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Hydraulic Decoder Flow Control Valve Leakage Simulation Based on AMESim

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Abstract

Internal leakage widely exists in the hydraulic system, directly affects the system performance. In this study, a flow control valve of a hydraulic decoder is taken as the object, and a flow control valve working simulation model is established by using the HCD library in AMESim software.The influences of pressure difference, clearance height, centricity and hydraulic oil viscosity of the hydraulic system are taken into account comprehensively. Combined with the simulation data, further analysis shows that pressure difference, clearance height, eccentricity and oil viscosity are the main influencing factors of leakage in the flow control valve. Among which the clearance height has the largest influence and the oil viscosity has the smallest influence.

Keywords

Hydraulic; Decoder; Flow Control; Valve Leakage; Amesim.

1. Introduction

Flow control valve is the main actuator of hydraulic decoder system, its performance directly affects the normal work and life of the whole hydraulic decoder. Leakage is widespread in the entire hydraulic system, and there are many reasons for leakage, mainly caused by the clearance and pressure difference, divided into internal leakage and external leakage. External leakage is easy to be observed, but internal leakage is difficult to be detected, and internal leakage has a high and hidden failure rate [1]. The author mainly studies the leakage fault in the flow control valve, takes the flow control valve working circuit of a hydraulic decoder as the research object, and establishes the simulation model of this circuit by using hydraulic mechanical system modeling, simulation and dynamic analysis software AMESim [2]. Furthermore, the batch operation function of AMESim was used to simulate and analyze the influence of various factors on the flow control valve.

2. Flow control valve leakage calculation

Leakage in flow control valves generally occurs in the fitting gap between the spool and the valve body, namely the annular gap leakage [3]. In annular gap sealing, the fluid Reynolds number is far less than the critical Reynolds number, and the flow state between the spool and the valve body is laminar flow [4]. There is a pressure difference between the two ends of the inner discharge gap, and the oil flows through the gap, resulting in pressure leakage.The second is shear flow. The two walls of the gap have relative motion, which makes the gap oil flow and causes shear leakage [5]. The leakage of hydraulic oil at crevasses can be equivalent to the concentric ring crevasses flow.

In the case of differential pressure flow only, the leakage amount is [6] :

$$Q = \frac{\pi d h^3}{12\mu l}\Delta p \tag{1}$$

In the formula， Q —— Leakage volume， m^3 /s

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d —— The valve core diameter， mm

h —— Spool body concentric side clearance height， mm

Δp —— Pressure difference between the two ends of the gap， Pa

μ—— Hydraulic fluid dynamic viscosity， Pa·s

l —— Cover the amount， mm

In the actual machining and assembly process, eccentricity exists, as shown in Figure 1.

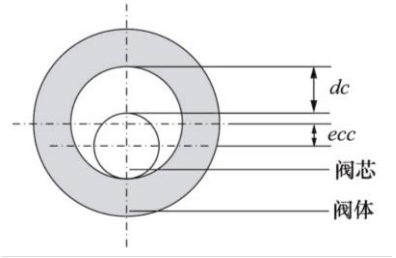

FIG 1 Eccentric diagram of slide valve

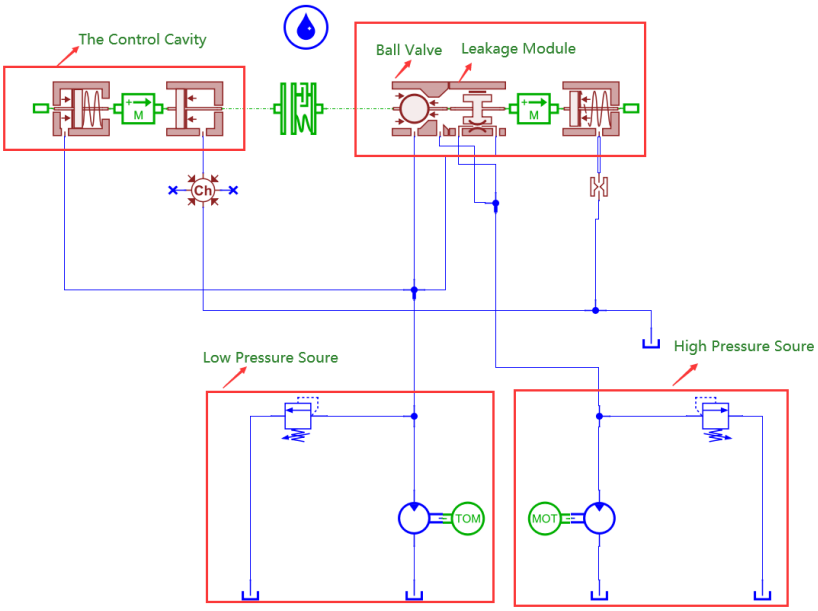

FIG 2 AMESim model of flow control valve

In figure 1, dc —— Clearance height on diameter of eccentric spool， mm

ecc —— eccentricity， mm

The eccentricity ratio is calculated as follows:

$$\varepsilon = \frac{ecc}{\frac{dc}{2}} \tag{2}$$

At this point, the leakage amount is [7]:

$$Q = \frac{\pi d h^3 \Delta p}{12 \mu l}(1 + 1.5\varepsilon^2) \tag{3}$$

In the formula,ε —— Eccentricity, dimensionless.

3. Modeling based on AMESim flow control valve

AMESim is France IMAGINE company research and development of hydraulic/mechanical system based on bond graph modeling, simulation and dynamic analysis software, covers the hydraulic, hydraulic pipe, hydraulic components, hydraulic resistance, mechanical design, start

the thermal fluid flow, control, cooling and power transmission, and other fields, with multi-disciplinary, multi-field system analysis standard environment [8].

The hydraulic system of the hydraulic decoder is all composed of flow control valves. In this study, the modeling of flow control valves is carried out through the mechanical library, hydraulic library, hydraulic component library and signal library in the AMESim software.

The simulation model of flow control valve AMESim is shown in Figure 2.

After the sketch model was built, sub-models of each component were set, BAP023 model was selected for ball valve, BAF01 model was selected for leakage module, other components were set as priority sub-models, and parameters of the model were then set. Set corresponding parameters according to the simulation requirements. The main parameters are shown in Table 1 below.

Tab 1 Para meters of flow control valve

High pressure pump rated capacity ($mL \cdot r^{-1}$)	1500
Rated speed of low pressure pump ($mL \cdot r^{-1}$)	1000
Initial setting pressure of high pressure relief valve (*MPa)*	3
Initial setting pressure of low pressure relief valve (*MPa)*	1
Control cavity piston diameter (mm)	14
Control the spring stiffness of cavity piston (N/mm)	300
Spring initial pressure (N)	100
Maximum displacement of piston rod (mm)	3
Ball valve spool diameter (mm)	8
Maximum displacement of ball valve (mm)	3

4. Analysis of simulation results of hydraulic decoder flow control valve

The simulation time was set as 5s, the simulation step length was set as 0.01s, and the leakage in the flow control valve belonged to differential pressure flow.

4.1. Influence of system pressure difference on internal leakage

In the initial state, high-pressure pump pressure is 3MPa, low-pressure pump pressure is 1MPa, and pressure difference is 2MPa. It is found that leakage is proportional to pressure difference, as shown in FIG. 3.

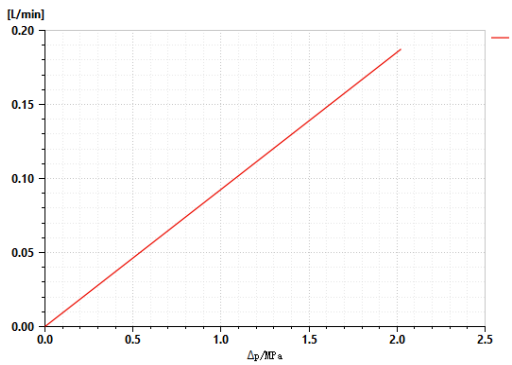

FIG 3 Leakage in flow control valve is proportional to pressure difference at both ends

The simulation results show that the flow rate at this time is 0.187 L/min, and the calculated Reynolds number is 57.71, which is far less than the critical Reynolds number of concentric annular gap of 1100, so the fluid flow state is laminar [9].

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Under the condition that other parameters remain unchanged, the high-pressure pump pressure is changed to make the pressure difference between the two ends of the flow control valve become 1MPa, 1.5mpa, 2MPa, 2.5mpa and 3mpa. The AMESim batch operation function is used to obtain the change curve of the leakage amount in the flow control valve under different pressure difference, as shown in Figure 4.

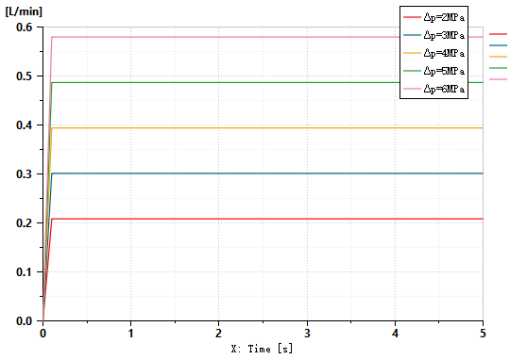

FIG 4 Internal leakage under different pressure differences

The analysis curve shows that the leakage in the flow control valve increases with the increase of the system pressure difference.The pressure difference changes from 2MPa to 6MPa, and the leakage rate is between 0.2L/min and 0.6L/min. It can be seen that the pressure difference has a certain influence on the leakage rate in the flow control valve.

4.2. Influence of eccentricity on internal leakage

Keeping other parameters unchanged, the eccentricity of the leak module was set to 0.02mm, 0.04mm, 0.06mm, 0.08mm and 0.1mm respectively. Then, the variation curve of internal leakage and eccentricity was obtained by running the simulation, as shown in Figure 5.

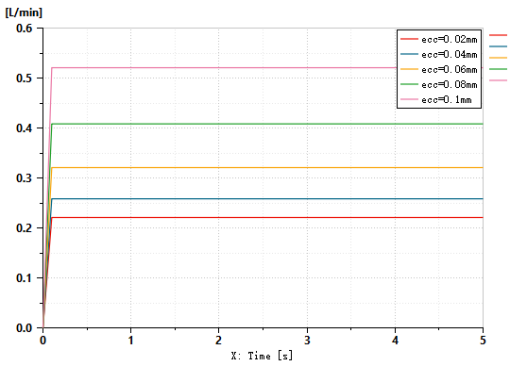

FIG 5 Internal leakage under different eccentricity

As shown in FIG. 5, as the eccentricity increases, the internal leakage also increases.The ecc of eccentricity varied from 0.02mm to 0.1mm, and the internal leakage ranged from 0.11L/min to 0.27L/min. Moreover, when the eccentricity is higher than 0.06mm, the internal leakage greatly increases. It can be seen that the eccentricity has a great influence on the leakage in the flow control valve, especially the large eccentricity.

4.3. Influence of clearance height on internal leakage

The initial value of the system remains unchanged. The clearance height of the leaking module is set to 5 batch operation quantities of 0mm, 0.05mm, 0.1mm, 0.15mm and 0.2mm, and then the simulation is carried out to obtain the change curve between the internal leakage and the clearance height, as shown in Figure 6.

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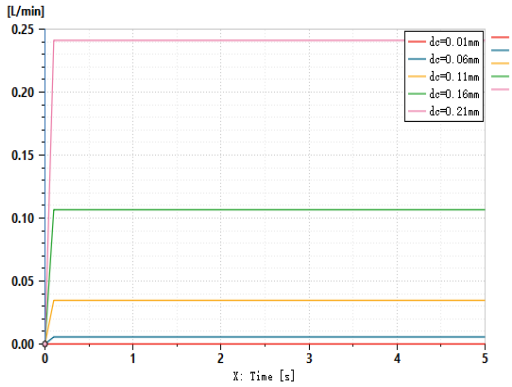

FIG 6 Internal leakage at different clearance heights

According to the curve analysis: with the increase of clearance height, the internal leakage of flow control valve also increases.When the clearance height increases from 0.01mm to 0.21mm, the leakage amount also increases from 0 L/min to 0.24 L/min. Especially when the clearance height is greater than 0.1mm, the leakage amount increases more obviously.

4.4. Influence of oil viscosity on internal leakage

Since the working location of the hydraulic decoder is below 3000 meters and the downhole temperature is about 100℃, the oil viscosity is respectively set as 0.031Pa·s, 0.051Pa·s, 0.071Pa·s, 0.091Pa·s and 0.111Pa·s, and the leakage curve in the flow control valve is shown in Figure 7.

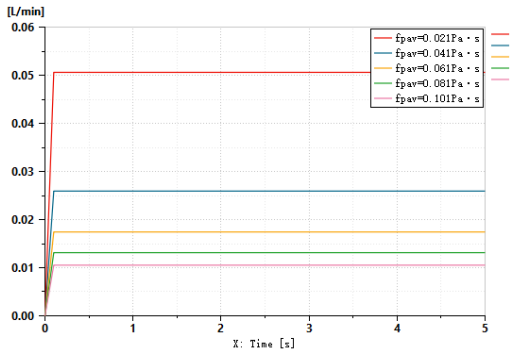

FIG 7 Internal leakage at different viscosities

As can be seen from the curve, the greater the oil viscosity, the smaller the internal leakage. When the viscosity of hydraulic oil varies between 0.021Pa·s-0.101Pa·s, the internal leakage is between 0.0.5L/min-0.01L/min. And when the oil viscosity is low at 0.041 Pa·s, the internal leakage increases significantly. It can be seen that the viscosity of hydraulic oil has a certain influence on the leakage in the flow control valve, but the influence is smaller than the pressure difference, eccentricity and clearance height.

5. Conclusion

(1) In this study, the flow control valve model established by AMESim can effectively simulate the internal leakage of the liquid-controlled one-way valve.

(2) Clearance height and eccentricity are the main factors affecting leakage in the liquid-controlled one-way valve, which provides a theoretical reference for the processing and selection of flow control valve.

(3) The pressure difference between the inlet and outlet of flow control valve and the viscosity of hydraulic oil also have a certain influence on internal leakage.The work of the passable fluid

control one-way valve is located below 3000 meters underground, and the viscosity of the hydraulic oil will change with the change of the environment, so this also provides a theoretical basis for the selection of hydraulic oil.

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