Simulation Study on the Design of Hydraulic Retarder Response Performance

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ABSTRACT

When the braking instruction given, the inlet control valve opens, and the oil flows into the retarder body chamber to generate braking torque. With the increase of the oil content in the chamber, the braking torque gradually increases to the required value and this is called the retarder response process. The effective response performance is affected by the working boundary of the retarder, which is the hydraulic import and export control mode and the structure of the retarder itself. In this paper, the design of hydraulic retarder response performance is studied by means of simulation.

INTRODUCTION

At present, hydraulic retarder is mainly used independently to slow down or brake the vehicle. The joint braking system of hydraulic retarder and mechanical brake is the future development direction from reducing the driving strength, improving the safety and reliability of the vehicle. Based on the characteristics of two braking modes, at the beginning stage of braking, namely at the high speed stage, the main braking power is borne by hydraulic retardation, and at the low speed stage, the main braking power is borne by mechanical braking. The brake torque of hydraulic retarder is established by filling the chamber with oil, so theoretically it needs a long response time than the brake. If the hydraulic retarder is made to bear the high-speed braking in the joint braking system, it is necessary that the hydraulic retarder has sufficient effective response speed. Therefore, it is

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important to improve the rapid response control technology of hydraulic retarder. The design of hydraulic retarder response performance is studied by means of simulation in this paper.

**ANALYSIS OF INFLUENCING FACTORS OF EFFECTIVE RESPONSE SPEED AND SELECTION OF DESIGN SCHEME**

When the braking instruction given, the inlet control valve opens, and the oil flows into the retarder body chamber to generate braking torque. With the increase of the dynamic oil content in the chamber of the retarder, the braking torque gradually increases to the required value and this is called the retarder response process. The effective response performance of hydraulic retarder is affected by the working boundary of the retarder, which is the hydraulic import and export control mode and the structure of the retarder itself. The influencing factors are generally ascertained according to the effective process of oil filling: oil supply mode, imported control valve form, the pump suction structure of the retarder body.

There are three types of hydraulic retarder oil supply modes: the oil pump supplying mode, the accumulator supplying mode and the pressure tank supplying mode. Oil supply from pressure tank is an ideal oil supply mode for retarder. It cannot only provide instantaneous large flow rate to meet the control requirements of rapid oil filling, but also can be used continuously for the oil quantity and pressure can be maintained within a certain range with directly returning oil from the outlet of the retarder to the pressure tank and the working of oil supply and gas supply system for the pressure tank.

The torque control of the retarder is generally focused on the outlet control. The requirements for the inlet valve of the retarder are: some "leakage amount" is allowed under the closed state, the opening process should be as fast as possible, and the overcurrent resistance should be as low as possible after opening. So butterfly valve is adopted as the inlet control valve in the retarder referenced in this paper for its light mass, small inertia, small opening resistance, fast opening speed, and the adaptability under larger diameter usage. The gap between the butterfly valve and the wall of the inlet oil channel can be designed to meet the proper "leakage amount" under the closed state to provide cooling and lubrication needs.

It is one of the key points of the retarder design that how to reduce the flow resistance of the oil filling to make the oil enter the chamber as soon as possible for required braking torque. In this paper, the oil inlet is arranged in the middle of the inner and outer ring of the torus, and the oil filling holes are placed on the rotor blades to use the centrifugal force. In order to further improve the suction characteristics of the rotor as a pump, a row of little blades are designed on the back of the rotor.
SIMULATION ANALYSIS OF THE INFLUENCING FACTORS

In this paper, the influencing factors such as pressure oil tank, inlet butterfly valve, oil channel type of body house, auxiliary pump suction blades on the back of the rotor, oil filling holes on the rotor blades and so on will be simulated and calculated successively to carry out the study of effective control design of the hydraulic retarder.

Pressure Oil Tank Impact Analysis

The pressure oil tank is analyzed in two aspects, one is the influence of pressure on oil supply speed, and the other is the influence of oil/gas ratio of pressure oil tank on pressure fluctuation.

THE PRESSURE IMPACT ANALYSIS OF THE PRESSURE OIL TANK

The pressure of the oil tank directly affects its oil supply capacity. The simulation calculation is conducted by CFX. The relationship between oil supply pressure and outlet flow rate is basically linear as shown in figure 1.

ANALYSIS OF THE INFLUENCE OF OIL/GAS RATIO OF OIL TANK ON PRESSURE FLUCTUATION

As the butterfly valve is opened, the instantaneous large flow of oil is discharged from oil tank to the retarder body, and it is much more than that of the oil and gas filling into the tank. The air in the tank expands instantaneously. Due to the compressibility of the air, it can continue to provide the oil supply pressure despite the decrease of the pressure. The oil/gas ratio affects the pressure fluctuation of the pressure tank. The oil supply pressure fluctuation curves of the pressure tank under different oil/gas ratios is shown in figure 2 through Matlab programming.
As shown in the curves above, the pressure of the oil tank drops sharply when the butterfly valve is opened, and then rises slowly. As the air content increases (the oil/gas ratio decreases), the pressure drop of the oil tank decreases. Increasing the air proportion can effectively improve the pressure maintenance capacity of the pressure oil tank and thus the oil supply capacity.

**Inlet Butterfly Valve Impact Analysis**

When the inlet butterfly valve opens, the outer profile of the butterfly valve will still have resistance to oil intake. In this paper, five types of butterfly valve modifications are proposed on the basis of the size of the valve installation space and the requirements of oil sealing effect, as shown in figure 3. In order to simplify the simulation analysis, the actual axle hole is omitted in the models. The data of the outlet flow is as shown in figure 4, the model of modification 2 has the maximum flow rate, namely the minimum flow resistance. Its outlet flow rate is 0.269 m³/s, which is 6.1% higher than the prototype’s flow rate of 0.253 m³/s.
Influent Analysis of the Oil Channel Forms of the Body House

According to the common form of the retarder body house, this paper puts forward two kinds of body house chamber structure, symmetrical type and asymmetrical type. The corresponding flow channel models are shown below. Under the same boundary conditions, the simulation results show that the flow rate of symmetric model is 0.27 m³/s and that of asymmetric model is 0.28 m³/s. The overall flow resistance of the asymmetric structure is slightly less than that of the symmetric structure.

Influent Analysis of the Auxiliary Blades on the Back of the Rotor

The three-dimensional models of the rotor are established based on different auxiliary blades angles and the simulation calculation is conducted. According to the simulation results, the relationship between the blades angle and the outlet flow is shown in figure 6 below. As shown in the figure, when the blades angle is designed in the range of 30° to 45°, the outlet flow only has little changes. While the blade angle exceeds 50°, the outlet flow encounters sharp declines. The reason may be that the excessive blade inclination angle causes great resistance to the oil flow, so it bad for the pumping performance. Simulation results show that the blade angle values can be controlled between 30° to 45° to provide fine pumping performance.
Influent Analysis of the Oil Filling Holes on the Rotor Blades

The basic form of flow channel of the oil filling holes on the rotor blades are shown in figure 7. Each group of oil channel consists of two parallel oil holes that are inclined along the blade inclination angle and inclined in the radial direction at a certain angle. From the basic form of oil passage, two oil passage holes are connected to form an overall long oil channel. The modified 3d model is shown in figure 8.

The simulation results of the two structural models under the same boundary conditions show that the outlet flow of the basic form is 0.307 m³/s, while that of the modified form is 0.364 m³/s. Under the same conditions, the outlet flow of the modified form is increased by 18.4% and the pump suction effect was improved significantly.

CONCLUSIONS

In this paper, all the influencing factors on the hydraulic retarder response performance are analyzed. From the parameters of the pressure oil tank to the inlet control valve forms, and then the structure of the retarder body with oil channel forms of the body house, the auxiliary blades angles on the back of the rotor and the oil filling holes forms on the rotor blades included. The simulation calculation results and the analysis in this paper lay the foundation of rapid response design by revealing the effect laws of all the influencing factors with the pressure and the
air/oil ratio of the oil tank, the forms and parameters of the inlet butterfly valve, the forms of the body house oil channel, the auxiliary blades angle on the back of the rotor and the forms of the oil filling holes on the rotor blades.

REFERENCES