Simulation and optimization for pressing system of hydraulic brick press based on AMESim

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Abstract: In order to solve the problems of impact vibration and roar in the working process of the automatic hydraulic brick press, a simulation model of the hydraulic system was established based on AMESim, and the dynamic simulation analysis of the upper cylinder was carried out to find out the cause of the problem. It was solved by installing a deceleration circuit and improving a pressure relief circuit. Finally, the optimized hydraulic system was simulated and verified, and the results proved that the optimized hydraulic system achieved the desired effect.

1. Introduction
As the key equipment in the process of brick production and molding, the automatic hydraulic brick press has gained great development in China. With the constant progress of hydraulic brick press technology, the stability, reliability and accuracy of the hydraulic system of hydraulic brick press are increasingly required[1]. Although the technical level of hydraulic brick press in China has reached or partly exceeded the level abroad, the design of hydraulic system is more based on experience, less on theoretical research. Due to the need for scientific research projects, our college purchased a 400T automatic hydraulic brick press, it was found that there were problems of shock vibration and excessive noise in the working process. To solve this problem, the author used the simulation software AMESim to simulate and analyze the hydraulic pressing system of this brick press, and on this basis, the optimization design was carried on.

2. Working principle of hydraulic system
The automatic hydraulic brick press has a structure of three beams and four columns. The fixed beams at the upper and lower ends of the columns are respectively inlaid with hydraulic cylinder liners. The upper and lower movable beams installed with the pressing head are rigidly connected with the upper and lower hydraulic cylinder piston rod, and are guided by the columns. A low-pressure liquid tank is installed on the upper fixed beam to provide a low pressure of about 0.2Mpa to make the upper movable beam fall quickly, and to provide a large flow of hydraulic oil for the upper chamber of the hydraulic cylinder. In the working process, the powder in the fixed mold frame is bidirectional pressure formed by the pressing head on the upper and lower movable beam, the upper pressing head exerts pressure actively, and the brick is pushed out by the lower pressing head after pressure forming.

The working principle diagram of the hydraulic pressing system of the brick press is shown in figure 1. The hydraulic ejecting system and distributing system have been simplified without affecting the working performance²-³.”
In the complete process of brick pressing and forming, the upper movable beam cycles in the order of fast down, pressure, pressure holding, unloading and return. The gain and loss of electromagnet of each hydraulic valve are shown in table 1. In the table “+” means the corresponding electromagnet is charged.

Table 1. State table of gain and loss of electromagnet

| YV1 | YV2 | YV3 | YV4 | YV5 | YV6 |
|-----|-----|-----|-----|-----|-----|
| Fast falling | + | + | + | + | + |
| Pressure | + | + | + | + | + |
| Pressure keeping | + | + | + | + | + |
| Pressure release | + | + | + | + | + |
| Return | + | + | + | + | + |
3. Hydraulic system modeling and analysis

3.1 Building the AMESim model of hydraulic system

For a specific hydraulic system, when the purpose of the analysis is different, the simulation model is also different. On the premise of meeting the requirements, the simpler and smaller the simulation model, the better. When establishing a dynamic simulation model for the hydraulic pressing system of the automatic hydraulic brick press, some factors which have little influence on the dynamic characteristics of the system can be ignored [4].

Since there is no specific model of two-way cartridge valve in the AMESim standard hydraulic library, the hydraulic Component Design Library (HCD) is used to build a specific simulation model according to the structure and working principle of cartridge valve. The cartridge valve model built is shown in figure 2 [5].

![Two-way cartridge valve model established by AMESim](image)

Figure 2. Two-way cartridge valve model established by AMESim

According to figure 1, the simulation model of the hydraulic pressing system established by AMESim is shown in figure 3.
Figure 3. AMESim simulation model of the hydraulic system

Setting reasonable parameters in hydraulic system simulation plays an important role in speeding up the simulation, improving the accuracy of results and stability of the system. To make the simulation as close as possible to the actual working state of the system, the parameters of each component in the simulation model are set with the parameters of the actual hydraulic system components. The motor power of the hydraulic system is 45kW, and a constant power variable plunger pump is adopted. The main models and simulation parameters are shown in table 2.

| parameter                           | Value |
|-------------------------------------|-------|
| Motor speed / (r·min⁻¹)             | 1460  |
| Variable pump displacement / (mL·r⁻¹) | 170   |
| Working pressure / MPa              | 22    |
| Diameter of the hydraulic cylinder / mm | 500   |
| Diameter of the piston rod / mm     | 490   |
| Maximum stroke /m                   | 0.50  |
| Mass of the upper movable beam / kg | 3000  |
| Simulation time / s                 | 6     |
| Simulation step size / s            | 0.002 |

3.2 System analysis

By analyzing the dynamic characteristic curves of displacement, pressure, velocity and acceleration of the upper cylinder in the hydraulic system, the actual working state of the system can be predicted.
Dynamic characteristic curves of displacement, pressure, velocity and acceleration of the upper cylinder of the hydraulic system in the complete working process obtained by running simulation are shown in figure 4~7. In these figures 0s~0.40s is the fast down stage, 0.40s~2.00s is the pressure stage, 2.00s~4.00s is the pressure holding stage, 4.00s~5.00s is the pressure release stage, and 5.00s~5.70s is the return stage.

![Figure 4. Displacement curve of upper cylinder](image1)

![Figure 5. Pressure curve of upper cylinder](image2)

![Figure 6. Cylinder speed curve](image3)

![Figure 7. Cylinder acceleration curve](image4)

It can be seen from figure 6 that the speed of the upper cylinder reaches its maximum value(2m/s) at 0.35s and rapidly decreases to 0m/s at 0.40s, from figure 7 it can be seen that the instantaneous acceleration of the upper cylinder reaches its maximum value (-90m/s²) at 0.38s, which is mainly due to the acceleration falling of the upper cylinder under the action of the 0.2Mpa oil pressure in the liquid-filled tank and the dead weight of the upper movable beam, when the pressing head comes into contact with the powder in the fixed frame it starts inertial pressure to produce the load on the cylinder, at the same time as the powder higher compression ratio, the adding compactness of the powder increases the upper cylinder load rapidly, the upper cylinder stops quickly. As can be seen from the pressure curve of the upper cylinder in figure 5, at the point of 4.00s the system pressure relief solenoid valve YV5 loses power, and the high-pressure oil is released through the reversing valve 14, and the pressure in the upper chamber of the upper cylinder plummets from 22Mpa to about 0.0Mpa.

In the debugging process of the automatic hydraulic brick press, it is found that the machine will produce huge "roaring" noise and strong vibration when the upper cylinder stops quickly and releases pressure in the reverse direction. According to the above-mentioned simulation analysis of the hydraulic pressing system, this is due to the inertial impact caused by rapid stop of the upper movable beam which weighs 3000 kg and the hydraulic shock caused by the rapid pressure release. In the process of holding pressure, large energy can be stored due to the compressibility of the hydraulic oil and the elastic deformation of the mechanical part, this will lead to strong vibration, affecting the normal operation of the hydraulic press.

3.3 Improvement of hydraulic system

According to the above analysis, to solve the impact vibration and huge sound problems of the brick press when it is fast down and releasing pressure, the upper cylinder should slow down to stop in the fast-falling stage and be controlled to release pressure when reversing, so that the deceleration circuit and the pressure release circuit can be added in the hydraulic system. The improved hydraulic schematic
The diagram is shown in figure 8, and the added deceleration circuit using the throttle valve is inside the double-dotted frame I. When the upper cylinder falls, the reversing valve 5 and 25 are charged, and the hydraulic oil in the lower chamber of the upper cylinder flows back to the tank through the cartridge valve 6 and 26 to fall rapidly. As soon as the upper pressing head contacts the powder, the reversing valve 25 loses power, and the hydraulic oil in the lower chamber of the upper cylinder flows back to the tank through the throttle valve 27 to achieve a slow drop. The falling speed can be adjusted by changing the size of the throttle valve opening.

![Figure 8. Improved hydraulic schematic diagram](image)

The improved pressure release circuit with the pilot relief valve is inside the double-dotted frame II. When the brick press is in the non-pressure release stage, YV6 is energized, the reversing valve 14 is in the right position, and the relief valve 28 is always in the maximum set pressure state. When the reversing and the pressure release start, YV6 loses power, the reversing valve 14 is in the left position, and the remote control port of relief valve 28 flows back to the tank through throttle valve 29 and one-way valve 30 to realize the pressure release of the upper chamber of the upper cylinder. The pressure release speed of the high-pressure oil can be adjusted by changing the opening size of the throttle valve 29.
Figure 9. AMESim model of improved hydraulic system

The AMESim simulation model established according to the improved hydraulic schematic diagram is shown in figure 9. The pressure release circuit can be simplified as a combination of a pilot relief valve and a control signal, as shown in double-dotted frame II of figure 9. Through the deceleration circuit to control the upper cylinder fast down speed, the upper cylinder fast falling inertial pressing distance becomes shorter, and the pressure pressing distance becomes longer, so the pressure time increases from 1.60s to 3.00s. The improved model is simulated, and the improved upper chamber pressure curve of the working cylinder and the acceleration curve of the movable beam are shown in figure 10 and figure 11. Compared with figure 7, as shown in figure 10, the fast falling maximum acceleration of the upper movable beam changes from -90m/s² (before improvement) to -30m/s² (improved), the effect is obvious; Compared with figure 6, as shown in figure 11, the oil pressure in the upper chamber of the working cylinder drops gently from 22.0MPa to 0.1mpa within 1.00s when the system reversing and the pressure releasing, and the hydraulic system reversing and pressure releasing changes from an instantaneous sudden drop to a controlled and stable pressure release. It can be seen that the optimized hydraulic system has a great improvement in the fast down and pressure release stage compared with that before optimization.
4. Conclusion
The optimized hydraulic pressing system of the automatic hydraulic brick press has been verified in practical production, and the results show that the inertial impact strength of the upper movable beam is greatly reduced, and the "roaring" sound during reversing pressure release is almost disappeared, which will greatly prolong the service life of the automatic hydraulic brick press. The optimized hydraulic system has a longer working cycle than the original system, how to shorten the working cycle will be the direction of further research.

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