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# Simulation and analysis of inclined flow channel of hydraulic slide valve

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Abstract. The inclined flow channel, that is, the flow channel axis is not parallel to the slide valve axis, is used in this paper. This flow channel is more conducive to the flow of fluid, thus reducing the kinetic energy loss when the fluid passes through the slide valve. FLUENT simulation software is used to simulate and analyze the two-dimensional flow field of slide valve flow channel at different angles between flow channel axis and spool axis, and the flow field nephogram at different inclination angles are obtained. The result of simulation is analyzed and the optimal angle is 45 degrees. It also analyzes the influence of different inlet flow velocities on the flow field. The results show that the higher the velocity, the easier the formation of vortices and the greater influence on the pressure difference between inlet and outlet.

#### 1. Introduction

Hydraulic sliding valve is an important component in hydraulic system [1], and its working quality directly affects the performance of the whole hydraulic system [2-4]. The flow state of fluid inside the slide valve affects the service life of the slide valve [5-6]. Conventional slide valve runners are parallel to the spool axis of the spool, and the fluid flows into flow channel from the inlet of the slide valve and directly impacts the valve spool [7-8]. The flow field changes drastically, and it is easy to produce vortex, vibration and noise, which will cause energy loss [9-10]. With the development of 3D printing technology, processing of complex flow channels becomes easier and easier, so inclined flow channels are relatively easy to achieve. By changing the flow channel inclination angle of the slide valve, it is as much as possible to reduce the impact of fluid on the spool and flow channel wall of the slide valve in the flow channel. At the same time, different inclination flow channel are simulated by FLUENT.

#### 2. Establishment of Geometric Model and Setting of Boundary Conditions

Figure 1 shows the two-dimensional model of the slide valve flow channel. The angle  $\alpha$  between the flow channel axis and the spool axis is shown in the figure. The tilt angle is set to 15 degrees, 25 degrees, 35 degrees, 45 degrees, 55 degrees and 65 degrees. The flow field of the slide valve is simulated under different conditions.

ICEM of meshing software was used to mesh the two-dimensional flow channel model. When the tilt angle is set to 45 degrees, the model is divided into structured grid partition and the number of grids is 15,000. The flow channel model in the slide valve is meshed as shown in Figure 2.

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When setting the boundary conditions, the model inlet boundary condition is set as pressure inlet and the inlet pressure is 9MPa. The outlet boundary condition of the model is set to pressure outlet and the outlet pressure is 8.8MPa. The fluid is an incompressible, constant Newtonian fluid and the reference pressure is set to 0. Standard k- $\varepsilon$  turbulence model is used.

### 3. Simulation Analysis

#### 3.1. The influence of outlet inclination angle on flow field

#### 3.1.1. Simulation results

According to the above parameters, the outlet inclination angle is changed. Figures 3 to 8 show the simulation results. The figure captions are as follows: (a) Pressure nephogram; (b) Streamline diagram; (c) Energy dissipation rate nephogram; (d) Turbulent kinetic energy nephogram.

- Outlet inclination of 15 degrees (inlet pressure is 9 MPa and outlet pressure is 8.8 MPa.) 8.9e+06 2.5e+01 2.4e+01 8.9e+06 8.9e+06 2.2e+01 2.0e+01 8.8e+06 8.8e+06 1.8e+01 8.8e+06 1.6e+0 8.7e+06 1.5e+0 1.3e+01 8.7e+06 1.1e+01 8.7e+06 8.6e+06 9.1e+00 7.3e+00 8.6e+06 8.6e+06 5.5e+00 3.6e+00 8.5e+06 8.5e+06 1.8e+00 0.0e+00 8.5e+06 (b) (a) 1e+0 3.6e+01 3.3e+01 4.0e+05 3.7e+05 3.4e+05 3.0e+01 3.1e+05 2.8e+0 2.8e+05 2.5e+01 2.2e+01 2.5e+05 2.2e+05 1.9e+01 1.8e+05 1.5e+05 1.7e+0 1.4e+01 1.2e+05 9.2e+04 1.1e+01 8.3e+00 6.2e+04 5.6e+00 3.1e+04 2.8e+00 4.5e+01 7.5e-02 (d) (c) Figure 3. Simulation results at exit inclination of 15 degrees.
  - Outlet inclination of 25 degrees (inlet pressure is 9 MPa and outlet pressure is 8.8 MPa.)



• Outlet inclination of 35 degrees (inlet pressure is 9 MPa and outlet pressure is 8.8 MPa.)



• Outlet inclination of 45 degrees (inlet pressure is 9 MPa and outlet pressure is 8.8 MPa.)



• Outlet inclination of 55 degrees (inlet pressure is 9 MPa and outlet pressure is 8.8 MPa.)



• Outlet inclination of 65 degrees (inlet pressure is 9 MPa and outlet pressure is 8.8 MPa.)



#### 3.1.2. Result analysis

When outlet inclination angle is 15 degrees ,pressure gradient changes regularly. When the fluid flows through the second corner, the pressure changes uniformly without a low pressure area and the high pressure area on the bottom wall of the flow channel is relatively small. It shows that the fluid transition is smooth here and the flow velocity changes little. At the same time, the change of the flow channel shape and structure has little effect on its flow field. It can be seen from the streamline diagram that the vortices in the two corner areas are basically small, and no strong vortices appear. At the same time, except for the higher turbulent kinetic energy in the first corner area, the turbulent kinetic energy of other positions does not change much. Therefore, when the outlet inclination angle of the flow channel is very small, although the outlet length becomes longer, the overall flow velocity in the hydraulic valve increases, and the fluency of the flow channel is also improved.

When the outlet angle increases continuously. First of all, the low pressure area on the wall of the first corner continues to expand, and the low pressure area gradually appears in the second corner area. When the inclination angle is 55 degrees, two low-pressure areas appear at the same time. When the inclination angle changes to 65 degrees, the low-pressure area at the first corner disappears and only appears at the second corner. Secondly, the vortices in the outlet region of the channel are strengthened, and the high-speed fluid gradually occupies the outlet. Correspondingly, the turbulent kinetic energy near this location also changes drastically, so the vortex has a wide range of influence and the noise will increase. Furthermore, it can be seen that the energy dissipation rate at the corners gradually decreases, and the ratio of kinetic energy converted into internal energy decreases. Therefore, the change of outlet inclination angle not only affects outlet length, but also plays a key role in the pressure change and velocity distribution in the channel. The smaller the inclination angle is, the longer the outlet section is, which increases the space occupied by the flow channel in the valve, but the fluid velocity is relatively uniform and stable under this structure, which can effectively reduce the vortex and energy loss. However, the larger the inclination angle is, the outlet area is mainly dominated by high pressure. And the variation range of velocity and turbulent kinetic energy is larger, which is not conducive to noise reduction.

#### *3.2.* The influence of inlet flow rate on flow field

Select the optimal flow channel inclination angle flow field model. That is, the outlet inclination angle is 45 degrees. Different inlet velocities are changed to observe the effect of inlet flow on flow field,

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while other simulation conditions remain unchanged. The simulation results are as follows.

#### 3.2.1. Simulation results

The inlet speed is 2m/s, the outlet pressure is 0. (the outlet angle of 45 degrees) • 4.9e+03 4.1e+03 3.3e+03 2.5e+03 3.8e+ 3.6e+00 3.3e+00 3.0e+00 2.9e+03 1.7e+03 8.4e+02 2.9e+01 -7.9e+02 2.7e+00 2.5e+00 2.2e+00 1.9e+00 -1.6e+03 -2.4e+03 1.6e+00 1.4e+00 1.1e+00 8.2e-01 -3.2e+03 -4.1e+03 -4.9e+03 -5.7e+03 5.5e-01 2.7e-01 -6.5e+03 0.0e+00 (b) (a) 2.2e+03 2.1e+03 8.1e-01 7.6e-01 1.9e+03 1.7e+03 7.0e-01 6.4e-01 1.6e+03 1.4e+03 5.8e-01 5.3e-01 4.7e-01 1.3e+03 4.1e-01 3.5e-01 1.1e+03 9.5e+02 7.9e+02 3.0e-01 2.4e-01 6.3e+02 4.8e+02 1.8e-01 1.2e-01 3.2e+02 1.6e+02 6.4e-02 6.6e-03 4.4e-01 (d) (c) Figure 9. Simulation results of inlet velocity of 2m/s.



• The inlet speed is 6m/s, the outlet pressure is 0. (the outlet angle of 45 degrees)



• The inlet speed is 8m/s, the outlet pressure is 0.(the outlet angle of 45 degrees)



• The inlet speed is 10m/s, the outlet pressure is 0 .(the outlet angle of 45 degrees)



• The inlet speed is 12m/s, the outlet pressure is 0. (the outlet angle of 45 degrees)



#### 3.2.2. Result analysis

At the same inlet velocity (that is, the inlet flow rate remains unchanged), the inlet is the pressure boundary. From the pressure cloud chart, it can be seen that the low pressure area at the two corners is reduced and negative pressure. In addition, the differential pressure between import and export is small, for example, when the import speed is 2m/s, the differential pressure is only 5.7KPa. The streamline diagram shows that the fluid accelerates in the area where the flow area is reduced, and the maximum velocity can reach more than twice the inlet velocity. Combining with turbulent kinetic energy, it can be found that although the turbulent kinetic energy value of the fluid is small, its gradient of change is large, and the rate of velocity change is also fast, especially in the exit area. Therefore, it is easier to form vortices at this location.

With the increase of the inlet flow rate, the pressure also increases, and the maximum differential pressure between the inlet and outlet is about 0.2MPa. However, the maximum flow velocity and turbulent kinetic energy in the flow channel have little change. At the maximum inlet flow velocity, the turbulent kinetic energy is only  $32m^2/s^2$ . At the same time, compared with the energy dissipation rate nephogram, it is found that with the increase of the inlet flow rate, the internal energy dissipated and transformed in the place with strong turbulent kinetic energy is more.

#### 4. Conclusions

On the whole, the flow velocity distribution in the hydraulic valve with 45 degree inclination angle is more uniform, and the vortex and noise are reduced. At the same time, the flow channel is more smooth, which improves the energy utilization rate of the hydraulic system, and the valve flow channel angle design is efficient and reasonable. The change of inlet flow rate has obvious influence on the pressure difference and energy dissipation rate, but it has little effect on the flow velocity distribution and turbulent kinetic energy.

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#### References

- [1] Liu L and Yu P 2020 Design and Experiment-Based Optimization of High-Flow Hydraulic One-Way Valves [J] *Fluid Dynamics and Materials Processing* **16** (2):211-224
- [2] Wang L X, Chen Y and Lu Y X 1999 Numerical analysis of three dimensional fluid flow in hydraulic valve channel [J] *China Mechanical Engineering* (02): 3-5
- [3] Zhao P, Li R C, Li Y S, Ma Y and Zhu L D 2018 Improved Design and Optimization of Hydraulic Valve Flow Channel [J] *Machine Tool & Hydraulics*
- [4] Wu P F, Sun J, Jiao L and Chen P F 2018 Flow Analysis and Flow Channel Optimization of High-pressure Solenoid Valve [J] *Machine Tool & Hydraulics*
- [5] Chen Y F, Wu D S, Fang S and Hu R 2018 Experimental study on two-phase flow in rough fracture: Phase diagram and localized flow channel [J] *International Journal of Heat and Mass Transfer* 122 (7) 1298-1307
- [6] Hong Z, Chen Y W and L C C 2019 Optimization of Flow Channel in 3D Printing Hydraulic Manifold Block Based on Response Surface Method [C] Proc. 2019 IEEE 8th International Conference on Fluid Power and Mechatronics (FPM) IEEE
- [7] Zhang D K, Li S D and Lin Y S 2018 Numerical research of flow characteristics in narrow crack flow channel [J] *Ship Science and Technology*
- [8] Turkmen A C, Celik C and Esen H 2018 The relationship between flow channel geometry and pressure drop in a direct methanol fuel cell with parallel channels [C] *Proc. 3th International Hydrogen Technologies Congress*
- [9] Zheng Y 2018 Study on Hydraulic Characteristics of U-Channel Channel Flow Measuring Device Based on FLOW-3D [J] *Guangdong Water Resources and Hydropower*

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[10] Xu T L and Zhang X Y 2008 Numberical Analysis of Fluid Flow in the Throttle Poppet Valve Channel in Precision Machinery [J] Proceedings of SPIE - The International Society for Optical Engineering 7130 71305I-71305I-6