Hydraulic System Design of Combined Harvester Header and Simulation of Header Lifting System

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Abstract. The combine harvester header is an important part of the whole machine design. The design of the hydraulic system of the header is the key to realize the hydraulic control part of the whole system. In this paper, AMESim is simulated on the combined harvester header lifting hydraulic system. Through the curve of the flow rate and displacement of the lifting hydraulic system of the header of the combine harvester, the movement process of the header is carried out. This paper studies the effect of different pump speeds on the working efficiency of the header lifting in the header hydraulic system. The simulation results verify that the designed hydraulic system can meet the hydraulic pressure range of the header during the harvesting process. The research in this paper provides a reference for the hydraulic design of the header of a similar combine harvester.

1. Introduction
The header is the core operating mechanism of the combine harvester. The performance of the hydraulic drive system of the header directly affects the performance of the whole machine and the layout of the transmission system [1]. The traditional combine harvester header adopts mechanical transmission mode. The whole machine has many moving parts, and the speed, torque and power consumption are different. The transmission system has long transmission path and complicated structure. The hydraulic control has the advantages of high power density and small volume. [2] In the hydraulic control of the harvester header, we use the double pump system as shown in Figure 1, which ensures the stability of the working system and reduces the temperature rise of the hydraulic oil caused by the single temperature valve. [3]
If a mechanical transmission (such as a belt drive or a chain drive) is used to achieve power transmission, multiple stages of deceleration are required to transmit power to the header drive shaft. Such a transmission system has a complicated structure, is difficult to install and maintain, and has a high failure rate. \[4\]

2. Working principle and design of the header hydraulic system

2.1. Working principle of the header hydraulic system

In the design of the hydraulic system of the header, the lifting, folding and adjustable line spacing of the header are mainly realized by the movement of the hydraulic cylinder. The hydraulic motor is the driving force source for the movement of the picking roller and the chain.

The lifting of the header is a joint control of the two-position six-way switching valve and the header lifting control valve to realize the balance of the header during the lifting process, which can keep the harvester always keep the header when passing the uneven road. Harvest food horizontally.

The picking roller offset cylinder is controlled by the combination flow valve group and the functional cylinder control valve to control the row spacing of the header, so that the header can adjust the harvesting pitch according to the actual working conditions.

The folding part of the header is realized by the movement of the hydraulic cylinder mounted on the cutting platform by the functional cylinder, and the folding structure of the header is as shown in figure 2.

2.1.1 Selection and calculation of components of the hydraulic system of the header

The formula $D$ of the cylinder diameter of the hydraulic cylinder in the hydraulic system is:

$$D = \sqrt{\frac{4F}{\pi \eta P}}$$
In the formula: \( F \) is the load when the hydraulic cylinder is working, \( P \) is the working pressure when the hydraulic cylinder is working, MPa, \( \eta \) is working efficiency for hydraulic cylinders, \( D \) is the cylinder diameter of the hydraulic cylinder, mm.

The load and working pressure received by the hydraulic cylinder during normal operation are substituted into the formula to obtain the specific values of the hydraulic system components of the combine harvester. The main parameters of the hydraulic system hydraulic cylinder are shown in Table 1.

### Table 1. Hydraulic system hydraulic cylinder main parameters

| name                        | Quantity | Stroke(mm) | Bore diameter(mm) | Rod diameter(mm) | flow(L/min) | Extend time(s) | Return time(s) |
|-----------------------------|----------|------------|-------------------|------------------|-------------|----------------|----------------|
| Header folding cylinder     | 2        | 713        | 50                | 30               | 5           | 9.04           | 6.03           |
| Line spacing adjustment     | 8        | 200        | 70                | 50               | 20          | 18.7           | 9.05           |
| Header lift cylinder        | 2        | 300        | 80                | 50               | 20          | 15.3           | 8.3            |

#### 2.1.2 Design of the hydraulic control system of the header

The combine harvester hydraulic system in this paper uses a dual pump system. The lifting of the header is a two-position six-way switching valve combined with the header lifting control valve to realize the balance of the header in the process of lifting. The picking roller offset cylinder is controlled by the combination flow valve group and the functional cylinder control valve to control the row spacing of the header, so that the header can adjust the harvest spacing according to the actual working conditions. The folded part of the header is realized by the movement of the hydraulic cylinder mounted on the cutting gantry by the functional cylinder. In the circuit of the cylinder, the manifold valve is used to balance the oil of the branch, and the manifold valve controls two cylinders or hydraulic motors to maintain the same speed in the hydraulic synchronous system. Drawing the header hydraulic system control according to the functional requirements is shown in Figure 3.

![Figure 3. Header hydraulic control system](image-url)
3. Header lifting hydraulic system AMESim modeling

AMESim is a software developed by IMAGINE of France for simulation analysis of fluid power, mechanical, thermal fluid 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]

The hydraulic system piping is assumed to be rigid during modeling, without considering the length of the pipe [6]. According to the above-mentioned header lifting hydraulic system principle, the simulation model of the header lifting hydraulic system established in the AMESim environment is shown in Figure 4.

![Figure 4. Header lifting system simulation model](image)

3.1. The influence of pump speed on the displacement of the header lifting cylinder

At three different pump speeds, the change in the displacement of the header lift cylinder over time is shown in Figure 5. As can be seen from the figure, the higher the rotational speed, the faster the rate of expansion and contraction of the cylinder.

![Figure 5. Movement displacement of the header lifting cylinder under three different pump speeds](image)

3.2. The effect of pump speed on the speed of the header lift cylinder

The speed of movement of the header lift cylinder at three different pump speeds varies with time, as shown in Figure 6. When the pump speed is 2200r/min, the moving speed of the piston rod of the header lifting hydraulic cylinder is fluctuating greatly, and the motion stability is poor. When the pump speed is 2500r/min and 2800r/min, the movement stability of the header lifting hydraulic
cylinder is better. The pump speed is 2500r/min compared with 2800r/min. When the pump speed is 2800r/min, the efficiency of the header lifting hydraulic cylinder is higher.

Figure 6. Movement speed of the header lifting cylinder under three different pump speeds

4. Conclusions
1. In this paper, the hydraulic system of the combine harvester header is designed. It is proved by simulation and actual work that the hydraulic system is reliable. It provides a reference for the hydraulic design of the header of a similar combine harvester.
2. The higher the speed of the pump, the faster the expansion speed of the header lift cylinder. By increasing the throttle, the pump speed can be increased, thereby increasing the efficiency of the expansion.
3. In this paper, the pump speed of the header working in the harvesting process is about 2500r/min. Especially when the pump speed is 2800r/min, the piston rod of the header lifting cylinder has the best motion stability.
4. In this paper, the AMESim simulation software is used to simulate the combined harvester header lifting system, which can reflect the movement characteristics of the header lifting. In this paper, AMESim software is used to study the influence of pump speed variation on the expansion efficiency and motion stability of the header lift cylinder, which provides a reference for the hydraulic system design of other related models.

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