Reduction Of Noise Generating Flow Fluctuations In Hydraulic Systems Driven By Swash Plate Pumps Through Improved Port Plate Design

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INTRODUCTION

Flow fluctuations in hydraulic systems driven by swash plate pumps generate noise. A swash plate pump contains a finite number of pistons arranged in a cylinder block. Motion of each piston is separated by a phase difference of (2π/9) Rad. The total pump flow is the sum of individual cylinder flows. An improved port plate design is proposed and analyzed for the pump flow characteristics.

PUMP PERFORMANCE

The flow should rise gradually as the cylinder port and the port plate delivery slot overlap during the pump action, in order to avoid undesirable flow fluctuations [1]. Delivery stroke starts when the piston is at its top dead center and ends when it is at its bottom dead center. The second stroke of the cylinder cycle is the suction stroke at which the cylinder does not contribute in generating fluid flow. Bernoulli principle is used to characterize the mathematical relationship between the cylinder delivery pressure and the corresponding flow rate. By considering a stream line path, which starts when the stream leaves the cylinder delivery port and ends at the port plate delivery slot, the cylinder delivery pressure, its flow rate and the porting area are considered and studied. The cylinder pressure variation with time can be given as

$$p'_k(\phi)=\frac{B}{V_{ck}(\phi)'}Q_k(\phi) \tag{1}$$

where

$$Q_k(\phi) = sign(p_k - p_d)\, c_d\, A_d \sqrt{\frac{2}{\rho}}\sqrt{|p_k - p_d|} \tag{2}$$

$$V_{ck}(\phi) = A_p\,(0.5l_c + c_t \cos(\phi)) \tag{3}$$

$$A_d = 2[\pi r_d^{\,2}\theta_1 - (0.5h_1 b_1)] + [\frac{h_g b_g}{2}] \tag{4}$$

Eq. (1), (2) ,(3) and (4) represent the cylinder delivery pressure change rate, cylinder delivery flow rate, cylinder fluid volume and the groove delivery area in the overlapping zone, respectively. Proper port plate design can lead to the best pump performance with minimum flow fluctuations.

PORT PLATE

The pump has two kidney-shaped ports that control the fluid traffic in/out the cylinder [2]. The current designs come with a shallow silencing groove or without groove. Fig. 1 shows the port plate general configuration. The delivery section was divided into 5 zones. The pump flow rate and porting area are simulated and presented in Fig. 2 and 3, the dashed line corresponding to the conventional design. From the result of simulation, the design experiences pressure overshooting twice in the delivery stroke, where the overshooting leads to maximum flow fluctuation, which is the source of high levels of noise.

NEW PORT PLATE

The need to reduce, or eliminate the overshooting can be achieved at the design level. The current designs experience an overshooting. The overshooting occurs at the beginning and end of the overlapping zones. The proposed design suggests utilizing a pair of deep silencing grooves in the beginning and end of the slot. These grooves help in achieving a gradual rise in the pressure, where the pressure increases as the cylinder leaves its T.D.C. This design can grant the pressure more time to rise gradually and to reach the value of load without any overshooting. Also, the triangular shape of the groove helps in achieving a smooth transitional pressure.

Fig. 1 illustrates the general configuration of the new design, the dashed line showing the proposed silencing grooves. The simulation results are presented in Figs. 2 and 3, with the solid line. From Fig. 3, it is seen that the pump flow fluctuation decreases remarkably. This reduction will be reflected on noise levels of the hydraulic system resulting in a quieter hydraulic system.

DISCUSSION

It is clear that the new design can eliminate the pressure overshooting and the flow rate fluctuations. Further work is needed to assess the extent of noise level reduction with the introduction of the proposed silencing grooves.

REFERENCES

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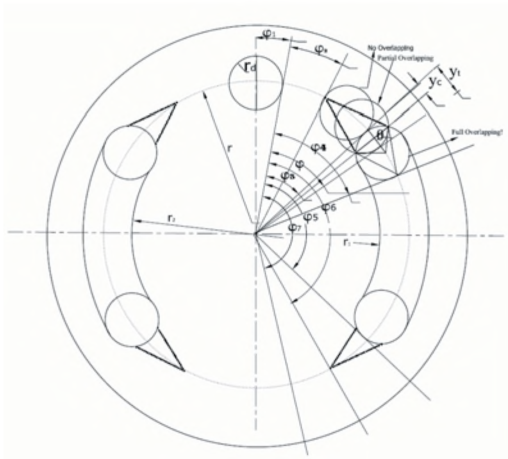

Fig. 1: General configuration for the port plate, (the dashed line for the groove, and the solid for the Non-groove plate)

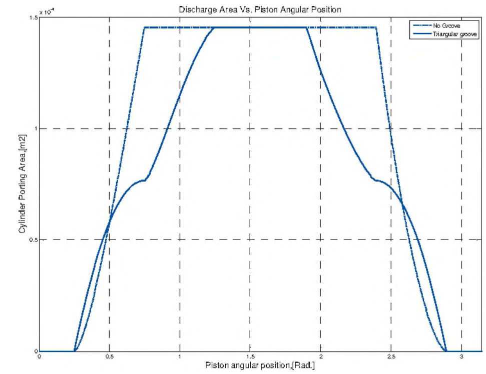

Fig. 2: Delivery area, dashed line for Non-groove and solid line for the new design

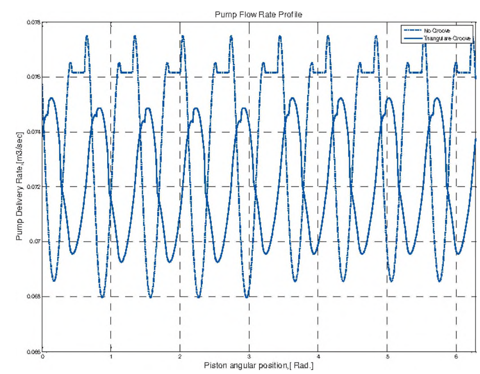

Fig. 3: Pump flow rate, dashed line for Non-groove and solid line for the new design