Design of steering hydraulic system for shotcreting trolley

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Abstract

Hydraulic steering system has many advantages, such as high power density ratio, flexible layout and so on. It is widely used in engineering machinery. This paper presents a load sensing hydraulic steering technology, which has the advantages of accurate and stable steering control performance signal. According to its work needs, the principle diagram of the steering hydraulic system is constructed, the mathematical model is established, and the feasibility of the system is analyzed.

Keywords

Hydraulic system steering, Load sensing technology.

1. Introduction

Vehicle steering systems are mainly mechanical steering, hydraulic power steering, electronic power steering and full hydraulic system steering. Full hydraulic steering has the advantages of high power density ratio, flexible layout, etc. It is widely used in engineering vehicles. In this paper, a load sensing hydraulic steering technology is proposed, which has the advantages of accurate and stable steering of control performance signal, and solves the shortcomings of slow and unstable steering of traditional hydraulic steering system.

2. Steering hydraulic system design

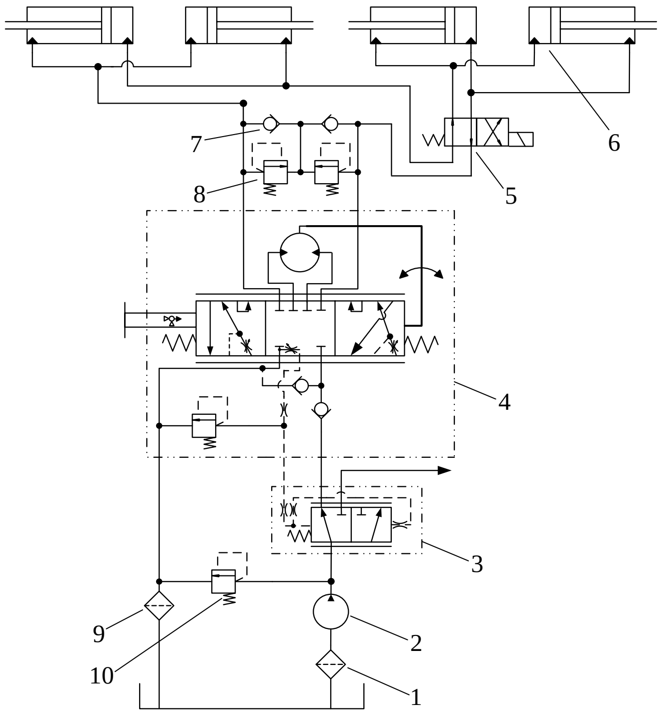
The basic steering principle of the full hydraulic steering system [1] is that the angular displacement of the wheel steering valve core is proportional to the displacement of the piston rod of the steering cylinder,the steering cycloid motor in the steering gear enables the volume of hydraulic oil flowing into the steering cylinder to establish a quantitative functional relationship with the angular displacement of the valve sleeve in the steering gear and the opening degree of the oil distribution port is determined by the relative displacement of the valve sleeve. The faster the operator rotates the steering wheel, the greater the opening of the oil distribution port and the greater the relative angular displacement. When the operator stops turning the steering wheel, the relative angular displacement of the valve sleeve becomes zero, and the oil distribution port closes automatically to realize the feedback control of the steering system. The priority valve in the system is a constant differential pressure reducing valve, which can keep the pressure difference constant on both sides of the throttle orifice of the hydraulic steering gear regardless of the change of the steering pressure and the pressure oil flow provided by the steering pump. Therefore, the flow through the steering gear is equal to the product of the steering gear's self displacement and the steering wheel rotation speed.

In order to reduce the steering radius and enlarge the range of wet spraying trolley, the trolley adopts four-wheel full hydraulic steering, the steering system adopts load sensing technology, and the principle of the four-wheel full hydraulic steering system is shown in Figure 2-1. This type of full hydraulic steering system has the following advantages:

(1) The control performance is good, and the steering is fast, accurate and stable. The use of electromagnetic reversing valve 5 can facilitate the switch between the four wheel steering and crab steering.

(2) When the wheel is steering, the system can automatically compensate for the change of steering load pressure.

(3) Priority valve can ensure that almost all of the system flow into other auxiliary working system when the wheel is not turning, reduce the energy loss of steering system and power loss.



1- Oil absorption filter 2- Steering pump 3- Priority valve 4- Steering gear 5- reversing valve 6- Steering cylinder 7- Check Valve 8- regulating valve 9- Oil return filter 10- Safety valve

Fig. 2-1 Steering hydraulic system principle

3. Mathematical model of steering hydraulic system

According to the principle diagram of the steering hydraulic system and referring to reference [2], it is simplified into the hydraulic oil circuit diagram as shown in Figure 2-1.

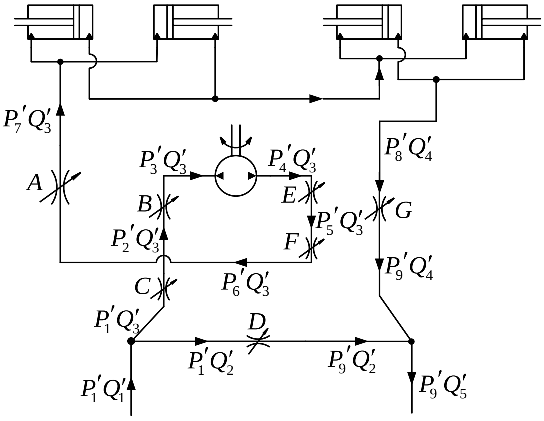


Fig. 3-1 Steering hydraulic system schematic

According to the continuous flow theorem of hydraulic system, it is known that the hydraulic oil flow Q_3' into the steering cylinder is:

$$Q_3' = \left(A_a + A_b\right)\left(\frac{dy}{dt} + \frac{y}{E}\frac{dP_7'}{dt}\right) \tag{3-1}$$

Where : A_a ——Steering cylinder has cavity area, m^2 ;

A_b ——Steering cylinder non rod cavity area, m^2 ;

y ——Displacement of steering cylinder piston rod, m ;

t ——Movement time of steering cylinder piston, s ;

E ——Elastic modulus of hydraulic oil, MPa;

P'_7 ——Oil inlet pressure, MPa;

Outflow of steering cylinder Q'_4 is:

$$Q_4' = \left(A_a + A_b\right)\left(\frac{dy}{dt} - \frac{L-y}{E}\frac{dP_8'}{dt}\right) \tag{3-2}$$

Where :

L ——Stroke of single steering cylinder, m ;

P'_8 ——Oil return pressure, MPa.

The force balance equation of steering cylinder piston is:

$$\left(P_7' - P_8'\right)\left(A_a + A_b\right) = 2M_p\frac{d^2y}{dt^2} + 2R_p\frac{dy}{dt} + F_{max} \tag{3-3}$$

Where :

M_p ——Equivalent quality of piston rod and piston, kg ;

R_p ——Damping coefficient, $N \cdot s / m$;

$F_{\max}$ ——Maximum steering resistance of single turn steering wheel, N;

The flow equation that flows through each orifice can be sorted out:

$$P_1' = P_7' + \left(\frac{Q_3'}{C_d}\right)^2\frac{\rho}{2}\left(\frac{1}{A_1^2} + \frac{1}{B_1^2} + \frac{1}{C_1^2} + \frac{1}{E_1^2} + \frac{1}{F_1^2}\right) + \frac{1}{D_m}\left(J_m\frac{d^2\theta_m}{dt^2} + B_m\frac{d\theta_m}{dt} - G\theta + M_F\right) \tag{3-4}$$

$$Q_3' = Q_1' - C_d D_1\sqrt{\frac{2}{\rho}\left(P_1' - P_9'\right)} \tag{3-5}$$

Where :

Q'_1 ——Constant flow after constant current valve, m^3 / s ;

Q'_3 ——Flow through the throttle hole C, B, E, F, A and into the steering cylinder, m^3 / s ;

ρ ——Hydraulic oil density, kg / m^3;

A_1, B_1, C_1, D_1, E_1, F_1 are the area of orificeA,B,C,D,E,F respectively, m^2 ;

D_m ——Theoretical radian displacement of motor, cm^3 / rad ;

J_m ——Rotational inertia of motor rotor, connecting shaft and axle sleeve , $N \cdot m^2 \cdot s$;

θ_m ——Motor rotor angle, rad ;

θ ——Relative rotation angle of valve core and valve sleeve, rad ;

B_m ——Viscous damping coefficient, $m \cdot N \cdot s$;

G ——The torque stiffness of the spool and valve sleeve in the steering gear is reset, $N \cdot m / rad$;

M_F ——Motor constant resistance moment, N / m;

C_d ——Flow coefficient of steering hydraulic throttle orifice;

P'_1 ——System inlet pressure, MPa;

P'_9 ——System oil return pressure, MPa;

The mathematical model of steering hydraulic system can be expressed by connecting the above (3-1) ~ (3-5) formula.

4. Conclusion

In this paper, a load sensing hydraulic steering technology is presented. By simplifying the four-wheel steering hydraulic system, the mathematical model of the four-wheel steering hydraulic system is deduced. The mathematical model can better describe their internal structural characteristics and dynamic characteristics of the system, so that the system can meet the ideal movement requirements for the future actual hydraulic system. It provides a theoretical reference for the establishment and performance analysis.

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