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Study of Dynamic characteristics of a compact hydraulic pump

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ABSTRACT
The swash plate hydraulic pump system is capable of achieving high power density and is advantageous for being compact and lightweight, so it has been used in a wide range of fields such as aviation and industrial construction machinery. In this study, we studied the determination of the gap size that minimizes power loss in the main parts of the pump for optimal design of the pump using the specification conditions of a sample compact piston pump

***Keywords*–**Swash plate, pump, power loss

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I. INTRODUCTION

The swash plate type axial piston pump enables high output density because it uses static pressure bearings in the relative lubrication area, and has been used not only in aviation but also in a wide range of fields such as industrial construction machinery and automobiles due to its advantages in compactness and weight reduction. Accordingly, there have been many studies such as groove slipper analysis of piston pumps, vibration analysis of pumps, flow analysis of slipper bearings, and abrasion of pumps [1-4].

In particular, the aerospace industry is a comprehensive system industry in which advanced technologies in various fields such as machinery, electronic components, and materials are concentrated, and requires a higher level of technology in almost all fields such as precision, reliability, weight reduction, and efficiency. In some companies that produce small piston pumps, the technology to analyze and optimize the performance of design conditions must be possessed for the independent development of piston pumps. Therefore, the determination of the gap height, which is important for pump design, was studied using the specifications of small samples.

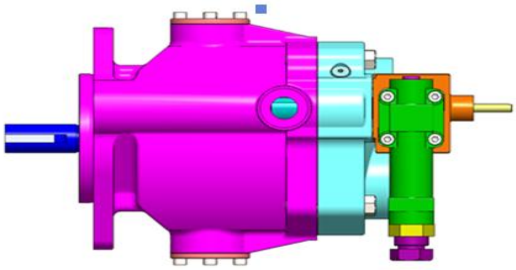


Fig. 1 3D diagram of piston pump

II. BASIC CONTENTS AND RELATEDEQUATION

The lubrication gap of a hydraulic piston pump is largely divided into three parts: the piston and cylinder, the slipper and swash plate, and the valve plate and cylinder block.

2.1 Lubrication gap between piston and cylinder

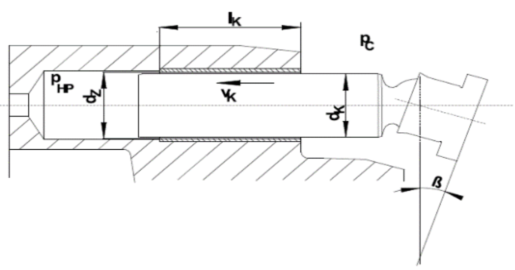


Fig. 2 Interface between piston and cylinder

The piston/cylinder interface may not be hydrostatically balanced. The clearance height is related to the operating parameters and varies within a given set of boundary shapes (sets) based on the cylinder bore diameter and piston diameter, as shown in Fig.2Assuming that the piston moves within the cylinder, the power losses due to the high-pressure side and low-pressure side flows $Q_{HP}$and Q_{LP} are given by the following equations, respectively [5].

$$Q_{HP} = \frac{\pi(P_{HP} - P_C)d_k h_k^3}{12\mu l_k} - \frac{\pi d_k v_k h_k}{2}$$

$$Q_{LP} = \frac{\pi(P_{LP} - P_C)d_k h_k^3}{12\mu l_k} - \frac{\pi d_k v_k h_k}{2}$$

The power loss due to volume loss in the high pressure side (discharge stroke) and low pressure side pumping modes can be written as follows, respectively.

$$P_{QHP} = Q_{HP}(p_{HP} - p_C)$$

$$P_{QLP} = Q_{LP}(p_{LP} - p_C)$$

The total power loss between the piston and the cylinder is expressed by the following equation:

$$P_R = \frac{z}{2}\left(P_{QHP} + P_{QLP}\right) + zP_R)$$

2.2 Lubrication gap between slipper and swash plate

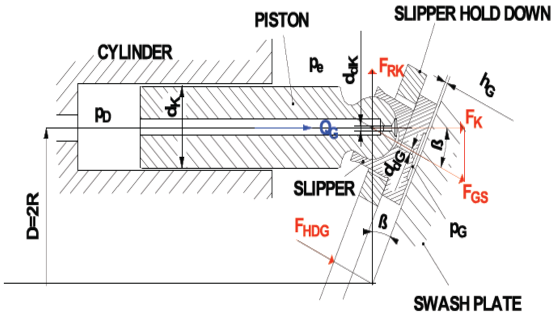


Fig.3 Interface between slipper and swash plate

The flow rate through the orifice in the piston and slipper can be expressed as follows

$$Q_G = \frac{\pi h_G^3}{6\mu ln\frac{D_G}{d_G}}(p_G - p_e)$$

The slipper piston design is currently used independently, and the contact between the piston and the swash plate is hydrostatically balanced. The power loss due to volume flow rate and the power loss due to friction force can be written as follows.

$$P_Q = p_D Q_G$$

$$P_T = \frac{\mu\omega^2 R^2}{h_G}\frac{\pi}{4}(D_G^2 - d_G^2)$$

The total power loss between the slipper and the swash plate is given by the following equation.

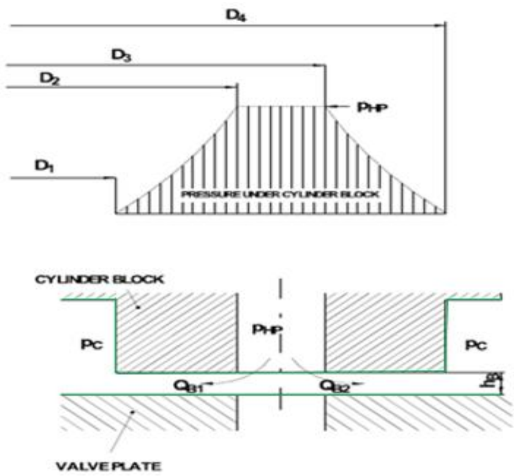
$$P_{SG} = P_Q + P_T$$

2.3 Lubrication gap between cylinder block and valve plate

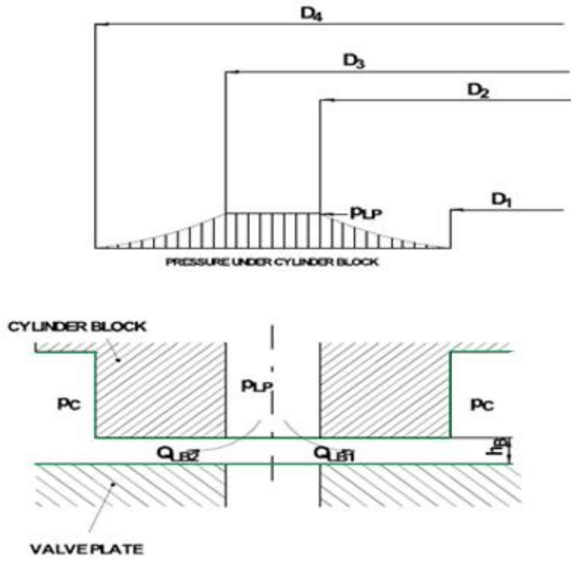
On the low pressure side of the internal and external sealing gaps, the flow rates are expressed as follows: Fig.4 (a) Pressure distribution on the high pressure side of the cylinder block and (b) pressure distribution on the low pressure side

$$Q_{BL1} = \frac{\pi}{12\mu}\frac{p_{LP} - p_C}{ln\frac{D_2}{D_1}}h_B^3$$

$$Q_{BL2} = \frac{\pi}{12\mu}\frac{p_{LP} - p_C}{ln\frac{D_4}{D_3}}h_B^3$$



(a)



(b)

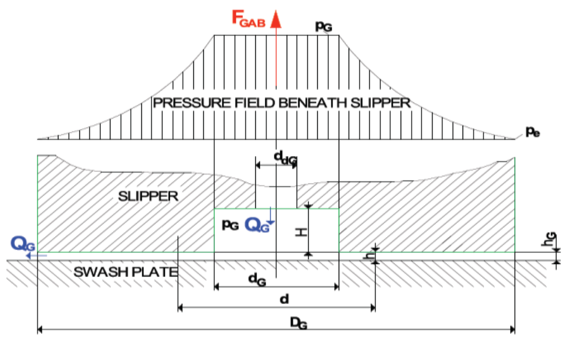


Fig.5 Interface between cylinder block and valve plate

The power losses on the high-pressure side and low-pressure side of the cylinder block can be written as follows, respectively.

$$P_{SQ} = Q_{BH}(p_{HP} - p_C) + Q_{BL}(p_{HL} - p_C)$$

$$P_{STB1} = \frac{\mu\pi}{4}(D_2^2 - D_1^2)\frac{v_{B2}^2}{h_B}$$

$$P_{STB2} = \frac{\mu\pi}{4}(D_4^2 - D_3^2)\frac{v_{B3}^2}{h_B}$$

The total power loss between the cylinder block and the valve plate is:

$$P_{SB} = P_{SQB} + P_{STB}$$

III. RESULTS AND ANALYSIS

Fig. 6, Fig. 7, and Fig.8 show the simulation results of the optimal clearance height for the minimum power loss of the aviation sample pump. It can be seen that the optimal clearance between the piston and the swash plate in the operating parameters is 8-12μm, between the slipper and the swash plate is 4-6μm, and between the valve plate and the block is 4-7μm. The clearance height that minimizes the power loss can be taken as the optimal gap.

The lubrication gap design substantially affects the basic characteristics of the axial piston pump. The correct size of the tolerance and the height of the gap are considered to have a decisive effect on the performance of the pump. Although various factors can affect the design of the pump, the gap between the parts to be joined is considered to be the most important factor

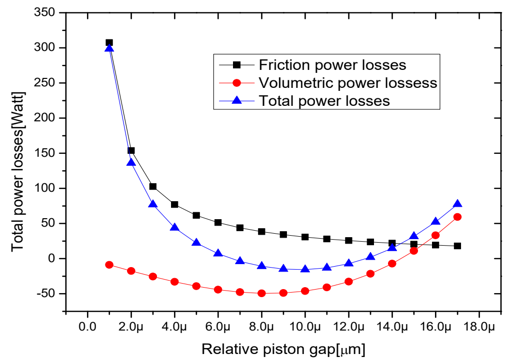


Fig.6 Power loss between the piston and cylinder block

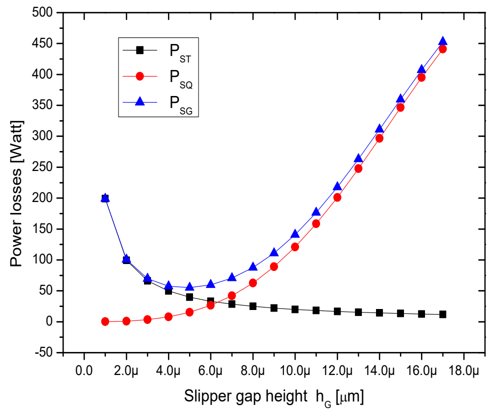


Fig.7 Power loss between the slipper and swash plate

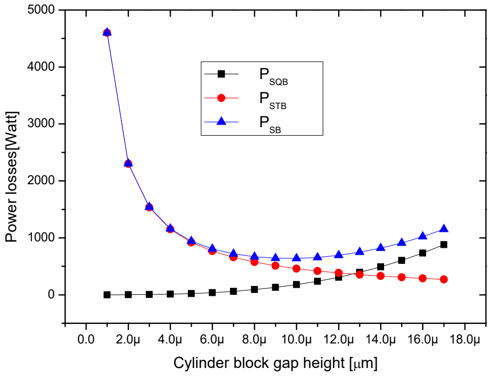


Fig.8 Power loss between the block and valve plate

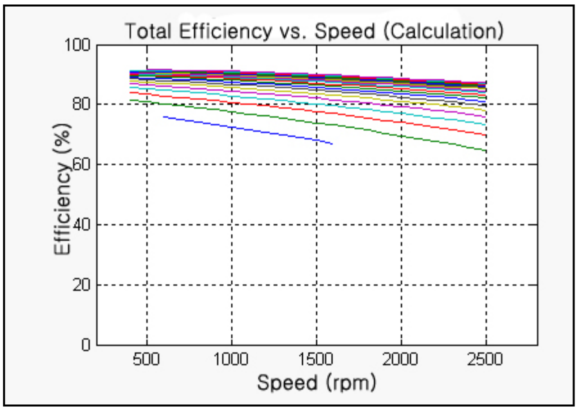


Fig.9 Efficiency prediction results with speed

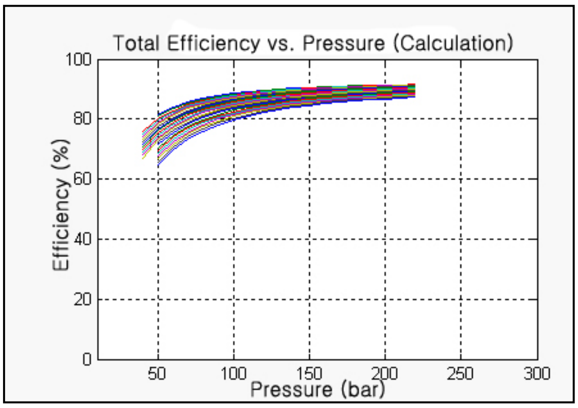


Fig.10 Efficiency prediction results with pressure

Fig. 9 and Fig. 10 show the efficiency prediction results obtained considering the minimum power loss by selecting appropriate design dimensions.

IV. CONCLUSION

The gap height was discussed for the sample piston pump, and the lubrication gap design substantially affects the basic characteristics of the axial piston pump. The correct size of the tolerance and the height of the gap have a decisive effect on the performance. If the gap height is designed to be very small, the friction loss in the mutually moving parts will be too large, and if the gap height is very large, the leakage loss will be very large. Therefore, it is necessary to determine the gap height under the minimum power loss condition. It should be noted that the optimum gap height may vary for different operating parameters and is selected according to most of the operating parameters in which the pump operates.

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