Optimization of safety valve block of the pitch mechanism of bucket wheel stacker reclaimer

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Abstract. The luffing mechanism of the 6# stacker-reclaimer (DQ3000/4200) of an ironmaking plant has malfunctions in production. After analyzing the fault reason of the original pitching mechanism, we optimize the hydraulic mechanism for solving these problems, and established a 3D model for the optimization part. The original hydraulic system and the improved hydraulic system model were established under AMEsim. The purpose of this study was to compare the movement speed of the hydraulic cylinder piston under different set pressures of the pressure valve to verify the improved hydraulic system meets production needs.

1. Introduction

Bucket wheel stacker reclaimer is a large and efficient material handling and stacking equipment in stockyard. As a continuous and efficient bulk material handling and conveying machine, it has been widely used in port, power plant, steel plant, mine and other industries [1].

As the key actuator of stacker reclaimer, the pitching device is used to support the gravity of reclaimer bucket wheel, cantilever mechanism and counterweight device, and change the height of reclaimer bucket wheel under the traction of pitching hydraulic cylinder, so that the bucket wheel mechanism can easily stack and reclaim materials at different heights of material pile in the yard. The safety and reliability of pitching mechanism is very important [2].

Figure 1. Pitching structure diagram.
As shown in Figure 1, it is the schematic diagram of the overall pitching structure. The pitching cylinder is used to push the tower, cantilever and counterweight of the equipment to rotate around the same hinge axis at the same angle [3].

Due to the long service life of dq3000 / 4200 stacker reclaimer in an iron making plant, the boom of its pitching device often fails to lock during the reclaiming process, the boom of luffing mechanism slides down, the pressure impact is too large, which leads to serious oil leakage in the hydraulic station, and the service life of some hydraulic valves is short. Zhang et al. encountered the problem of "nodding" the boom of the luffing mechanism at the Baotou Iron and Steel Coking Plant. Zhang et al. used a hydraulic lock and balance valve to replace the original slide valve-type balance valve of the luffing mechanism to ensure the original design. The lock and balance function of the spool valve eliminates the trace leakage of the slide valve, and effectively avoids the trace sinking of the boom of the luffing mechanism [4].

After field investigation, the original pitching mechanism of the hydraulic system of the safety valve block design is unreasonable, resulting in the reversing hydraulic impact is too large. Therefore, it is optimized and the dynamic analysis of the hydraulic system is carried out.

2. Schematic diagram and three-dimensional model of safety pressure regulating valve block of stacker reclaimer pitching mechanism

Considering that the pressure increases locally when the hydraulic cylinder is working, it is necessary to set up a safety valve in the two chambers. After the pressure valve is exceeded, the hydraulic oil will overflow through the safety valve (add a safety valve in the two chambers of the hydraulic cylinder); prevent the hydraulic hose from bursting Phenomenon, when the return oil flow increases sharply, the oil circuit needs to be automatically cut off (explosion-proof valves are added to the two chambers of the hydraulic cylinder); during the pressure adjustment process of the system, the actual load pressure of the pitch mechanism at different heights is different, when the pump outlet The pressure is constant, and the inlet pressure of the hydraulic cylinder needs to be set (add sequence valves in the two chambers of the hydraulic cylinder) [5].

The schematic diagram of the designed balance pressure regulating valve block is shown in Figure 2.

[Diagram showing schematic diagram of top pressure regulating valve block of pitching hydraulic cylinder]

Figure 2. Schematic diagram of top pressure regulating valve block of pitching hydraulic cylinder.
The initial parameters are as follows:
- System pressure: 15MPa.
- Relevant parameters of safety valve block:
  - Pressure setting of overflow valve: 20MPa;
  - Pressure setting of counterbalance valve: 18MPa;
  - Explosion-proof valve opening (F value): 5mm

The functions of related components are as follows:
- Counterbalance valve (28): When the pitch hydraulic cylinder works up and down normally, it prevents the hydraulic cylinder from impacting. When the oil is in, the oil is supplied from the one-way valve of 28, and the oil is returned from the sequence valve of 28 (with a certain opening pressure, the set value 1/3).
- Explosion-proof valve (29): heavy objects are suspended high to prevent the load from increasing. When the high-pressure hose is broken, the hydraulic oil will leak in large quantities, the beam will drop sharply, and a major safety accident will occur.
- Overflow valve (30): a safety valve for extreme situations. When the back pressure of the hydraulic cylinder is too large, the working pressure set by the safety valve is reached, and the oil will overflow from this valve back to the tank.

Use SOLIDWORKS to establish a three-dimensional model of the new safety regulator block, and the resulting model is shown in Figure 3.

![Figure 3. Three-dimensional model of safety regulating valve block.](image)

3. **Modeling and simulation analysis of safety pressure regulating valve block of stacker reclaimer pitching mechanism**

3.1. **Hydraulic system parameters**

The pitch mechanism of the bucket turbine is powered by a hydraulic pump. The main performance parameters of the hydraulic pump are as follows.
- Working pressure of pump: 16MPa;
- Maximum flow rate of pump: 80L/min;
- Drive motor power: 25kW;
- Driving motor speed: 1460 R/min;
- Pitching cylinder: 63*45-1053mm.
3.2. Simulation data analysis

The improved hydraulic system is simplified, and the simulation model diagram is established in AMEsim according to the principle diagram of the safety regulator, as shown in Figure 4. Set the parameters of each component model block with reference to the actual hydraulic component parameters. The hydraulic oil density is $0.85 \times 10^3 \text{kg/m}^3$, and the control signal 2 controls the on position of the electromagnetic reversing valve, which is in the middle position within 6 seconds, and the left position of the electromagnetic reversing valve is turned on from the 6th to the 28th second. After 28 seconds, the right position is turned on.

The main parameters of the hydraulic system are shown in Table 1.

| name                              | Parameter value                  |
|----------------------------------|----------------------------------|
| Hydraulic oil density (Kg/m³)    | $0.85 \times 10^3$               |
| Acceleration of gravity (m/s²)   | 9.8                              |
| Constant voltage source (MPa)    | 15                               |
| Hydraulic cylinder parameters (m)| Rod diameter 45; trip 1035        |
| Opening pressure of safety valve (MPa)| 19                          |

Figure 4. Simulation model diagram of safety voltage regulating system.

The simulation system adopts automatic selection of integration, and sets the simulation step length and simulation time to 0.1 seconds and 50 seconds respectively [6], and the obtained data curve is shown in Figures 5, 6 and 7.

In Figure 5, the solenoid directional valve is in the neutral position within 6 seconds, and the hydraulic oil is dumped back to the oil tank through the overflow valve. Between the 6th and 28th seconds, the solenoid directional valve is in the right position, the oil enters the hydraulic cylinder from the rodless cavity. When the oil enters, the pressure rises rapidly and stabilizes after a small fluctuation. At the same time, the hydraulic cylinder has a rod cavity and maintains a certain pressure. When the piston rod rises to the maximum stroke, the pressure in the rod chamber reaches the...
maximum pressure of the system, and the hydraulic oil returns to the tank through the overflow valve. At the beginning of the 28th second, the solenoid directional valve changes to the right position, the oil enters the rod cavity of the hydraulic cylinder, and the pressure rises, which is finally higher than the pressure in the rodless cavity.

The direction in which the rod extends out of the hydraulic cylinder in the picture is positive. The direction of the load force is opposite to the extension direction of the rod. Figure 6 shows the speed curve of the piston. The piston starts to accelerate and rise after the 6th second, reaches the maximum speed after 0.5 seconds and stays for about 14 seconds, and then starts to fall; the falling speed is also very fast. There is a small fluctuation when the reversing valve changes direction in 28 seconds.

It can be seen from Figure 7 that it took 14 seconds for the piston rod to rise to its maximum stroke. It took 17 seconds to return to the initial position. Basically, meet our requirements for the rapid action of the hydraulic system, that is, rapid ascent and slow descent.

![Figure 5. Pressure curve of two cavities of hydraulic cylinder.](image1)

1 - pressure of rodless cavity of hydraulic cylinder; 2 - pressure of rod cavity of hydraulic cylinder

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**Figure 5.** Pressure curve of two cavities of hydraulic cylinder.

![Figure 6. Velocity curve of piston.](image2)

**Figure 6.** Velocity curve of piston.
3.3. Modeling and Simulation of original pressure regulating valve block

In order to form a comparison, the original pressure regulating valve block was modeled and simulated under the same conditions. The simulation model diagram in AMEsim is shown in Figure 8.

Set the parameters of each model, and the simulation results are shown in Figures 9, 10 and 11.

Figure 7. Displacement curve of piston rod.

Figure 8. Model of original safety pressure regulating valve block.
Figure 9. Two-cavities pressure curve of the original pressure regulating valve block hydraulic cylinder.

Figure 10. Piston velocity curve of the original pressure regulating valve block.

Figure 11. Piston rod displacement curve of the original pressure regulating valve block.
From the simulation speed curve of the new and old safety regulator block, it can be seen that after the new regulator block is installed, the speed is more stable, within 0~6s, the speed quickly reaches the maximum 0.7m/s, in the time of 6s~22s During this period, the speed remained almost unchanged, and the original hydraulic system during this period of time, due to serious oil leakage from the hydraulic station, under the same pressure supply conditions, it could hardly reach the maximum speed, and the speed increased slowly. Does not comply with the principle of rapid rise and slow fall. It can be seen from the displacement curve that the piston rod of the hydraulic cylinder of the new system can be fully extended in only 12s, while the original system needs 24s to achieve the same displacement, wasting a lot of time, as can be seen from the two-chamber pressure curve of the hydraulic cylinder The new hydraulic system can maintain a good pressure difference within a certain period of time, while the pressure difference of the original hydraulic system changes relatively quickly.

4. Conclusions

(1) Use a new safety valve block, adjust the overflow valve to 19MPa, and adjust the counterbalance valve to 27MPa, the phenomenon that the luffing mechanism declines disappears, and the equipment meets the production needs.

(2) After replacing the new balance valve block, the piston speed changes smoothly, and the leakage of the hydraulic station is reduced, so that under the same pressure supply conditions, the piston can reach a higher speed when the new balance valve block is used, which improves Action efficiency.

(3) In summary, the new safety pressure regulating valve block has less pressure disturbance when working, and has less impact on the system, which greatly extends the service life of the hydraulic station.

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