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Fluid film measurements on the spherical valve plate in oil hydraulic axial piston pumps

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The fluid film between the valve plate and the cylinder block was measured by use of a gap sensor and the mercury-cell slip ring unit under real working conditions. During the operating periods, experiments with discharge pressure, revolution speed, and valve geometry was carried out for the fluid film on the valve plate. To investigate the effect of the valve shape, we designed two valve plates each having a different shape; the first valve plate was a plane valve plate, while the second valve plate was a spherical valve plate. It was noted that these two valve plates observed different aspects of the fluid film characteristics between the cylinder block and the valve plate. The leakage flow rate and the shaft torque were also investigated in order to clarify the difference between these two types of valve plates. From the results of this study, we found that the spherical valve plate estimated good fluid film patterns and performance more than the other valve plate in oil hydraulic axial piston pumps.

Keywords : Oil Hydraulic Axial Piston Pump, Fluid Film, Valve Plate, Cylinder Block

1. INTRODUCTION

The clearance between the valve plate and the cylinder block must be small because of the required high volumetric efficiency. The valve plate performs the functions of a timing device, a thrust bearing and a seal. As a thrust bearing it balances the axial's steady state and dynamic reaction forces of the cylinder block. As a seal, it minimizes leakage of the high pressure fluid from the valve plate/cylinder block interface. If the closing force between the cylinder block and the valve plate produced by the fluid pressure in the high pressure cylinders is excessive, the faces may touch and cause wear or seizure of the valve plate and the cylinder block. Alternatively, if the opening force caused by the fluid pressure in the high pressure port and across the sealing lands of the valve plate is too great then the cylinder block will be forced away from the valve plate and excessive leakage occurs. Since both the cylinder and the valve plate forces vary cyclically during rotation, it is important to determine their precise behavior so that any out of balance can be minimized. The fluid film on the valve plate is produced by balancing these two forces.

This paper reports an experimental study of the fluid film on the valve plate within the oil hydraulic axial piston pumps. The fluid film formed at this interface is examined not only for the plane valve plate but also for the spherical valve plate. The fluid film thickness between the valve plate and the cylinder block was measured by use of a gap sensor and slip ring system under dynamic conditions in order to investigate the tribological mechanism in greater detail.

2. EXPERIMENTAL APPARATUS

A section diagram of the test piston pump is shown in Fig. 1. The miniature gap sensor was mounted in the hole of the around cylinder to continuously measure fluid film thickness while test pump working period. The wire of gap sensor was led through the center of shaft in the cylinder block and taken out through the center of the valve plate and the rear housing. The signals from the gap sensor are transmitted to recorder via a mercury-cell slip ring unit during the rotating cylinder block. A digital oscillographic recorder was used in order to display the gap sensor signals which stored permanently in recorder memory and plotted by some other graphic means in personal computer.

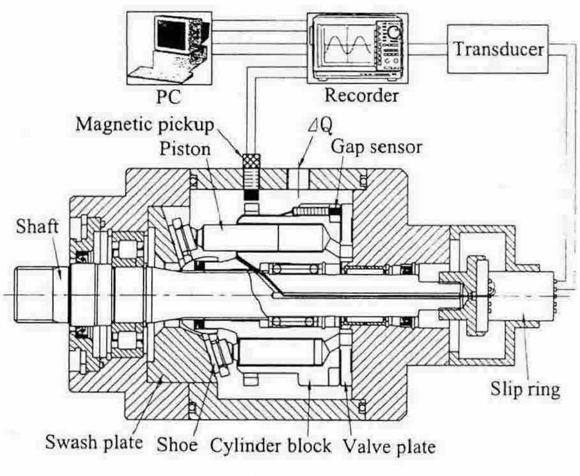

Fig. 1 Schematic diagram of the test piston pump

3. EXPERIMENTAL RESULTS

Fig. 2 shows the variations of fluid film thickness on the valve plate without bearing pad with discharge pressure at 1,500rpm during the cylinder block's rotation of one revolution. It was found that small pulsation of fluid film thickness during one revolution result from pressure pulsation produced by nine pistons in Fig. 2. The tilting of the cylinder block is caused by the clearance of spline and the clearance of bearing in shaft. The angle of the tilting increases with increased discharge pressure. Thus, because the cylinder block is tilted from the center of valve plate, the large pattern of fluid film shows opposed phenomena in both the discharge, and suction regions.

At 10MPa discharge pressure, the minimum fluid film thickness was measured to be 20 μm but at 30MPa discharge pressure, the minimum fluid film thickness was measured to be 2 ㎛ which is equivalent to 10 percent of 20 ㎛. The direction of the cylinder block is from left to right and the associated minimum fluid film thickness exists in the discharge region (=90° ~ 135°). The location of minimum fluid film thickness depends on the balancing forces between the cylinder block, the valve plate, and the eccentricity of the cylinder block. In case of the plane valve plate, the possibility of line contact between the cylinder block and the valve plate is remarkably increasing in high pressure condition. This remarkable high increase can be attributed to the severe tilting of the cylinder block.

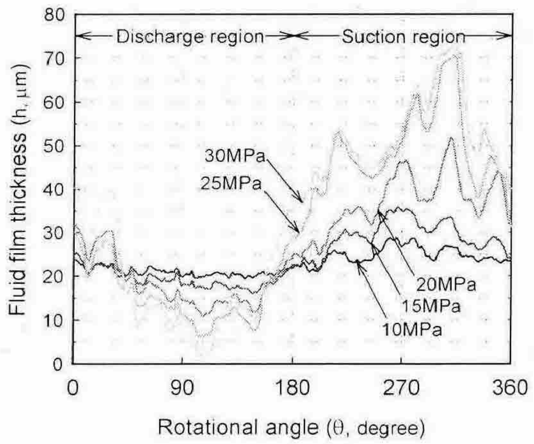

Fig. 2 Variation of fluid film on the plane valve plate

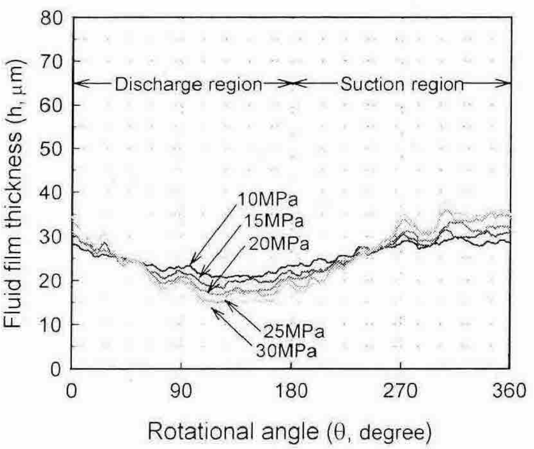

Fig. 3 Variation of fluid film on the spherical valve plate

The variations of fluid film thickness on the spherical valve plate, with discharge pressure at 1,500rpm during the cylinder block's rotation of one revolution is shown in Fig. 3. At 30MPa discharge pressure, the minimum fluid film thickness was measured to be 13 ㎛ which is a higher value i.e. 11 ㎛ more than the value of the plane valve plate. The difference of fluid film thickness between discharge region and suction region is remarkably deduced compared with that of the plane valve plate(see Fig. 2). Therefore, the shape of fluid film shows a desirable pattern (in Fig. 3), and the tilting of the cylinder block is also decreased.

The measured fluid film thickness linearly decreased with discharge pressure. Especially, the fluid film thickness of the plane valve plate decreased more than those of the spherical valve plate in high pressure range. Thus, for the high pressure range, the design of spherical type on the valve plate could ensure bigger fluid film thickness from 9 ㎛ to 11 ㎛ than the plane valve plate. The spherical valve plate maintains good stable fluid film thickness patterns between the cylinder block and the valve plate, particularly for high pressure region.

Fig. 4 shows the variations of minimum fluid film thickness with rotational speed at discharge pressure 20MPa. On the whole, the fluid film thickness is slightly increased as the rotational speed increase. The minimum fluid film thickness of the spherical valve plate is more bigger increasing than the plane valve plate in terms of overall rotational speed range.

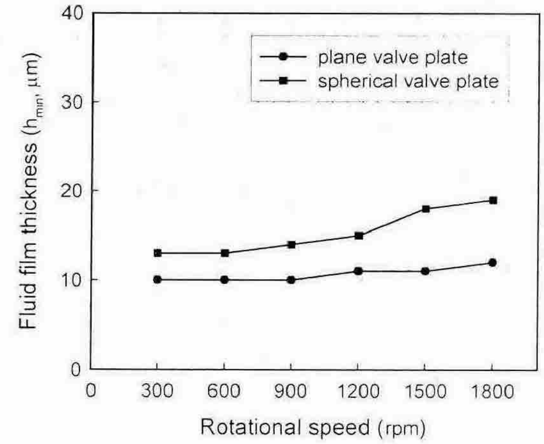

Fig. 4 Variation of minimum fluid film with rotational speed at 20MPa

4. CONCLUSIONS

The fluid film thickness between the cylinder block and the valve plate was measured experimentally in real driving conditions and the following results were obtained:

1. The minimum fluid film thickness on the valve plate exists in the discharge region(=90°-135°) and the maximum fluid film thickness is located in the suction region due to the tilting of the cylinder block.
2. The minimum fluid film thickness on the valve plate sharply decreases as the discharge pressure increase and the design of spherical type on the valve plate could ensure more bigger minimum fluid film thickness from 9 ㎛ to 11 ㎛ than the plane valve plate.
3. The fluid film thickness on the valve plate slightly increases as the rotational speed increase.
4. The spherical valve plate could obtain very stable fluid film thickness and maintain good performance compared with the plane valve plate for overall operating range.

5. REFERENCES

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