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ABSTRACT

This paper describes the oil feeding characteristics and oil pumping head of a gas viscous oil pump for a horizontal type small rotary compressor. This pump which consists of groove made on journal surface and bearing acts at starting by taking advantage of gas viscosity. If oil is raised to lubricating surfaces by pump, then another oil feeder acts to supply adequate quantity of oil. The depth of groove of pump affects oil pumping head critically. Therefore, it is important to select the depth of groove adequately. We have calculated the oil pumping head and proved it experimentally. As a result, the recommendable depth of groove for raising the oil about 50mm is 0.1mm for our products dimension.

NOMENCLATURE

C : radial clearance
D : width of groove
h : axis along groove depth
H : depth of pump groove
H_1: depth of oil feeder groove
HH: oil pumping head
L : length of pump or oil feeder
P : pressure
Pa: ambient pressure
Pc: pressure in middle chamber
Pi: inner side pressure
Q : oil flow rate
qi: hollow leakage
R : radius of journal
u : velocity of fluid
z : axial direction of journal
z': axis along groove
β : groove angle of pump groove
β_1: groove angle of oil feeder
ϵ : eccentricity of journal
μ : viscosity of gas
μ_o: viscosity of oil
ρ : oil density

INTRODUCTION

The rotary compressor proved excellence by its high efficiency and low noise, and every effort has been made to use rotary compressor for refrigerator. On the whole, the length of rotary compressor is longer than the diameter. Therefore, it is required to set this compressor horizontally in refrigerator to get more effective refrigeration volume. Generally, in vertically setted rotary compressor, one of the shaft ends is immersed in oil charged in the bottom of the shell. The oil is raised by centrifugal force induced by shaft rotation. This type of lubricating system had been analysed by ASANUMA[1]. But in horizontally setted rotary compressor the oil level must be below the rotor for its running with low energy consumption. In the sequel, the lubricating surfaces are higher than the oil level and a special oil supply system is needed to lubricate. Several kinds of lubricating system for small horizontal rotary compressor is introduced in [2]. Especially TAKEBAYASHI[3] has analysed fluidic diodes oil pump. In this study, we used gas viscous pump for raising oil to lubricating surfaces. This type of lubricating system has not yet been used. If lubricating surface is connected to oil with a connecting tube, the tube will be filled with refrigerant inevitably, and the oil will be raised by evacuating the tube. The viscous force between refrigerant and groove which is made on the shaft can decrease pressure in the tube by extracting the refrigerant. The main purposes of this study are to calculate the oil pumping head for this pump and compare it with experiment, moreover, to characterize oil feeding quantity with another oil feeder.

STRUCTURE

Sectional view of small horizontal rotary compressor is shown in Fig. 1. The crank shaft is connected to oil through oil suction hole. The shape of crank shaft is shown in Fig. 2. This shaft has two kinds of grooves. First one is gas pumping groove(gas pump). This acts at starting. Second one is oil feeding groove. This is needed to supply a large amount of oil to the bearing surfaces. At first, the oil suction hole is filled with refrigerant. The refrigerant is extracted by two gas pump located in each side of bearing as shaft rotates. Then the oil goes up to the shaft as the pressure in the hole is decreasing. This raised oil is devided into two part, one to the right and another to the left side of bearing respectively. After oil raising, oil feeder supply the oil to the lubricating surfaces.

ANALYSIS

Consider the grooved shaft and bearing shown in Fig. 3 to calculate oil pumping head of gas viscous pump, and assume Newtonian fluid and isothermal condition.
The pressure derivative along z' axis is expressed by

$$\frac{dp}{dz'} = \mu \frac{du}{dh} \tag{1}$$

By integrating equation (1) about h with boundary conditions,
$u=0$ at $h=0$, $u=R\omega\cos\beta$ at $h=H$
We have

$$u = \frac{1}{2\mu}\left[\frac{dp}{dz'}\right](h^2 - Hh) + \frac{R\omega h\cos\beta}{H} \tag{2}$$

The flow go out along z axis is,

$$Q = \int_0^H uDdh + qi = A\left(\frac{dp}{dz}\right) + B \tag{3}$$

$$A = -\left[\frac{H^2D}{12\mu}\sin\beta + \frac{\pi RC^3\left(1 + \frac{3}{2}\epsilon^2\right)}{6\mu}\right] \qquad B = \frac{HR\omega D\cos\beta}{2} \tag{4}$$

where qi is hollow leakage through radial clearance. From[4] qi is expressed approximately by the following equation.

$$qi = -\frac{\pi RC^3}{6\mu}\left[\frac{dp}{dz}\right]\left(1+\frac{3}{2}\epsilon^2\right) \tag{5}$$

From continuity of compressible flow under isothermal conditions we get,

$$PQ = PaQo = \text{constant} \tag{6}$$

From equations (3) and (6) we get,

$$Qo = \left(\frac{P}{Pa}\right)\left(A\frac{dp}{dz} + B\right) \tag{7}$$

Convert equation (7) into integration form as follows.

$$\int \frac{P}{\frac{B}{A}P - \frac{QoPa}{A}}\,dP = \int -\,dz \tag{8}$$

By integrating equation (8) with boundary conditions,

$P = Pa$ at $z = L$

We have

$$\frac{P - Pa}{B} + \frac{QoPa}{B^2} \ln\left(\frac{BP - QoPa}{BPa - QoPa}\right) = -\frac{1}{A}(z-L) \qquad (9)$$

From equation(9) and $z' = z/\sin\beta$ pressure distribution along z' axis is approximately linear with short distance L. When there is no flow along z axis, the pressure difference between Pa and Pi is expressed by following equation.

$$Pa - Pi = -\frac{B}{A} L \qquad (10)$$

Therefore, oil pumping head is

$$HH = (Pa - Pi)/\rho g \qquad (11)$$

The results of calculation are shown in Fig. 5,5',6 with conditions as follows, $Pa = 1\ Kgf/cm^2$, $\mu = 0.01265cp$, $R = 7mm$, $\omega = 3550rpm$. In Fig.5 oil pumping head depends on groove depth H critically. Fig.5'is magnification of Fig.5 in small HH. Oil raises less then HH because of gas flow Qo. When H is about 0.1 mm, the head is about 55mm in $\beta = 30°$. From the result of experiment, head is about 53mm in $\beta = 30°$ and H=0.1mm. Therefore, it is reasonable H=0.1mm for raising oil more than 50mm.The schematic diagram of tester is shown in Fig.4.Fig.6 shows the trend of pumping head with varying the radial clearance. The maximum head decreases as radial clearance increases and moves to deep groove. But there are no apparent changes more than 0.15mm depth of groove with groove angle β. Consider Fig.7 to calculate oil flow quantity with oil feeder and gas vicous pump. The oil flow along groove for incompressible flow is expressed by following equation.

$$Q = -\frac{H^3 D\sin\beta}{12\mu o}\left[\frac{dp}{dz}\right] + \frac{HR\omega D\cos\beta}{2} \qquad (11)$$

From equations (5) and (11) net flow Qt through groove is

$$Qt = Q_1 + 2k(Pa - Pc) \qquad (12)$$

where $k = -\frac{\pi RC^3}{6\mu oL}\left(1 + \frac{3}{2}\epsilon^2\right)$

We obtain following equations from equations (11) and (12)

$$Pc = Pa + \frac{(f - f_1)}{(e_1 + e + 2g)}$$

$$f = \frac{HR\omega D\cos\beta}{2} \qquad (13)$$

$$e = -\frac{H^3 D\sin\beta}{12\mu o}$$

where subscript 1 changes H and β to $H_1$and β_1. The results are shown in Fig.8-11. Fig.8 shows the relation ship between pressure ratio (P/Pa) and depth of groove H1.Fig.9 shows the relation ship between oil flow rate and depth of groove H1. In this calculation the viscosity of oil is 7cp. The pressure ratio has peak point according to groove angle β_1, but pressure ratio and oil flow rate change small in depth of groove 1.0mm - 1.5mm. To make groove at maximum pressure point have disadvantages for the leakage and power consumption. Therefore, it is recommended that the depth of groove of oil feeder is 1.0 - 1.5mm. Fig. 9,10 shows the oil flow rate and pressure ratio depend linearly on depth of groove H of gas viscous pump. But it is not available to choose deeper than 0.15mm.

CONCLUSIONS

1. The oil pumping head of gas viscous pump could be predicted by calculation and the experiment has clarified it.
2. The recommendable depth of groove of gas viscous pump for raising oil about 50mm is 0.1mm.
3. The recommendable depth of groove of oil feeder is 1.0 - 1.5mm for low energy consumption in oil feeding.
4. The oil flow rate depend linearly on depth of groove of gas viscous pump.

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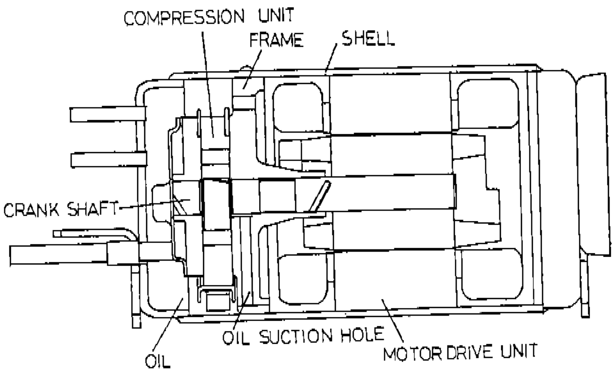

Fig. 1 Horizontal rolling piston type Rotary compressor.

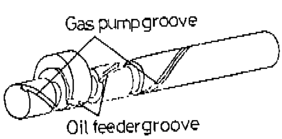

Fig. 2 Grooves of crank shaft.

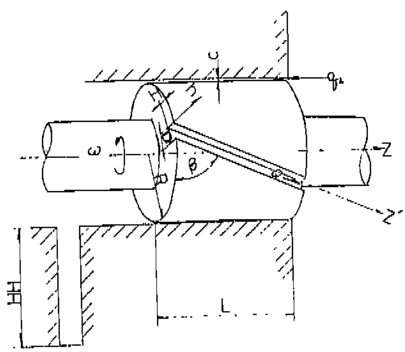

Fig. 3 Geometry of gas viscous pump.

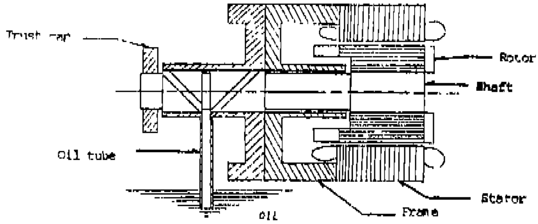

Fig. 4 Schematic diagram of oil pumping head tester.

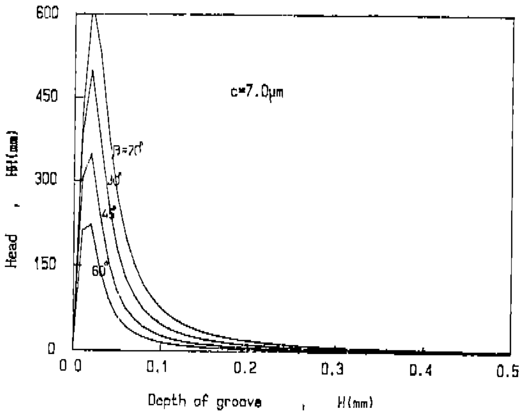

Fig 5 OIL SUCTION HEAD

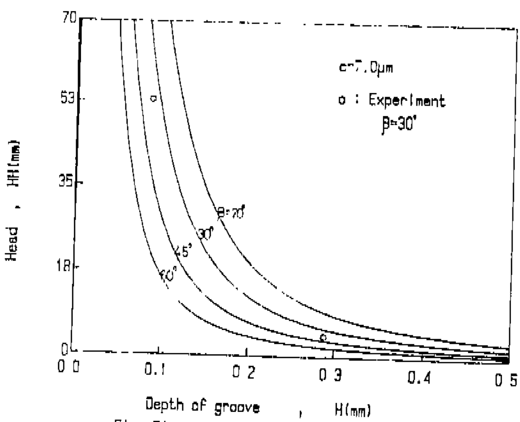

Fig. 5' OIL SUCTION HEAD

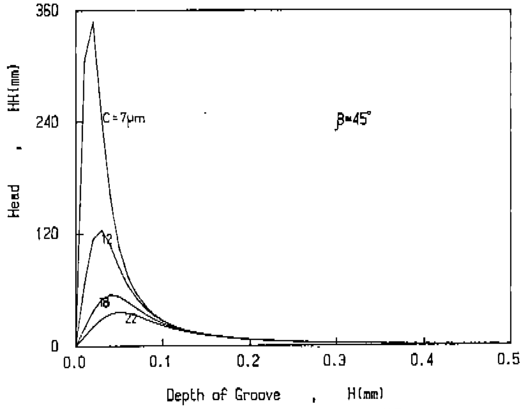

Fig. 6 OIL SUCTION HEAD BY CLEARANCE

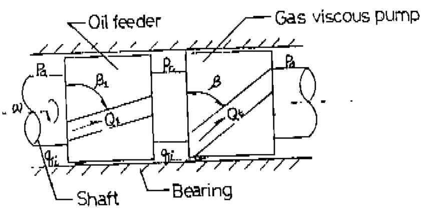

Fig. 7 Geometry of oil feeder and pump.

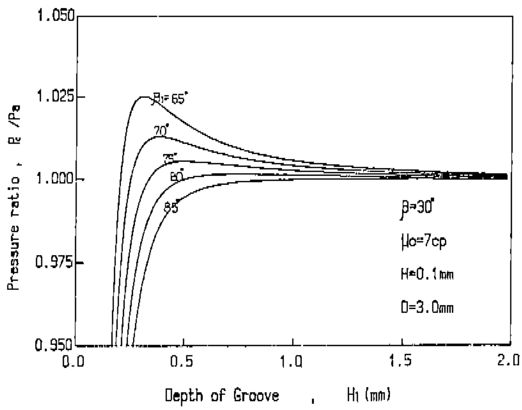

Fig. 8 Pressure ratio vs. H1

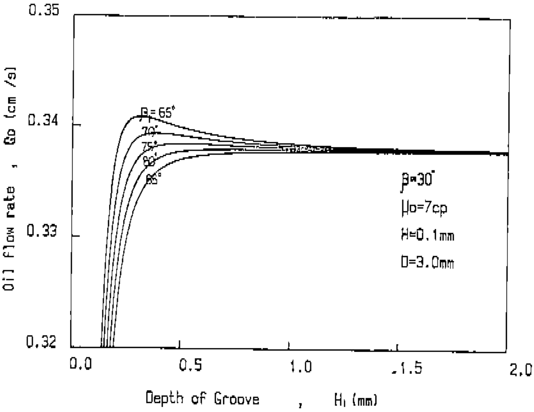

Fig. 9 Oil flow rate vs. H_1

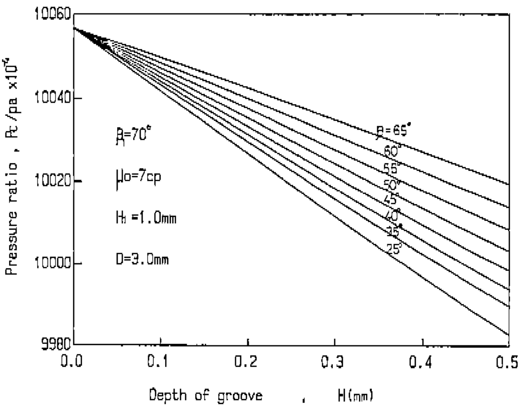

Fig. 10 Pressure ratio vs. H

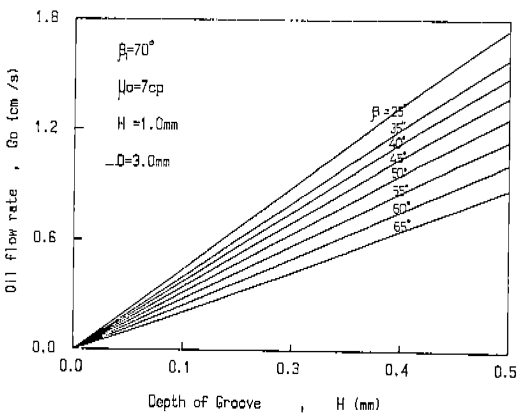

Fig. 11 Oil flow rate vs. H