

Design and Analysis of Hydraulic Chassis with Obstacle Avoidance Function

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Abstract. This article mainly expounds the design of hydraulic system for the hydraulic chassis with obstacle avoidance function. Including the selection of hydraulic motor wheels, hydraulic pump, digital hydraulic cylinder and the matching of engine power. And briefly introduces the principle of obstacle avoidance.

1. Introduction

Modern walking machinery mainly adopts four ways of transmission, Including the traditional pure mechanical transmission, electric drive, hydrodynamic drive and Hydraulic transmission. Chassis as the core part of the walking machinery, the selection and combination of the drive is particularly important. Most of the existing chassis can only achieve the vehicle walking function. In actual work, often have to face different road conditions. When some uneven surface road, may encounter some rocks and obstacles, such as nails, easy to cause damage to the tire, and even have significant impact to burst or rollover. So the design of a wheel track adjustable chassis can effectively reduce the incidence of accidents.

The traditional pure mechanical transmission is difficult to realize the driving, steering and expansion function of the wheel at the same time. Hydraulic transmission belongs to the field of fluid power transmission, drive arrangement the advantages of flexible and can be stepless speed regulation^[1], Used to the hydraulic cylinder and hydraulic motor can well realize the chassis of the drive and obstacle avoidance, and other functions.

2. General structure design of hydraulic drive chassis

Hydraulic drive chassis includes engine, variable hydraulic pump, fuel tank, digital hydraulic cylinder, hydraulic motor, manual valve and other components. Hydraulic system drive as shown in figure 1. Engine connected to the variable hydraulic pump by belt transmission, drive hydraulic pump draws oil from the fuel tank, can convert mechanical energy into pressure. The hydraulic pump provides power for two digital cylinders and the two hydraulic motors by tubing. By controlling three position four-way directional control valve manually walking three working position to realize mechanical forward backward and parking. A sensor is arranged at the front end of the wheel, and the left and right expansion of the digital hydraulic cylinder is adjusted by the pulse signal which is fed back by the sensor, and the left and right movement of the driving wheel is realized. So as to avoid the direct contact between the walking machine and the obstacle, and can effectively reduce the failure rate of the vehicle. At the same time equipped with a relief valve with the function of overload protection and hydraulic auxiliary components such as filter, cooler, guarantee the normal work of the system^[2]. Hydraulic system structure diagram as shown in figure 2.



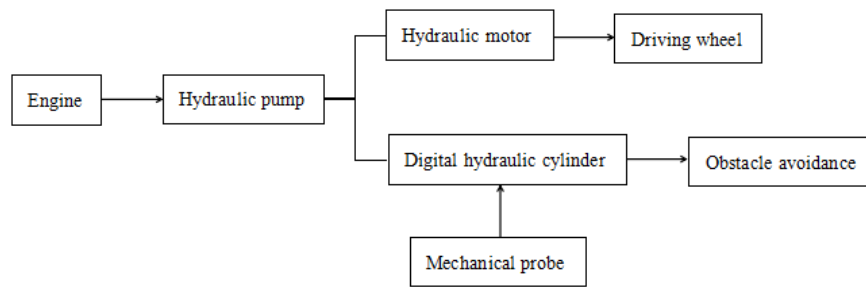


Figure 1. Schematic diagram of hydraulic system drive.

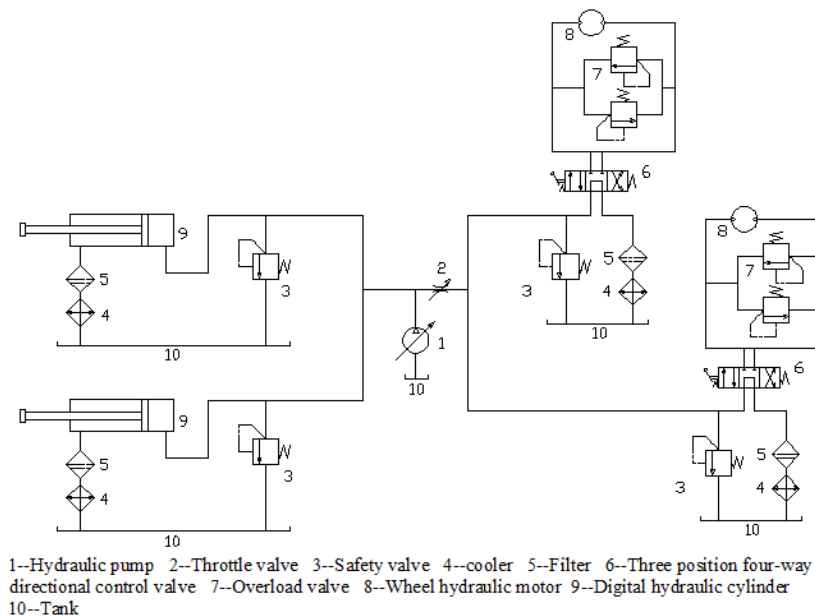


Figure 2. Hydraulic system.

3. Main hydraulic components^[3]

3.1 Hydraulic motor

Hydraulic motor as the implementation of components, the direct drive wheel rotation, to drive the machinery. Hydraulic motor type and the choice of relevant parameters directly affect the efficiency of the walking machine, The design of hydraulic chassis is mainly guarantee walking machine can adapt to all kinds of road conditions, In areas where the road is more complex, a hydraulic motor is required to provide a greater torque to accommodate the ascent and mud, At the same time, the two driving wheels of the walking machine to achieve obstacle avoidance function, must ensure that its independence, so the two wheels driven by hydraulic motor respectively.

Common low speed high torque hydraulic motor mainly include vane hydraulic motor and radial piston hydraulic motor, the vane hydraulic motor can keep stable in the process of low speed rotation speed, suitable for low voltage system, but the leakage is more serious, is not conducive to the harsh environment conditions. Radial piston hydraulic motor has the advantages of high volumetric efficiency, large starting torque and stronger adaptability^[4].

In order to ensure the normal running of the walking machine, it is necessary to meet the requirement of traction. If the maximum climbing angle is α , the maximum tangential traction:

$$F_{\max} = (f + \sin\alpha + a)m_t g \quad (1)$$

In the formula: F_{\max} is the most effective traction(N); f is the coefficient of rolling resistance; α is the acceleration resistance conversion factor; m_t is the full load mass of walking machine(kg); g is the gravitational acceleration.

According to the requirement of the maximum traction force of the walking machine, the torque that the motor needs to be supplied is:

$$M_{\max}=F_{\max}r_1/\eta_{mm} \quad (2)$$

In the formula: r_1 is the driving wheel radius of walking machine(m); η_{mm} is the mechanical efficiency of hydraulic drive motor.

Hydraulic motor displacement:

$$q_m=M_{\max}Z_q/(159\Delta p_m i_j Z_L \eta_{mm} \eta_{jt}) \quad (3)$$

In the formula: Z_q is the number of drive wheels per hydraulic motor drive; Δp_m is the hydraulic motor inlet and outlet pressure difference(MPa); i_j is the mechanical transmission ratio between the hydraulic motor and the actual wheel driven by motor; Z_L is the number of driving wheel; η_{jt} is the total transmission efficiency between the output shaft of the hydraulic motor and the drive wheel.

According to the motor displacement, determine the minimum size of the hydraulic motor to meet the mechanical requirements, Considering the load characteristics of the walking machine, the internal curve hydraulic motor can be selected(Part of the motor parameters such as table 1), facilitate directly installed on the driven wheel. It has the advantages of small size, light weight, reliable operation, large speed range, etc.. It has been widely used in mines, ships, cranes and other large walking equipment, and it has strong adaptability to environment change.

Table 1. QJM type hydraulic motor.

Type	Theoretical displacement	Rated pressure	Peak pressure	Speed range	Rated torque	maximum power
	ml/r	MPa	MPa	r/min	N.m	KW
1QJM02-0.4Z	0.406	10	16	5-320	483	13
1QJM12-1.25Z	1.33	10	16	4-160	1968	25
1QJM21-1.6Z	1.65	10	16	2-100	2442	25
1QJM32-3.2Z	3.3	10	16	1-125	4884	62
1QJM52-6.3Z	6.36	10	16	1-125	9413	120

3.2. Variable hydraulic pump

Variable hydraulic pump as a power component plays an important role in the hydraulic system. Driven by the engine, drain the oil from the fuel tank, can convert mechanical energy into hydraulic pressure, provide power for hydraulic motors and digital hydraulic cylinders^[5]. And variable hydraulic pump can control the output power of the hydraulic motor by adjusting the swashplate opening.

There are three common types of hydraulic pumps, gear, vane and piston type. Gear pump has the characteristics of small size and simple structure. However, due to the imbalance of the pump shaft force, easy to wear. The vane pump is running smoothly, but it is difficult to adapt to the high pressure working conditions. Therefore, it is possible to use the axial piston variable pump with high volumetric efficiency and small leakage to improve the working efficiency of the walking machine.

According to the different condition of speed and total displacement calculation, a set of corresponding maximum main circuit flow value can be obtained:

$$Q_{\max}=1000V_{\max}\sum q_{md}/(120\pi r_{10}\eta_{vm}\eta_{\delta}) \quad (4)$$

In the formula: V_{\max} is the maximum travel speed of walking machine(km/h); $\sum q_{md}$ is the Total displacement of hydraulic motor(L/r); η_{vm} is the Volumetric efficiency of hydraulic motor; η_{δ} is the driving efficiency of driving wheel at maximum speed in no-load condition.

The displacement of the hydraulic pump is estimated based on the maximum displacement of the main circuit:

$$q_{p\max}=1000Q_{\max}/(n_{p\max}\eta_{vp}) \quad (5)$$

In the formula: $n_{p\max}$ is the actual maximum speed of hydraulic pump(r/min), The hydraulic pump is usually connected with the engine through a belt drive, and its maximum speed is determined by the rated speed of the engine and the transmission ratio between them; η_{vp} is the volumetric efficiency of hydraulic pump.

According to the hydraulic pump displacement, select the appropriate axial piston variable pump(As shown in Table 2). Due to its high pressure, compact structure and convenient flow control, etc, has been widely used in engineering machinery such as need to high pressure, large flow, high power applications.

Table 2. Axial piston variable displacement pump.

Type	Nominal	Nominal	Theoretical flow		Maximum	Maximum
	pressure	displacement	L/min		power	torque
	MPa	ml/r	1000r/min	1500r/min	KW	N.m
2.5YCY14-1B	31.5	2.5	2.5	3.75	1.43	17.5
10YCY14-1B	31.5	10	10	15	5.7	54.6
25YCY14-1B	31.5	25	25	37.5	14.1	134.9
40YCY14-1B	31.5	40	40	60	22.6	201.5
63YCY14-1B	31.5	63	63	94.5	35.6	339.9

3.3 Digital hydraulic cylinder

Digital hydraulic cylinder is by controlling the stepper motor, the use of digital pulse signal to complete the length of the vector control. Digital hydraulic cylinder movement characteristics of the fully digital, can be directly by controlling the frequency and number of electrical pulses to achieve control the hydraulic cylinder piston rod movement speed and stroke. It has the advantages of high control precision, simple operation, convenient maintenance, etc.^[6].

4. Obstacle avoidance principle

The walking machine is driven by hydraulic pressure, and the function of obstacle avoidance is achieved by controlling the expansion of the piston rod of the digital hydraulic cylinder. Respectively, in the front of the two drive wheel to install a mechanical probe, the end of the mechanical probe is equipped with an angle sensor, By measuring the deflection angle of the probe α , and using formula:

$$d=rsin\alpha \quad (6)$$

In the formula: r is the probe rod length. The offset distance of the probe rod d is the displacement of the driving wheel. First shift the distance into a digital pulse signal, by controlling the number of electrical pulses to control the number of digital hydraulic cylinder piston rod expansion and contraction, to achieve the hydraulic walking machine obstacle avoidance function. The working

principle of the probe is shown in figure 3.

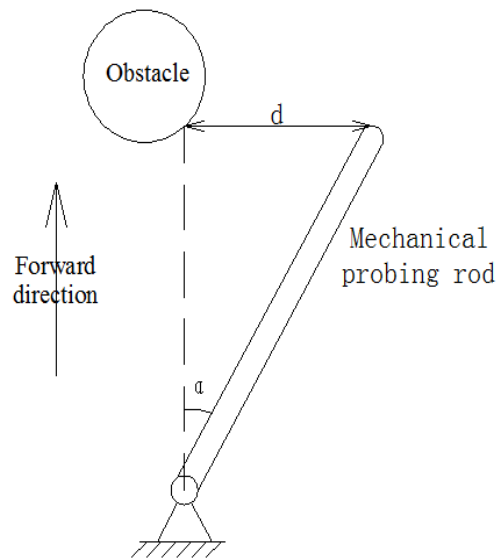


Figure 3. Mechanical probing rod.

5. Concluding remarks

The application of hydraulic drive to the obstacle avoidance function of walking machinery, you can use its low-speed high torque and high degree of digital, etc., to ensure that walking machinery can adapt to complex and changeable environment and better achieve obstacle avoidance function.

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