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Evaluation of the Effective Variables on the Performance of the Hydraulic Pilot Valve Including the Orifice with the Fixed and Moving Parallel Surfaces

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Abstract

Considering the widespread use of hydraulic pilot valves, including orifices with fixed and moving parallel surfaces in the structure of two-stage pressure control valves, it is necessary to evaluate and analyze their performance to optimize and control them. In this article, the effect of slope, length, and curvature of the valve seat on pressure distribution and oil flow rate passing through the pilot valve chamber, flow coefficient, force coefficient, and force on the moving part of the valve were investigated using numerical and experimental methods. In all working conditions, the difference between the results obtained from the experimental measurements of the flow coefficient and the force on the moving part of the pilot valve with the numerical results was determined to be less than 6%. Investigation results showed that by reducing the slope and length of the seat, the force on the moving part of the valve is increased. Meanwhile, creating a curve in the inlet port of the valve causes 36% reduction in the force on the moving part of the valve and 70% increase in its flow coefficient.

Keywords: Hydraulic Pilot Valve; Orifice; Flow Coefficient; Orifice Curvature; Orifice Length.

1. Introduction

In recent years, valves including orifices with parallel fixed and moving surfaces have been used in the pilot unit of some two-stage pressure relief valves, as shown in Figure 1 [1 and 2]. According to Figure 1, the pilot valve consists of a conical moving part and an inclined seat, with an equal inclination angle. With the movement of the movable component, an opening with a variable cross-section including parallel surfaces is created [1].

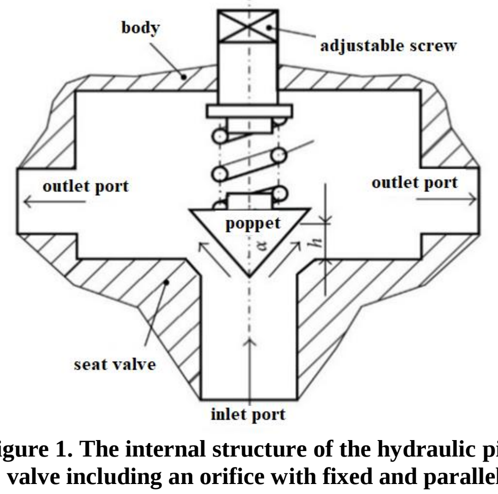

Figure 1. The internal structure of the hydraulic pilot valve including an orifice with fixed and parallel moving surfaces

In recent years, due to the increasing use of valves including orifices with fixed and moving parallel surfaces as main and pilot valves, and the importance of designing, manufacturing, and optimizing them, this research, investigating the effect of geometric variables on the performance of this sample of valves, are carried out experimental and numerical methods. The review of the research conducted in the past years shows that the analysis of the performance of hydraulic valves including orifices with parallel fixed and moving surfaces has been given less attention [2 and 3]. Therefore, in this article, to design and optimize steering valves including orifices with fixed and moving parallel surfaces, the effect of other geometric quantities, such as the seat angle, length, and curvature of the seat in the inlet port on the pressure distribution, oil flow rate passing through the chamber of the valve, the force on the moving part of the valve, the force and flow coefficients are investigated numerically and experimentally.

2. Methodology

After the geometrical modeling of the hydraulic pilot valve with fixed and moving parallel surfaces, the meshing of the inner chamber of the valve is done. For the numerical analysis of the oil flow passing through the orifice created in the hydraulic pilot valve, including two parallel fixed and moving surfaces, the Fluent section of the Ansys software is used. To evaluate the results of the numerical analysis of the oil flow passing through the hydraulic pilot valve including the orifice with fixed and moving parallel surfaces, the design and construction of the system shown in Figure 2 is done.

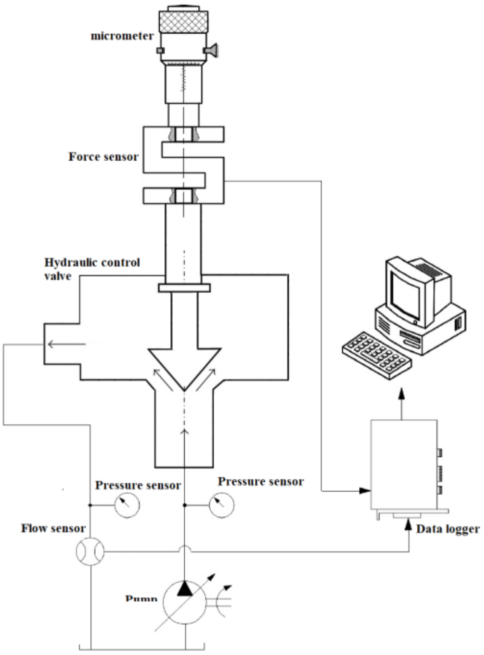

Figure 2. A hydraulic power transmission system including hydraulic pilot valve

3. Discussion and Results

Figure 3 illustrates the effect of seat length on changes in force applied to the moving component of the pilot valve. Furthermore, the effect of the length of the seat on the flow coefficient of the hydraulic pilot valve, including the orifice with fixed and moving parallel surfaces, is shown in Figure 4. According to Figure 4, the flow coefficient decreases if the length of the valve seat is increased, as well as the resistance to oil flow.

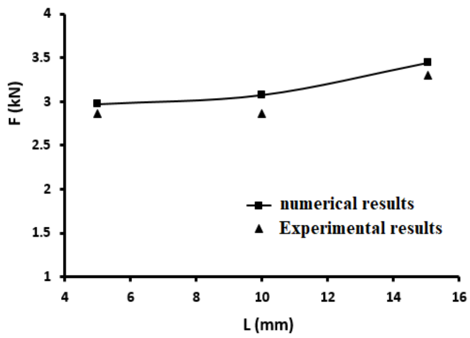

Figure 3. The effect of seat length on changes in force applied to the moving component of the pilot valve.

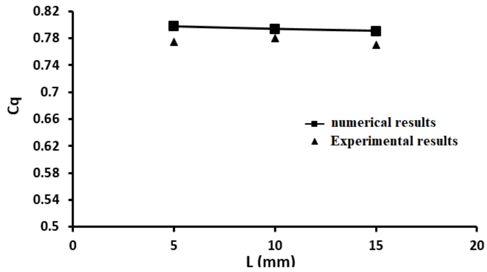

Figure 4. The effect of the length of the seat on the flow coefficient of the pilot valve

On the other hand, the experimental and numerical evaluations of the hydraulic pilot valve show that the force applied to the moving component of the hydraulic pilot valve increases with the increase of the seat slope and the increase of the effective surface of the moving component against the oil pressure of the inlet port (figure 5). In the meantime, increasing the slope of the pilot valve seat, while changing the size and location of the vortices, increases the resistance to the oil flow. Therefore, according to Figure 6, with the increase of the seat slope, the flow coefficient decreases in the opening created in the pilot valve.

Figure 7 shows the effect of the curvature size in the pilot valve inlet port on the axial force applied to the conical movable member. As shown in Figure 7, by creating a 2 mm curve in the inlet port, the axial force on the mobile tapered valve component is reduced by approximately 36%. Whereas with the change of curvature in the entrance port, the force on the moving part does not change much. Furthermore, Figure 8 shows the influence of seat curvature in the inlet port on the flow coefficient of the pilot valve with fixed and parallel mobile surfaces.

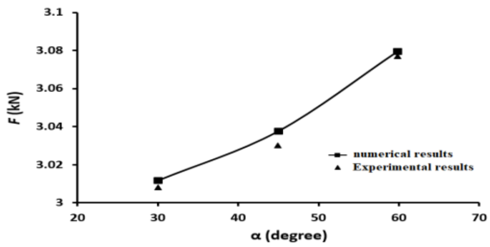

Figure 5. The effect of seat slop on changes in the force applied to the moving component of the pilot valve.

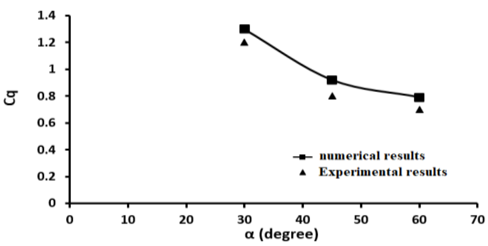

Figure 6. The effect of seat slop on changes in the flow coefficient of the pilot valve

Further investigations show that, creating curvature and increasing the curvature in the inlet port of the valve, on average, causes a 70% increase in the flow coefficient, due to the presence of less resistance to the oil flow.

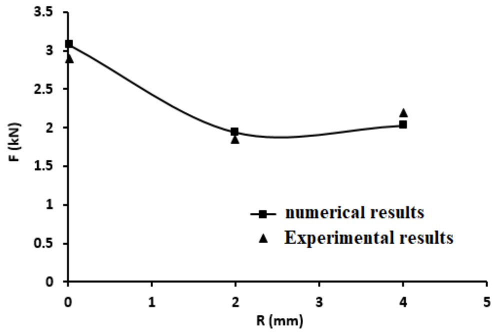

Figure 7. The effect of the curvature size in the inlet port on the axial force applied to the conical movable member

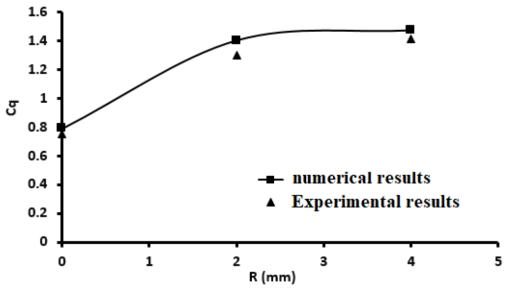

Figure 8. The effect of the curvature size in the inlet port on the flow coefficient of the pilot valve

4. Conclusion

Some of the outcomes of this research include:

- In all working conditions, the results obtained from the experimental measurement of the flow coefficient and the force acting on the moving component of the pilot valve are in acceptable agreement with the results obtained from the numerical analysis of the oil flow passing through the valve chamber.

-The force exerted on the moving component and the valve force coefficient increase and decrease, respectively, as the slope and length of the seat increase. In the meantime, the increased curve of the seat reduces the force exerted on the moving part of the valve and increases the coefficient of force.

- The flow coefficient of the valve is inversely related to the length and slope of the seat and directly related to the curvature of the seat.

5. References

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