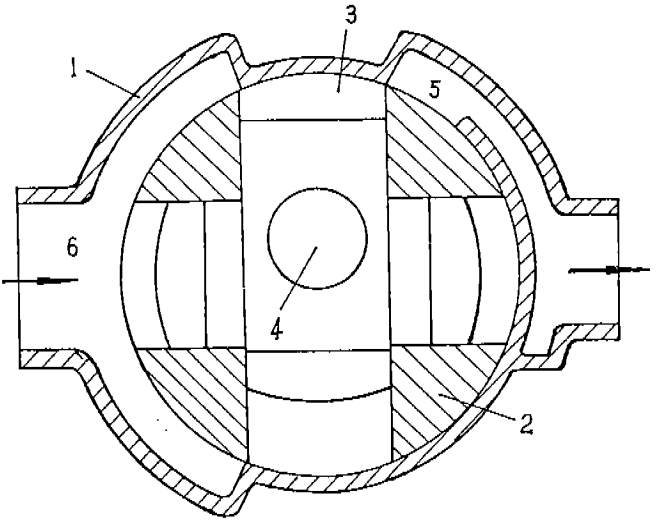

Fig. 1

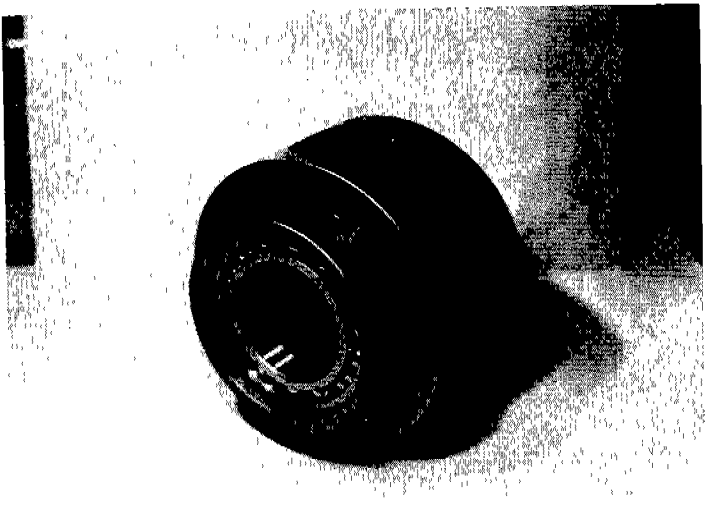

Fig. 2

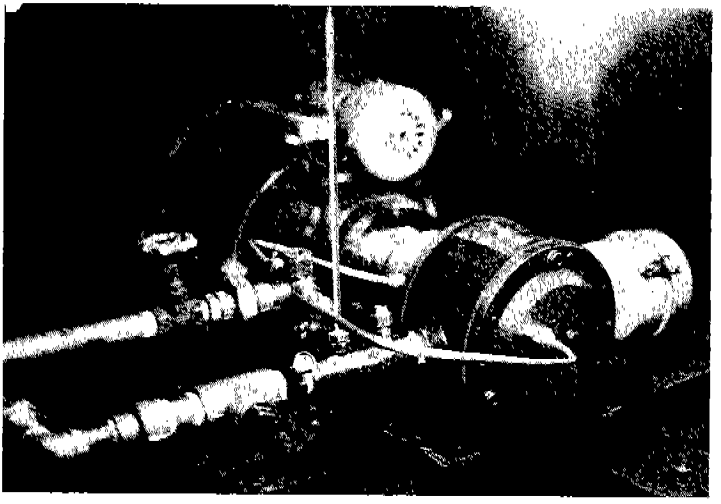

Fig. 3

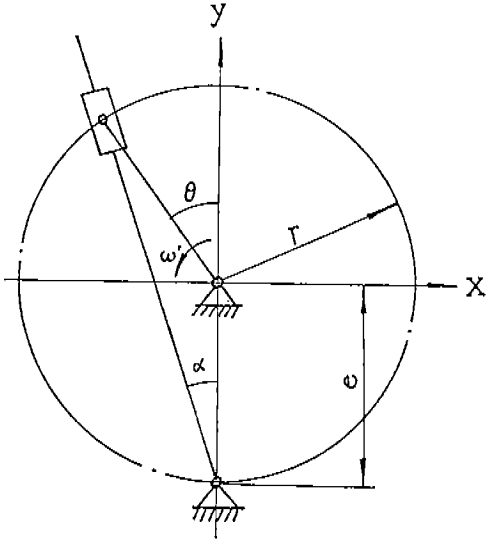

Fig. 4

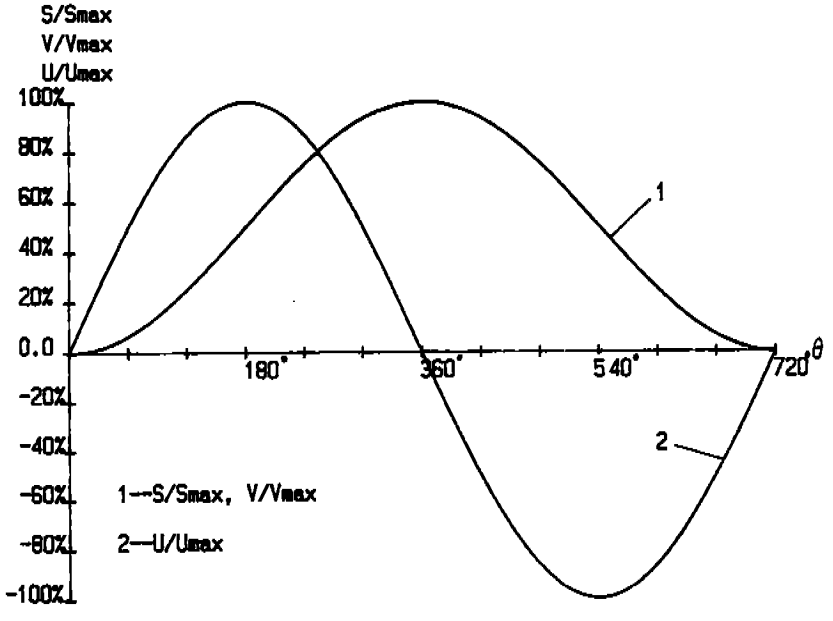
S/Smax
V/Vmax
U/Umax
100%
80%
60%
40%
20%
0.0
-20%
-40%
-60%
-80%
-100%
180°
360°
540°
720°
θ
1
2
1—S/Smax, V/Vmax
2—U/Umax

Fig.5

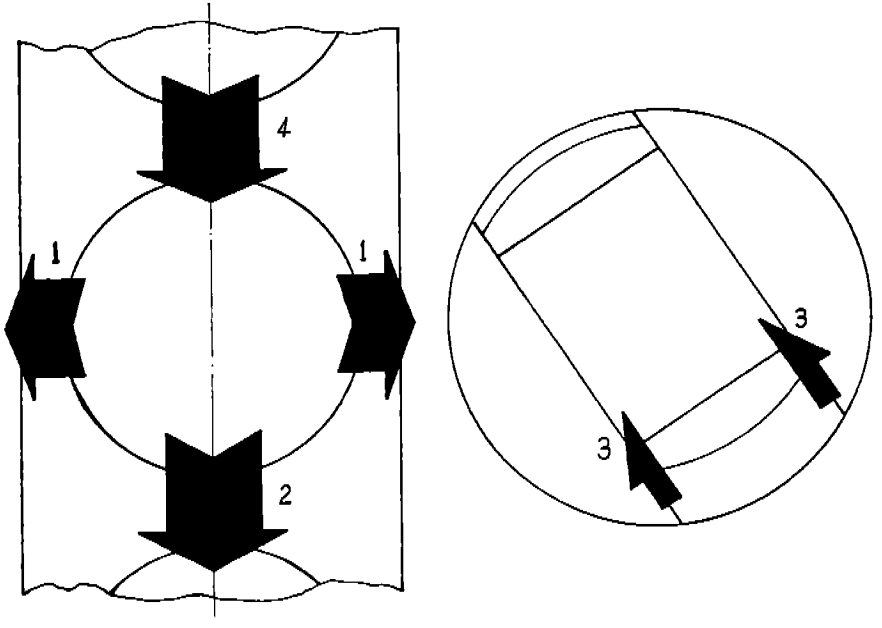
4
1
1
2
3
3

Fig. 6

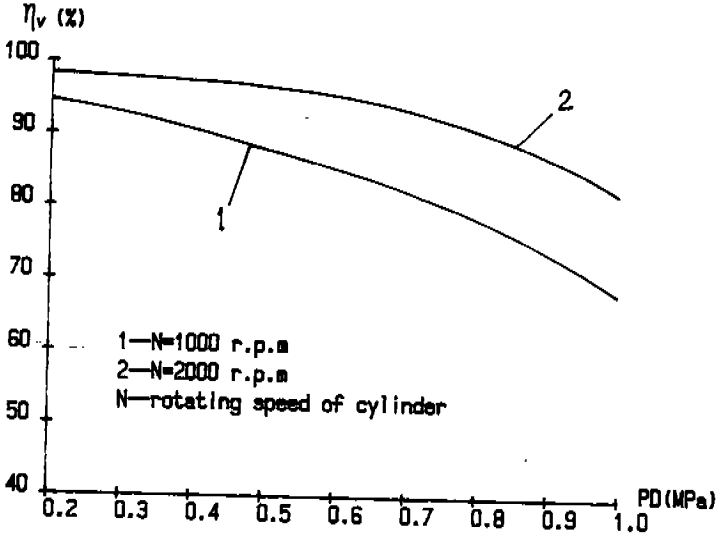
η_v (%)
100
90
80
70
60
50
40
2
1
1—N=1000 r.p.m
2—N=2000 r.p.m
N—rotating speed of cylinder
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
PD(MPa)

Fig.7

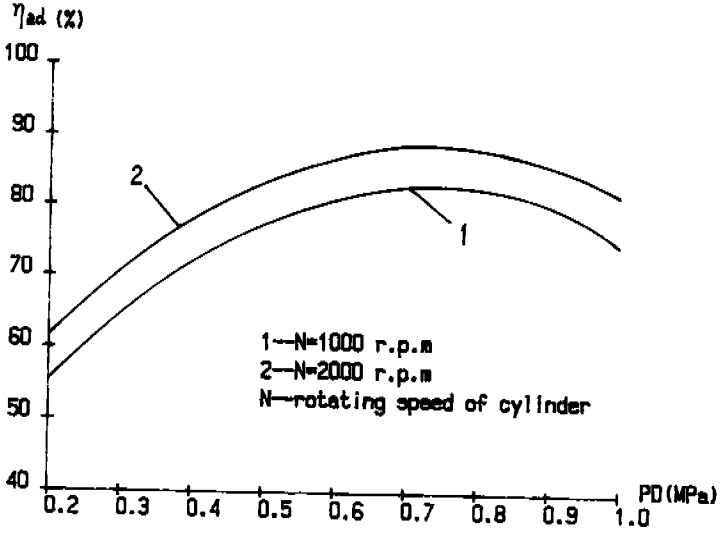
η_{ad} (%)
100
90
80
70
60
50
40
2
1
1—N=1000 r.p.m
2—N=2000 r.p.m
N—rotating speed of cylinder
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
PD(MPa)

Fig.8