Innovative Design of Hydraulic Drive and Intelligent Control System for Corn Harvesters

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Abstract. This study addresses the issues of high failure rates and high impurity levels in traditional corn harvesters by proposing an improved solution based on hydraulic principles. Through theoretical analysis and computer technology, a hydraulic drive system and intelligent control system were designed to enhance the stability, reliability, and operational efficiency of corn harvesters. The research selected a closed hydraulic circuit and optimized the design for header speed, feed rate monitoring, concave screen gap adjustment, and threshing drum speed. The results indicate that the improved system effectively reduces failure rates, increases harvesting efficiency, and improves grain integrity. This study provides an efficient and reliable corn harvesting technology solution for agricultural production, demonstrating practical application value.

Keywords: corn harvester; hydraulic improvement; intelligence; operational efficiency

1 Introduction

The performance of corn harvesters significantly impacts agricultural productivity and farmers' economic benefits. Traditional models face design flaws, such as high failure rates and impurity levels, leading to efficiency losses and economic drawbacks for farmers [1]. Hence, enhancing the stability and reliability of corn harvesters is crucial for improving harvesting efficiency and reducing costs [2].

The demand for intelligent and automated corn harvesters is rising globally. Companies like Kubota and Iseki have introduced automated models featuring high-precision sensors and intelligent control systems. Although domestic research has made strides in automation and intelligent control, disparities remain in the application of hydraulic technology for corn harvesters. Foreign research is often more advanced but less adaptable, while domestic studies are more attuned to local agricultural needs [3].

As automation levels increase, the reliability and energy efficiency of harvesters have become more critical. Hydraulic transmission systems offer advantages over mechanical systems and are receiving extensive study. Researchers, such as Y Kan et al., have developed innovative hydraulic transmission systems, like a power return system with a capacity adjustment device, maintaining low speed and high torque to enhance transmission efficiency (As shown in Figure 1) [4].

2 Hydraulic Drive Scheme for Corn Harvester

2.1 Selection of Hydraulic System Circuit

The closed circuit (Figure 2) is compact in structure, with the oil circulating in the pipeline and equipped with a replenishing pump to compensate for oil loss. It has high transmission efficiency. Closed circuits are typically suitable for complex hydraulic systems, ensuring system pressure stability and improving work efficiency. The open circuit (Figure 3) is relatively simple and flexible compared to the closed system, but it requires a larger oil tank and the oil is more prone to contamination, resulting in lower transmission efficiency. It is suitable for systems with lower control precision requirements. Considering the working conditions of the corn harvester, the closed circuit is more suitable for the hydraulic system of the corn harvester [5].

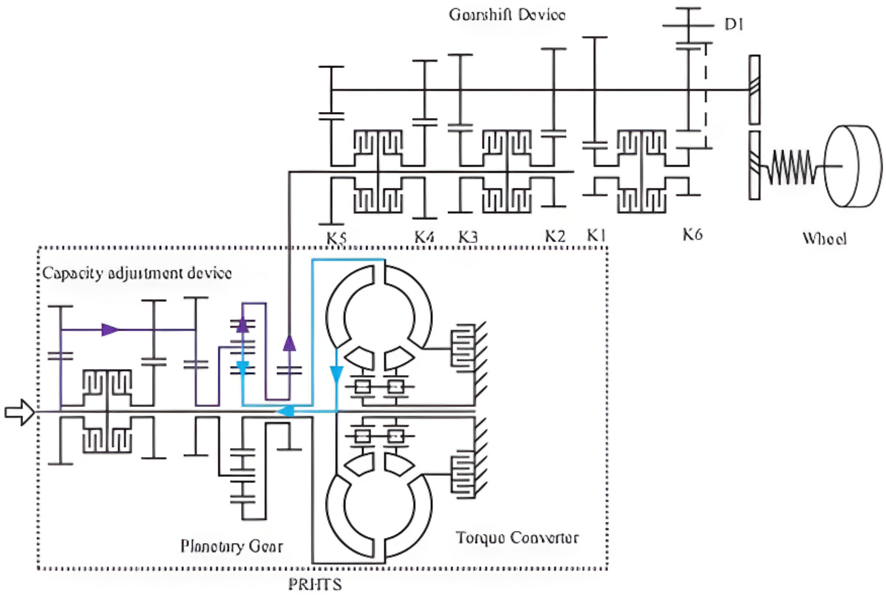

Fig. 1. Power reflux hydraulic transmission system studied by Yingzhe Kan et al.

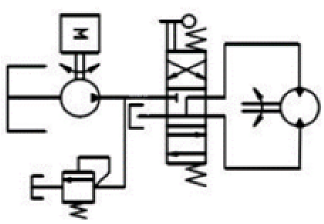

Fig. 2. Closed Circuit Diagram.

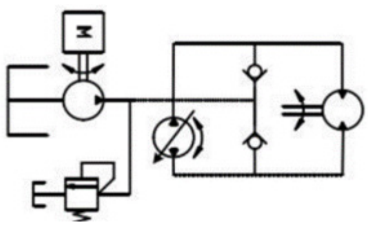

Fig. 3. Open Circuit.

2.2 Speed Regulation Methods

There are three main methods of speed regulation: volumetric speed regulation, throttle speed regulation, and volumetric-throttle speed regulation. This paper selects volumetric speed regulation. Volumetric speed regulation does not have throttling losses or overflow losses, resulting in high circuit efficiency and low system temperature rise. It is suitable for high-speed, high-power speed regulation systems and is widely used in high-power hydraulic systems such as bulldozers, slotting machines, and broaching machines.

2.3 Travel System Design

This section studies the design of the hydraulic travel system of the corn harvester, focusing on achieving stepless speed drive. The system consists of a hydraulic pump, hydraulic valve, hydraulic cylinder, and mechanical transmission part, directly operated by a controller to optimize power distribution. A closed circuit design is selected to maintain system pressure stability, improve suction capacity, and ensure oil supply. The variable pump is connected to the engine. By adjusting the swashplate angle, the hydraulic oil flow and direction are controlled to achieve precise speed and direction control. The design of the replenishing pump and overflow valve ensures the replenishment of system oil and pressure control, maintaining stable system operation. Figure 4 shows the designed hydraulic system schematic diagram.

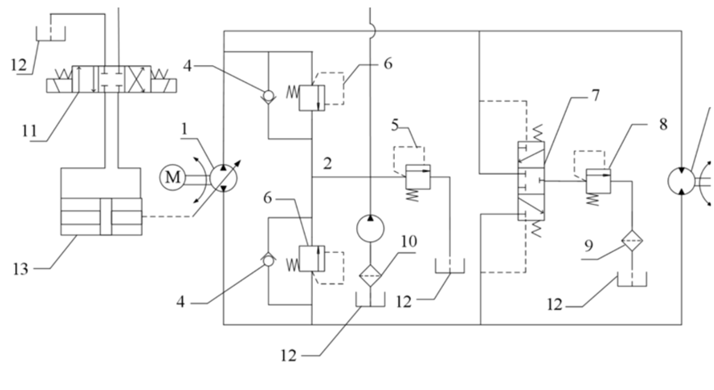

Fig. 4. Hydraulic schematic diagram.

2.4 Header System Design

During the operation of the header, corn stalks first come into contact with the divider. As the machine moves forward, the corn stalks are cut by the lower header cutter. The corn ears are then removed by the snapping rollers and stalk rollers. The auger transfers the corn ears through the conveyor bridge to the threshing and cleaning system. The resulting corn stalks enter the chopper. The shredded stalks and husks can either be returned to the field or collected in a straw box. The field-returning machine can directly chop the root of the stalks.

3 Modeling and Simulation of the Hydraulic System of the Corn Harvester

3.1 Modeling and Parameter Setting of the Hydraulic Walking System

The hydraulic system of the harvester experiences external loads of 6500kg, 7500kg, and 8500kg under light, medium, and heavy loads, respectively. A simulation over 12 seconds with a 0.01-second printing interval reveals that the hydraulic motor exhibits flow fluctuations, with maximum values of 152L/min, 155L/min, and 158L/min for each load condition. The time to stabilize flow decreases with increasing loads, stabilizing at 139L/min. The analysis indicates that load significantly influences motor flow.

In starting, the hydraulic motor shows speed fluctuations, with higher loads resulting in greater peak speeds, though the steady speed remains affected minimally by the load. The motor's output torque stabilizes around 2 seconds after overcoming the load, with steady-state torques of 98N/m, 197N/m, and 299N/m for light, medium, and heavy loads, respectively. Overall, the walking motor operates steadily at approximately 1834r/min and maintains a flow rate of about 140L/min, aligning with design specifications.

Furthermore, the relationship between pump displacement and motor speed is studied by varying the displacement control valve's cylinder displacement, which influences the output speed of the traveling motor, as illustrated in Figure 5 and Figure 6.

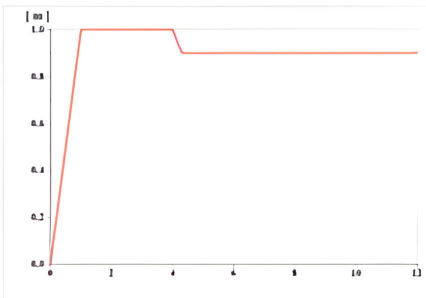

Fig. 5. Displacement diagram of displacement control valve cylinder.

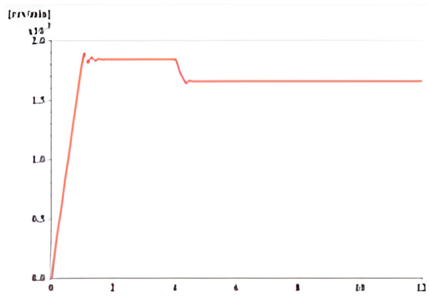

Fig. 6. Motor speed diagram in the event of variable pump displacement alteration.

3.2 Cutting Table Hydraulic System Simulation

According to Figure 7, AMESim software is used to build its simulation model, as shown in Figure 7.

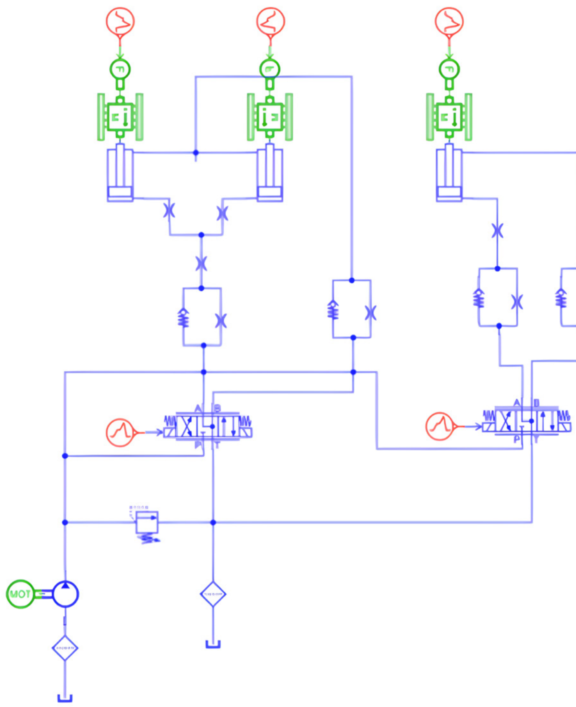

Fig. 7. Simulation model of cutting platform hydraulic cylinder system.

According to the actual working conditions of the hydraulic system of the cutting platform, the external loads corresponding to light load, medium load, and heavy load of the system are 500kg, 600kg, and 700kg, respectively. The simulation time is set to 10s. The printing interval is 0.2. After running the simulation, the simulation results show that the hydraulic cylinder would produce large flow fluctuations at the beginning stage. Under light load, medium load, and heavy load conditions, the fluctuation range is 0.75~0.82L/min, 0.70~0.83L/min, and 0.62~0.85L/min, respectively. The stability time of the flow fluctuation range is 2.1s, 2.3s, 2.2s. It can be concluded that the fluctuation of hydraulic cylinder flow increases with the increase of load. The load has a greater impact on the hydraulic cylinder of the cutting platform system.

4 Translated Summary

This study proposes an innovative hydraulic drive and intelligent control system design to address the high failure rate and impurity issues of traditional corn harvesters. Through theoretical analysis and computer-aided design, the system achieves stepless speed regulation, automatic adjustment of the header speed, real-time monitoring of feed quantity, and optimization of the threshing and cleaning system. The improved system significantly reduces failure rates and enhances harvesting efficiency and grain integrity. The hardware includes Hall sensors, dynamic torque sensors, pressure sensors, a C490 controller, and FBOX communication equipment, forming an intelligent control system verified through computer simulation and field tests.

Despite the achievements, there are limitations, such as simulations and tests based on theoretical models that may encounter complex conditions in practical applications, and the need for further optimization of control system algorithms and logic. Future work will focus on optimizing control algorithms, expanding the system's applicability, and integrating with actual agricultural production processes to continuously improve the corn harvester's performance, thereby promoting agricultural mechanization and modernization.

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