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Measurement of Hydrodynamic Pressure Distribution between a Piston and Cylinder

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The piston-cylinder mechanism is widely adopted in the hydraulic machine components. In these cases, the hydrodynamic pressures are generated in the clearance gap between the piston and cylinder under lubrication action of the oils. Under the eccentric condition of the piston in the cylinder bore, the asymmetric pressure distributions in the circumferential direction result in lateral forces on the piston. When the lateral forces act as increasing the piston eccentricity, excessive wear can be occurs in the cylinder bore and piston. In this paper, the hydrodynamic pressures generated in the clearance are measured using a stationary piston and moving cylinder apparatus. The experimental results showed that the hydrodynamic pressure distributions are highly affected by the eccentricity of the piston.

Keywords : Piston, Cylinder, Lubrication, Hydrodynamic pressure, Eccentricity

1. INTRODUCTION

The piston and cylinder is the most widely used mechanism in hydraulic machine components such as hydraulic piston pumps and motors, spool valves and linear actuators. This is the reason that it can easily generate and control very high hydraulic pressure in spite of its simple structure and relatively small size. The high mechanical output and light weight requirements in hydraulic machinery can be satisfied adoption of high oil pressure system which can be achieved by designing the clearance of the cylinder and piston more smaller. However this results in many new tribological problems.

Generally the piston is subjected to a large pressure gradients in the axial direction, and the piston and the cylinder axis are non-coincident and non-parallel. The clearance between the piston and the cylinder barrel permits leakage flow which is induced by the pressure differences by the lubrication action of hydraulic oil. Thus, the hydrodynamic lateral force acting on the piston would result from asymmetric pressure distribution, and the piston would be pushed against the barrel wall.[1-4] When the conditions are such as to produce a large enough lateral force, excessive metal to contacts would result in excessive wear at the edges of piston[5] or lead to so called 'hydraulic locking'.

However, in spite of its importance to estimate exact pressure distribution in the clearance relatively small research were carried out and most of the works were confined theoretical results.[6-8] Until now the results of exactly measured hydrodynamic pressures are not presented.

In this paper, the pressure distributions in clearance between piston and cylinder are experimentally measured. The pressure distributions in clearance affect directly the friction force acting on the piston, leakage flow rate and reciprocating motion of piston.

2. EXPERIMENTAL METHODS

It has many limitations to measure the hydrodynamic pressure distributions in clearance using real piston pump, we designed and manufactured test machine for piston-cylinder mechanism.

Fig. 1 shows a detail drawing of the piston-cylinder mechanism adopted in this paper to measure the pressure distribution in the clearance. The tapered piston has uniform eccentricity, e, from the cylinder bore axis. In order to measure hydrodynamic pressure profiles, the cylinder moved with constant speed while the piston rod was fixed.

Fig. 2 shows a schematic drawing of the experimental setup and hydraulic circuits to control the systems. To measure axial pressure distributions, the cylinder bore was moved to the left. The Piezo type pressure transducers were attached inside of the piston rod to pick up the signal at the center of length direction. Hydraulic source to supply high pressure chamber for test is separated from to supply actuator for feeding. Not to influence the pressure down respectively, in case of single hydraulic source can occur. A accumulator is installed to minimize the pressure fluctuation for moving bore in supplying hydraulic line for high pressure chamber. Pressure control valves are used to regulate the pressure of chamber in output line. A photograph of the experimental apparatus is shown in Fig. 3 and Table 1 show the test conditions used.

Table 1 Test conditions.

Feed speed , cm/sec	30
Supply pressure, MPa	1
Oil viscosity, cSt	130
Oil temperature, °C	20
Eccentricity, μm	2, 4

3. RESULTS AND DISCUSSION

The measured hydrodynamic pressure profiles in the clearance were showed in Fig. 4. Because, the piston has uniform eccentricity toward $\Phi = 0°$ direction, the clearances are smaller than those of $\Phi = 180°$ direction. By the wedge action of the lubricating oils, higher pressure was generated in the $\Phi = 0°$ direction. And the larger eccentricity, the higher pressures are occurred. The pressure differences between $\Phi = 0°$ and $\Phi = 180°$ direction act as the lateral forces on the piston. Especially, it is shown that the magnitude of pressure generated by lubrication action is higher than that of supply pressure.

4. CONCLUSION

In this paper, the hydrodynamic pressure distribution in the clearance between the piston and the cylinder in relative motion was successfully measured using an experimental apparatus. The pressure distribution in the clearance was highly affected by the eccentricity of the piston in the cylinder bore and the hydrodynamic effects become dominant as the eccentricity increase. The results of present paper can be used usefully in designing of piston-cylinder type hydraulic machine components.

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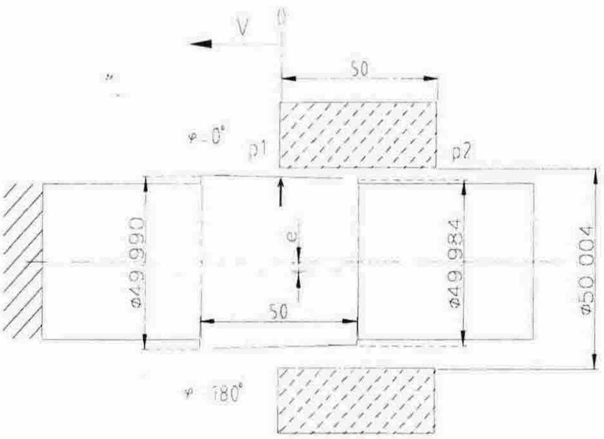

Fig. 1 Shape and dimension of test section.

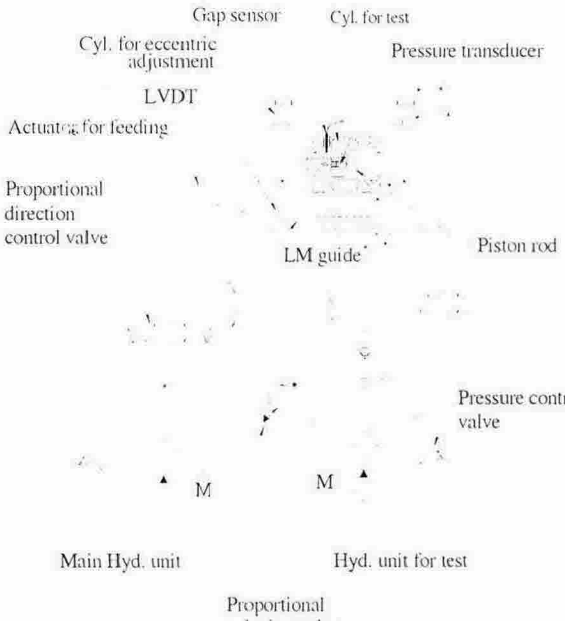

Fig. 2 Schematic drawing of experimental setup.

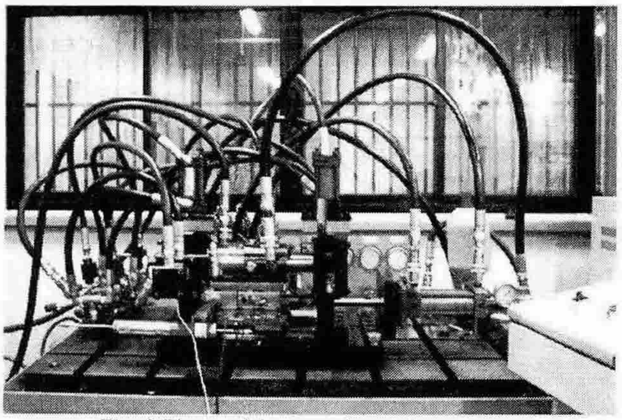

Fig. 3 Photo of the experimental apparatus.

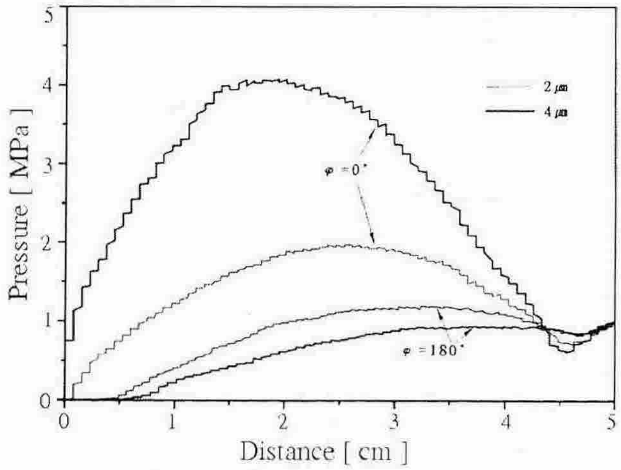

Fig. 4 Pressure distributions. $p_1=0$, $p_2=1$ MPa

5. REFERENCES

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