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The Friction Characteristics of the Journal Bearing in the Refrigerant Compressor

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Abstract : The rotary-vane compressor has become one of the most successful types of compressors because of its mechanical reliability, compactness, and adaptability to moderately high-speed operation in virtually an unlimited range of sizes. However recently, the depletion of the ozone layer due to the current refrigerant(R22) has been getting worse, and it is one of the world's pressing issues. In this paper, we will discuss the use of R410a in the compressor of a room air-conditioner as an alternative refrigerant and air-conditioning system to R22, since R410a has greater refrigerant characteristics than R22. Miniaturization of the rotary compressor for the new refrigerant and air-conditioning system is also possible, which reduces the prime cost of production, hence R410a is naturally a better refrigerant. But to apply the new HFC refrigerant system in refrigeration and air-conditioning systems, a significant redesign of the current refrigerant system is also required, because as the refrigeration changes, lubrication characteristics vary. Close attention must be paid to friction force and energy loss due to friction and wear at many sliding areas.

Key words : friction force, energy loss, lubrication characteristics, eccentric shaft, sub bearing, alternative refrigerant

Introduction

The new non-chlorine refrigerant, compared to the existing chlorine refrigerant, exhibits lesser boundary lubrication. Therefore, lubrication issues with the use of the alternative refrigerant are on the rise, and the greatest problem in using the alternative refrigerant is to improve efficiency of the compressor. The operation inferiority and loss due to friction and wear on each sliding part must be decreased. Therefore, in this work, to observe the lubrication characteristics in the sliding area between the shaft and the bearing which greatly influences the performance of the compressor, we have constructed an apparatus to measure the friction under the changing operation conditions. We measured the friction force at the sliding parts under the mixed pressure of the refrigerant and the refrigerating machine oil to examine the effect of the lubrication.

To execute this experiment, we designed and made the hydrostatic journal bearing for our experimental apparatus and used it to measure the friction force. We applied the multi-recess type of hydrostatic journal bearing for the sub bearing to obtain the accurate lubrication characteristics at this sliding area.

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The Structure of the Rotary Compressor

Fig. 1 shows the structure of the rotary compressor of the

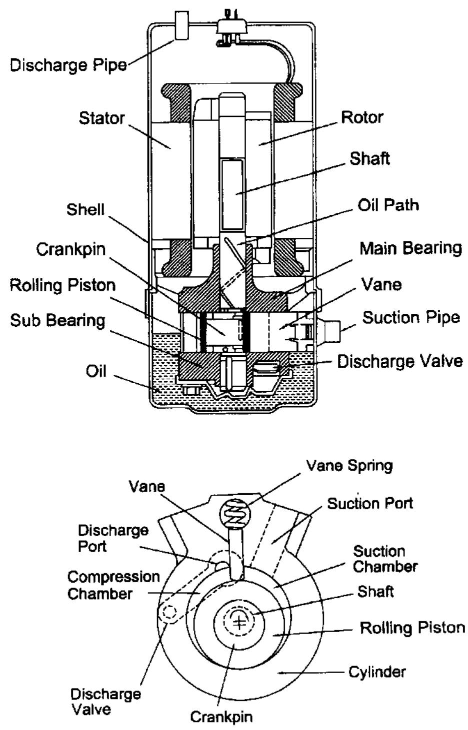

Fig. 1. The rotary compressor of rolling piston type.

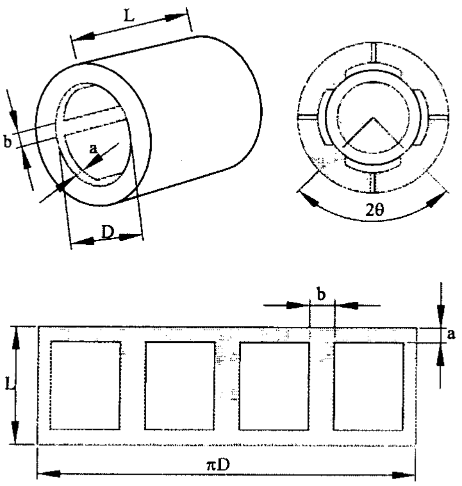

Fig. 2. The basic structure of the hydrostatic bearing.

rolling piston type. The shaft is eccentric at the cylinder part. It is inserted into the rolling piston. Therefore, as the eccentric shaft rotates, the rolling piston revolves and rotates along the inner wall of the cylinder and the vane continuously presses against the rolling piston by a reciprocating spring in the cylinder slot. A cross-sectional view of the cylinder part is divided by the suction and compression chamber by the rolling piston and the vane. In other words, the refrigerant flows in the cylinder through the suction port, and is compressed by the rolling piston as the eccentric shaft rotates and then, as its pressure reaches the fixed pressure, it flows out through delivery port.

The Experimental Apparatus and Procedure

The Structure and Operating Characteristics of hydrostatic journal bearing

Fig. 2 shows the basic structure of the hydrostatic journal bearing system. The lubricating oil pressurized by the bearing through the pipe arrangement creates lubricating film as it supports the load of bearing in the recess. If the lubricating oil leaves the recess, the pressure of the lubricating oil drops gradually, and when it reaches the oil groove through the bearing's space between the land and shaft, the pressure becomes the atmospheric pressure. The lubricating oil flows outside of bearing through the oil groove and then it is returned to the oil reservoir.

In this paper, we have adopted the hydrostatic journal bearing of multi-recess type, which has a higher stiffness than the multi-pad type. The recess is machined to support the heavy load and the orifice prevents the eccentricity of the shaft.

The Experimental Apparatus

In this paper, the hydrostatic journal bearing is applied to obtain the accurate friction force between shaft and sub bearing in the refrigerant compressor. Because it is possible that removing the thrust force and the radial force acting on the hydrostatic cylinder by using it.

The design of the hydrostatic journal bearing: Table 1

Table 1. Geometrical shapes and design conditions of hydrostatic journal bearing.

Items	Symbol	Dim	Unit
Axial land width	*a*	2	*mm*
Circumferential land width	*b*	3	*mm*
Inner dia. of hydrostatic journal bearing	*D*	19	*mm*
Length of bearing	*L*	20	*mm*

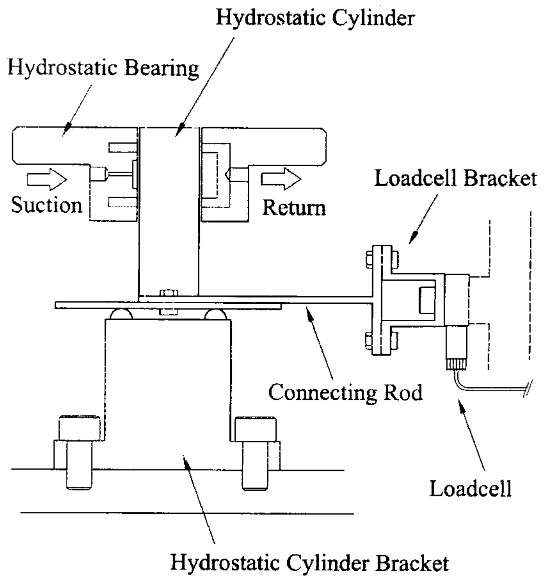

Fig. 3. The measuring device of friction force and its principle.

shows all of the whole dimensions of the hydrostatic journal bearing that is used in this experiment.

The principle and procedure of the friction force: In the case of applying the hydrostatic journal bearing, Fig. 3 shows the experimental apparatus and its method of measuring the

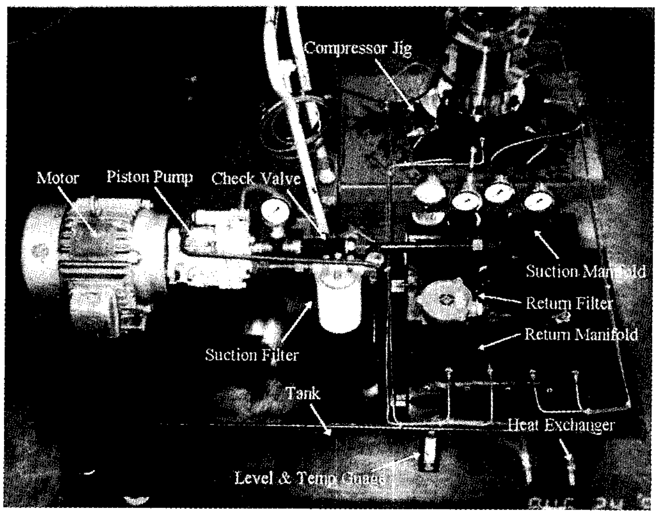

Fig. 4. The photograph of the measuring device of the fricton force.

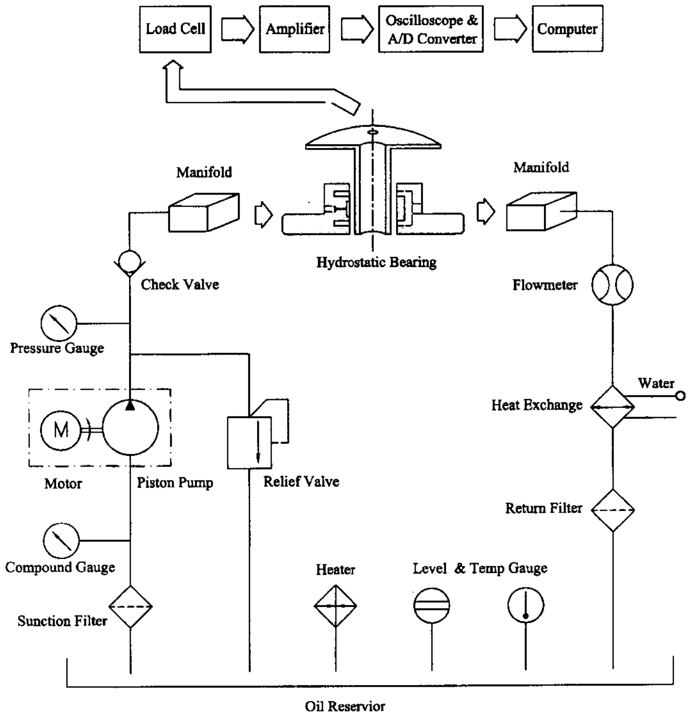

Fig. 5. The hydraulic circuit diagram of the measuring device of the friction force.

friction force that occurs between the rotating shaft and the lower bearing in the rotary compressor.

At first, the high-pressure oil supplied with the suction pressurethrough the hydrostatic journal bearing passes through the capillary tube, and then the recess pressureis formed. This forcibly supports the hydrostatic cylinder. And it is clear that the hydrodynamic lubrication state is formed between the hydrostatic journal bearing and the hydrostatic cylinder. Here, the friction force is negligible because it is very small.

Therefore, the film is formed supporting the hydrostatic cylinder forcibly with the high hydraulic pressure, and a parallel state is maintained between the shaft and the hydrostatic cylinder. At this state, if the rotary compressor is operated, the shaft rotates and the friction force occurs between the eccentric shaft and hydrostatic cylinder. This friction force is transferred to the force sensor through the connecting rod from the hydrostatic cylinder and the voltage that results here is transferred to the data processing unit. It is the exact friction force between the eccentric shaft and sub bearing.

The design of experimental apparatus and experimental procedure : Fig. 4 shows a photograph of the experimental apparatus. We have designed and fabricated the experimental apparatus to measure the friction force with the following procedure. First, as the electric motor rotates, the hydraulic piston pump of the swash plate type supplies the pressurized oil as suction pressure (P_s) to the relief valve fixed in the pump itself. The oil flows into the manifold of the solid type via the check valve to prevent a backward flow. Then it flows into the hydrostatic journal bearing with the recess pressure (P_r), and after, it forcibly supports the hydrostatic cylinder to prevent the eccentricity of the shaft, the oil flows out from the hydrostatic journal bearing and then returns to the heat exchanger to maintain constant temperature in the experimental apparatus. In this experiment, we used oil corresponding to VG56 as the refrigeration oil of the refrigerant(R22).

We executed the experiment by the following procedure: As the motor rotated at 1735 rpm, the hydraulic piston pump pressurized the oil at 80 and supported the hydrostatic journal bearing and hydrostatic cylinder horizontally in oil. Therefore,

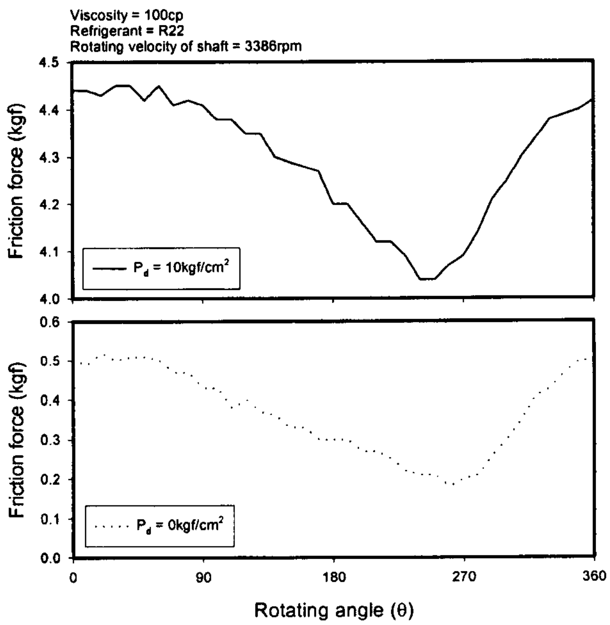

Fig. 6. friction force according to the variation of discharge pressure.

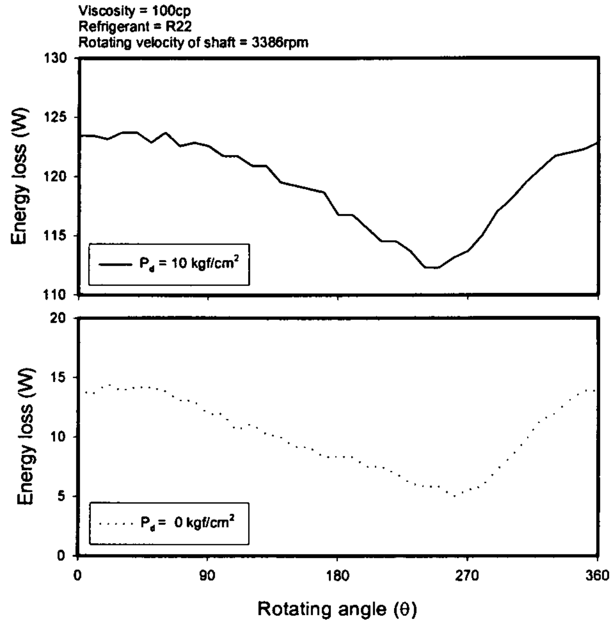

Fig. 7. Energy loss according to the variation of discharge pressure.

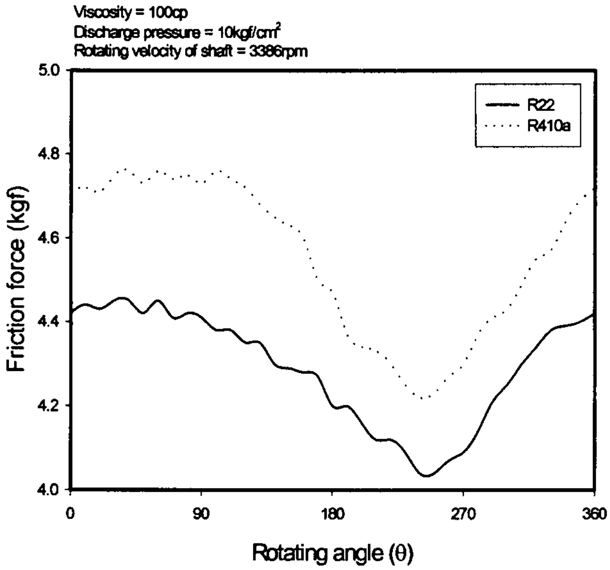

Fig. 8. Friction force according to the variation of refrigerants

we ran the rotary compressor and measured the friction force in the condition that the external effect, except the friction force that occurs between the hydrostatic cylinder and the rotating shaft, was removed entirely.

The circuit of the measuring device of the friction force : Fig. 5 shows the hydraulic circuit diagram of the measuring device of the friction force. It shows a series of processes by which the oil delivered from the pump returns to the tank via the hydrostatic journal bearing.

The Result of Experiment

Fig. 6 shows the variation of the friction force with the variation of the discharge pressure at the viscosity of 100 cp.

We can see that the average friction force at the pressure of 10 kgf/cm^2 is 12 times larger than that of 0 kgf/cm^2.

Fig. 7 shows the energy loss based on Fig. 4.1.

Fig. 8 shows the variation of the friction force with the change of the refrigerant. At the constant discharge pressure of 10 kgf/cm^2, we can see that the friction force has the smallest value at where the rotational angle θ of the shaft is about 230°. And we can see that the friction force is higher by 0.2 kgf/cm^2 when R410a is used.

Fig. 9 shows the energy loss based on Fig. 8.

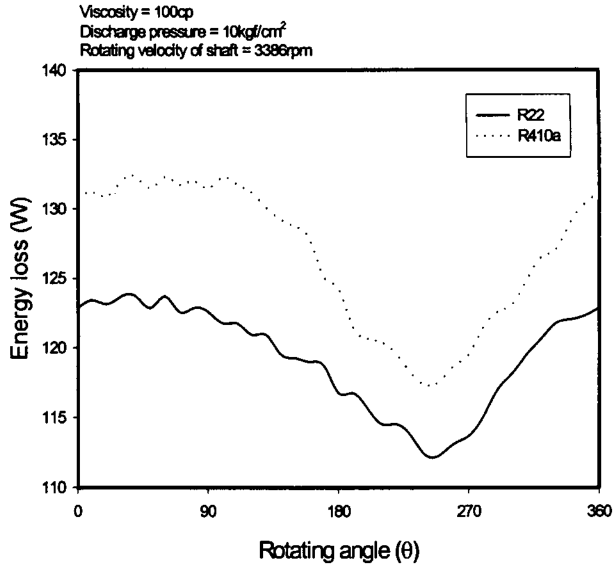

Fig. 9. Energy loss according to the variation of refrigerants.

Conclusion

The result brought the conclusion as follows.

1. The variation of the viscosity significantly influences the friction force. In other words, if the viscosity increases from 3cp to 100cp, the friction force increases about 33 times.
2. As the discharge pressure of the compressor increases, the friction force increases between the shaft and sub bearing. That is, if the discharge pressure increases from 0 to 10 kgf/cm^2 when the viscosity is 100 cp, the friction force increases by 12 times.
3. In the case of using R22 and R410a under the same conditions, the friction force of R410a is larger than that of R22.
4. In the case of using R22 and R410a under the same conditions, the energy loss of R410a is larger than that of R22.

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