Design and analysis of the leveling hydraulic system of the combine harvester

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Abstract: The grain combine harvester is a large and complex agricultural machine, and the transmission system is an important part of the combine harvester. The effect of the transmission system has a significant impact on the performance of the combine harvester. Hydraulic systems play an increasingly important role in harvester drive systems. The body leveling hydraulic system generally has overflow loss and heavy throttling loss leading to hydraulic energy loss. There is a power mismatch between the power source and the load, and the power mismatch causes the energy loss problem. At present, there is less research on the leveling of harvesting locomotives in China. In this paper, reasonable power matching is carried out for the components of the grain combine harvester body, and the hydraulic drive scheme of the functional module that meets the requirements is designed. The parameters of the hydraulic system are optimized by AMESim simulation software, and the subsequent combine harvester drive system design provides a reference.

1. Introduction

In the mountainous and hilly areas of the northwest, due to the complex topography, the harvesting machine is affected by the unevenness of the ground during field operations, coupled with the real-time changes in the car body's own feeding volume, granary quality, header attitude, and drum speed[1]. The centroid changes, which leads to the real-time change of the oil and gas suspension cylinder load[2]. The harvester is prone to rollover phenomenon. The rollover reduces the efficiency, reliability and safety of the harvester, causing major economic losses such as casualties[3]. We design a set the hydraulic system for automatic leveling of the combine harvester body is very necessary[4].

![Figure 1 Oil and gas suspension structure layout](image_url)
In this paper, we designed a concrete combiner that can be automatically leveled by the vehicle body. The connected oil and gas suspension system is adopted. The layout of the oil and gas suspension structure is shown in Figure 1. In terms of anti-rollover performance, the combined oil and gas suspension can significantly improve the anti-rollover performance of the vehicle, reduce the roll angle generated when the vehicle turns, make the vehicle more stable, and the hydraulic system is simple. We designed a hydraulic system for the automatic leveling of the combine harvester body to use a connected oil and gas suspension system.

2. Working principle and design of the car body leveling hydraulic system

2.1 Working principle of the car body leveling hydraulic system

In view of the huge difference in load bearing between the front and rear axles of the harvester, when the left and right leveling is leveled, the one-sided hydraulic cylinder cannot be lifted synchronously. The reason for the analysis is that the flow control is not carried out on the oil inlet path of the suspension cylinder, so that the suspension cylinder is entered. The flow rate is different. We can install the flow control valve on the oil inlet to ensure the same flow at both ends. Second, we can't eliminate the influence of the accumulator on the load and discharge caused by the load change. For this, due to the suspension of the oil and gas During the flat process, the load of each hydraulic cylinder is different, then the accumulator can only be cut off during the leveling, that is, the accumulator is first cut off during the raising process, and the suspension is extended by the control of the flow valve, because there is no energy storage. The influence of the device can be controlled by the flow valve to simultaneously raise and lower the suspension cylinder on one side. However, after the leveling, due to the difference between the pressure in the accumulator and the pressure in the oil circuit, when the accumulator is reconnected, the hydraulic cylinder changes rapidly due to the large difference in pressure, causing the hydraulic cylinder to shake. In this paper, a pressure tracking valve is installed in the hydraulic control system. When the accumulator is cut off, the pressure in the accumulator is always kept the same as the pressure in the oil circuit during the leveling process.

The grain combine harvester designed in this paper uses a hydraulic cylinder base mounted on both the frame and the axle. The innovative non-rigid connection of the traditional harvester is adopted, and the hydraulic suspension cylinder is used to connect the frame and the axle. The hydraulic cylinder of the oil and gas suspension not only has the effect of adjusting the posture of the vehicle body, but also the effect of damping the oil body in the flow process due to the small oil port inside the hydraulic cylinder of the oil and gas suspension. The connection between the frame and the axle is shown in Figure 2.

![Figure 2. Frame and Axle](image)

1-Workshop, 2-Hydraulic Cylinder, 3-Hydraulic Suspension

2.2 Design of car body leveling hydraulic system

2.2.1 Selection and calculation of components for car body leveling hydraulic system

According to the overall layout of our harvester, the full load of the harvester is around 14 tons! The front axle bears 10 tons when the harvester is fully loaded, and the rear axle has a load of 4 tons when
the harvester is fully loaded. At the same time, the working pressure of the harvester hydraulic cylinder is 7-16Mpa, because the harvester is tilted and leveled, in the extreme position. When all the weights are concentrated on one hydraulic cylinder, it is assumed that all the weights are vertically pressed onto a single hydraulic cylinder. According to the same, the inner diameter of the harvester hydraulic cylinder is 105mm. According to the data provided by Xinhua Hydraulic Company, we select the inner diameter of the hydraulic cylinder to be 110mm. When the hydraulic cylinder is in the neutral position, the hinge center distance is 833 mm. The hydraulic cylinder structure diagram and parameters are shown in figure 3.

![Figure 3 Hydraulic cylinder structure and parameters](image)

2.2.2 Design of hydraulic control system for car body leveling

According to the functional requirements, this paper draws the hydraulic system control of the header as shown in figure 4:

![Figure 4. Constant flow system for connected hydro-pneumatic suspension](image)

1, 2-filters 2, 13, 2-way valve 3, 4-hydraulic cylinder 5, 7, 18-two-position two-way electromagnetic reversing valve 6, 8-energy device 9, 10 - two four-way electromagnetic reversing ball valve 11, 12-pressure tracking valve 14, 16-three four-way electromagnetic reversing valve 15, 17-speed control valve

The hydraulic principle of the whole system is: firstly close the solenoid valves 5, 7, cut off the accumulator and the suspension cylinder, and simultaneously open the solenoid valves 9, 10, 14, 16 and the high-pressure oil pushes the suspension cylinder to rise, passing the speed control valve The control of 15, 17 makes the flow rate into the single-side suspension cylinder the same, then the suspension cylinder on one side is extended synchronously, so that the side of the harvester is synchronously raised, and the solenoid valves 9, 10 are opened during the raising process. By engaging the pressure tracking valves 11, 12, the pressure in the accumulator can always follow the pressure in the suspension cylinder, the pressure in the accumulator is the same as the pressure in the suspension cylinder. When it is raised into position, the solenoid valves 9, 10, 14, 16 lose power and the solenoid valves 5, 7 are energized, the high pressure port is closed, and the accumulator is connected to the system. At this time, the pressure in the accumulator and the suspension cylinder are
inside. The pressure is equal, and smooth switching can be achieved to ensure the stability of the whole vehicle.

The working principle of the common hydraulic control check valve in figure 4 is: when the hydraulic control port has the control oil pressure, the pressure oil pushes the piston, and then pushes the poppet valve spool to open, so that the oil P1 to P2 and P1P2 are connected, when the liquid oil pressure of the oil control port K is zero, the function of the normal check valve is the same, the oil P1 to P2 are connected, and the P1P2 is not connected. 2Car body leveling hydraulic system AMESim modeling.

AMESim is a software from France's IMAGINE for simulation analysis of fluid power, mechanical, thermal fluids and control systems. AMESim uses a graphical model based on physical models to provide users with a rich library of component applications. Modeling in AMESim can directly select the model of the component from the AMESim component library, or use the model in the HCD library to build the components you need [5].

In this paper, the hydraulic system piping is assumed to be rigid, and the length of the pipeline is not considered [6]. The simulation model of the vehicle body leveling hydraulic system established in the AMESim environment according to the above-mentioned car body leveling hydraulic system principle is shown in figure 5.

![Figure 5. Simulation model of vehicle body leveling hydraulic system](image)

When the grain combine harvester is leveling the car, the working conditions that need to be leveled mainly include slopes, brakes, and sharp turns. The eccentric load of the harvester is mainly caused by the offset of the position of the center of gravity of the harvester. The AMESim simulation verifies the correctness of the leveling hydraulic system by simulating the two working conditions of the model, observing the pressure of the hydraulic cylinder and the eccentric load of the hydraulic cylinder. The pressure and displacement of the hydraulic cylinder of the combine harvester during the load change are shown in figure 6. The pressure and displacement of the hydraulic cylinder of the combine harvester when the eccentric load changes are shown in figure 7.
As shown in figure 6 and figure 7, during the change of the load and the eccentric load, it can be seen that the displacement values of the four support points under the two working conditions are basically the same, and there is no "virtual leg" phenomenon; the eccentric load condition the pressure of the lower four support points is also equal, and there is no "virtual leg" phenomenon at four points. The simulation results prove that the hydraulic system of the grain combine harvester designed in this paper can meet the requirements of the car body leveling in the actual working process.

### 3. Conclusions

1. In this paper, the hydraulic system of the combine harvester body is designed, and the hydraulic system is proved to be reliable through simulation and actual work. It provides a reference for the hydraulic design of the similar combine harvester.

2. This paper simulates and analyzes the combined harvesting vehicle body leveling system through AMESim. Through simulation analysis, it can reflect the motion characteristics of the car body leveling more intuitively. Using AMESim software to study the pump speed change to the car body leveling cylinder the effects of telescopic efficiency and motion stability provide a reference for the hydraulic system design of other related models.

3. This chapter determines that the hydraulic control system of the oil and gas suspension adopts the connected oil and gas suspension hydraulic control system, which controls the single cylinder compared with the traditional single valve, and the anti-rollover effect is better. In the case of analyzing the difference of the bearing load of the traditional harvester before and after the traditional connected oil and gas suspension is insufficient, the hydraulic control system of the connected oil and gas suspension based on the speed regulating valve and the pressure tracking valve is proposed.

4. The simulation results prove that the design of the leveling hydraulic system of the harvester body meets the actual working conditions.
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