

Study of Dynamic Characteristics for Hydraulic System on 300MN Die-forging Press

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Abstract. The faults such as seal breakdown and pressure sensor damage occur in 300MN Die-forging press frequently. First, the fault phenomenon and harm of the hydraulic system was compiled statistics, the theoretical analysis of the hydraulic impact of hydraulic system are carried out based on the momentum theorem; Then, the co-simulation model of hydraulic system was established by AMESim and Simulink software and the correctness was verified. Finally, the dynamic characteristics of hydraulic system for the key working condition “forging stroke changing to mold collision” was analyzed, the influences rules of system parameters such as the leak gap of valve, diameter of water way pipeline, emulsion temperature and air contain act on hydraulic system are obtained. This conclusions have a theoretical guiding significance to the improvement and maintains of high pressure and large flow hydraulic system.

1. Introduction

The hydraulic system of 300MN Die-forging press has the characteristics of high pressure and large flow rate, the faults such as seal breakdown and pressure sensor damage occur frequently during using. In order to realize the performance indicators, the stable dynamic characteristics were needed especially^[1]. In general, the dynamic characteristics of the hydraulic system is mainly manifested in the amplitude of pressure wave. The numerical simulation method has become an effective methods to study the dynamic characteristics of hydraulic system^[2-5]. In this paper, the hydraulic system of 300MN die forging press was taken as research object, the hydraulic impact mechanism and dynamic characteristics of hydraulic system with high pressure and large flow were systematic studied based on theoretical analysis and numerical simulation.

2. The structure and hydraulic system of 300MN die forging hydraulic press

The hydraulic system of 300MN die forging hydraulic press includes lift cylinder, balance cylinder, working cylinder, pump station, main distributor pipeline, filling valve, filling tank and other matching components. The lift cylinder, balance cylinder and working cylinder of hydraulic press were connected with the machine body, the working cylinder is fixed on the upper beam, the lifting cylinder and balance cylinder is fixed on the lower beam, each plunger of all cylinders connected on



moving beam together. The normal working pressure is 320bar 300MN die forging hydraulic press from the pump station.

The operation of hydraulic system is realized by the main distributor valve, the opening or closing process of valve is controlled by the operating handle which can input angle signal at first, then rotate driving cam to the specified angle, finally, the inlet and drain valve are opening and closing by the push of driving cam, the valve should be in accordance with the laws of coordination in order to achieve the conversion of four kinds of working state: stop, virtual travel, forging and lift, the operation handle angle signal can be converted to the sequence order and the height of valve opening signal, the valve opening and closing angle and the relationship with the operation handle as shown in Figure 1, where 1-8 is the number of valve: 1,3 - inlet valve of working cylinder, 2- the drain valve of working cylinder, 5- inlet valve of balance cylinder, 4- drain valve of balance cylinder, 7- inlet valve of lift cylinder, 8- drain valve of lift cylinder.

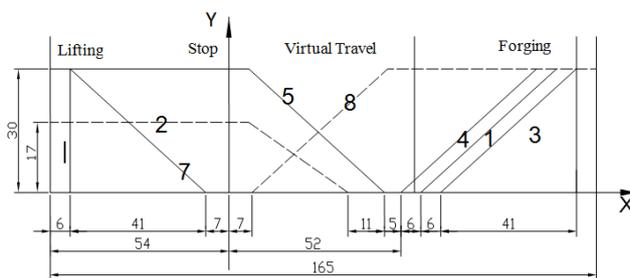


Figure 1. The opening control chart of valve core for main distributor

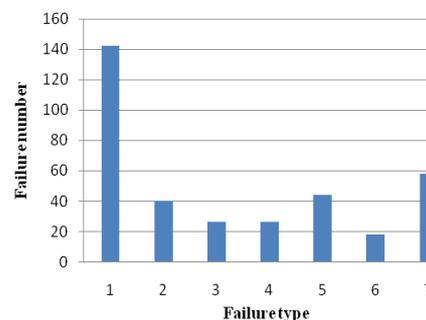


Figure 2. The failure statistics of 300MN die forging press

In Figure 1, the X-axis represents the handle rotation angle, the Y-axis is the opening height of the related valve. The "stop" indicating the position of the cam angle 0 degrees, the cam angle value is negative during top to lifting, cam angle is positive during stop to forging.

3. Hydraulic impact mechanism analysis of waterway system

3.1 Hydraulic impact of waterway system on 300MN die forging hydraulic press

The hydraulic impact, which has great impact on the performance of stability and reliability of the hydraulic system, widely exist in various types of hydraulic systems, and is a problem often encountered in the working process of the system. Studies show that the high pressure and large flow of hydraulic pressure is the main cause of seal failure in the system^[6], and will lead to vibration noise, loose connections and other phenomena, even the occurrence of pipeline rupture, hydraulic components and measuring instrument damage.

According to the failure statistics of mechanical and hydraulic part on 300MN die forging hydraulic press during 10th Nov., 2008 to 24th Nov., 2009, the total of 354 times of failures and its distribution are shown in Figure 2, where, 1-Valve seal leakage, 2-Valve opening failure, 3-Pipeline loose, 4-plate loose, 5-flange leakage, 6- Hydraulic cylinder leakage, 7 - other faults; As we can see from Figure 2 that the seal failure, pipeline loose flange leakage fault accounted for the proportion of the failure of the entire system is great, seriously affect the normal production equipment.

3.2 Hydraulic impact analysis based on momentum theorem

There two reasons for the hydraulic impact of hydraulic system, the first one, the closing of valve can lead the high pressure flow liquid in pipeline stopped quickly, the inertial would cause the hydraulic impact inevitable; the second one, with the status changed, the huge inertial of moving parts such as beam can cause the hydraulic impact obviously, the hydraulic impact and dynamic characteristics is more larger especially when the state transiting quickly.

In the whole process, the hydraulic system will follow the law of conservation of momentum, so we can complete the theoretical analysis and accurate calculation of hydraulic impact based on

momentum theorem. The working cycle of 300MN die forging hydraulic press comprises stop, virtual travel, and forging and lifting, the scene shows that when hydraulic press in “virtual travel to lifting” and “forging stroke changing to mold collision”, the switching process appear obvious vibration. In here, the state switch of “virtual travel to lifting” was taken as the object to analyze the hydraulic impact in theoretically.

3.2.1 The Hydraulic impact of lift pipeline when the valve closing Δp_1

Set ρ as the density of liquid, v is the liquid velocity, the valve flow rate is zero after the closure of valve, follow the momentum equation:

$$\Delta p_1 = \rho c v \quad (1)$$

The parameter c is not only related to the bulk modulus K , but also to the elastic modulus of pipeline material E , the inner diameter d and the thickness of the pipeline δ , which can be calculated by :

$$c = \sqrt{\frac{K}{\rho}} / \sqrt{1 + \frac{Kd}{E\delta}} \quad (2)$$

Here, ρ —fluid density, 1017.9kg/m^3 ; K —Liquid bulk modulus, $2.06 \times 10^9\text{N/m}$;

E —Elastic modulus of pipeline material, $2.2 \times 10^9\text{N/m}$; The pipeline diameter of lifting cylinder $d=112\text{mm}$; the wall thickness $\delta=26\text{mm}$; the beam maximum speed: 150mm/s ; $S_{\text{cylinder}}=0.7235\text{m}^2$, the flow rate of the valve port v :

$$v = V_{\text{beam}} \cdot S_{\text{cylinder}} / S_{\text{pipeline}} = 0.15 \cdot 0.7235 / 0.009847 = 11.2 \text{ (m/s)}$$

Follow the formula (2), parameter c can be calculated as $c=1270 \text{ (m/s)}$.

Based on the momentum theorem formula (1), $\Delta p_1 = 14.47\text{Mpa}$.

3.2.2 The hydraulic impact caused by moving parts during braking Δp_2

Set the deceleration time of moving parts which total mass $\sum m$ for Δt , Δv as the speed decreases value, the effective area of hydraulic cylinder as A , according to the theorem of momentum:

$$\Delta p_2 = \frac{\sum m \Delta v}{A \Delta t} \quad (3)$$

In 300MN die forging hydraulic press, the moving parts includes a movable beam and the lift cylinder piston, which the total mass of movable beam is $2.3 \times 10^6\text{Kg}$, the piston mass is too light compared with the beam, so it can be ignored, the maximum velocity of movable beam air travel is 0.15m/s , piston total area of lifting cylinder is 0.7235m^2 , take the above parameters into formula (3), the hydraulic impact caused by movable beam in the fall time Δt can be obtained:

$$\Delta p_2 = 0.467 / \Delta t \quad (4)$$

3.2.3 The total hydraulic impact during virtual travel to lifting Δp

For the movable beam falling from the virtual travel to a sudden stop, the hydraulic impact generated by follow formula(5):

$$\Delta p = \Delta p_1 + \Delta p_2 = 14.47 + 0.467 / \Delta t \quad (5)$$

Set p_0 as the initial internal pressure of pipeline, in the virtual travel, the gravity of the movable beam is balanced by the balance cylinder and the lifting cylinder, so it can be regarded as the initial pressure of the lifting loop system at this time is 9.68MPa , so the total pressure in pipeline is follow formula:

$$p_{\text{max}} = p_0 + \Delta p = 24.15 + 0.467 / \Delta t \quad (6)$$

4. The dynamic characteristics analysis of hydraulic system

The AMESim software has the characteristics of simple and intuitive in the hydraulic simulation modeling work, and the Simulink software has Superior performance in data processing, so, this paper adopts the co-simulation of AMESim and Simulink software to analyze the hydraulic impact and dynamic characteristics of the hydraulic system.

4.1 Simulation model of hydraulic system

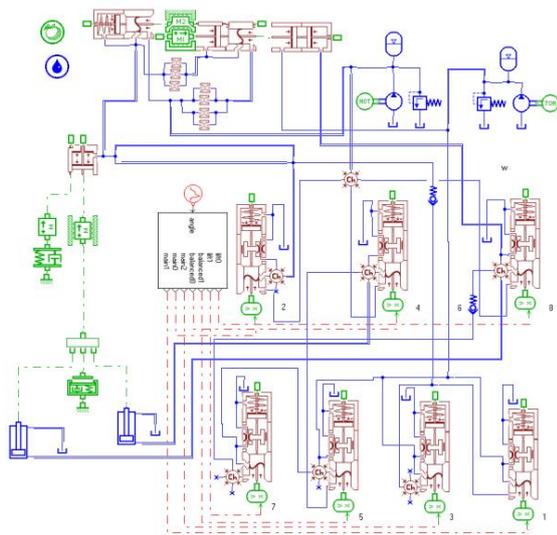


Figure3. AMESim model of hydraulic system

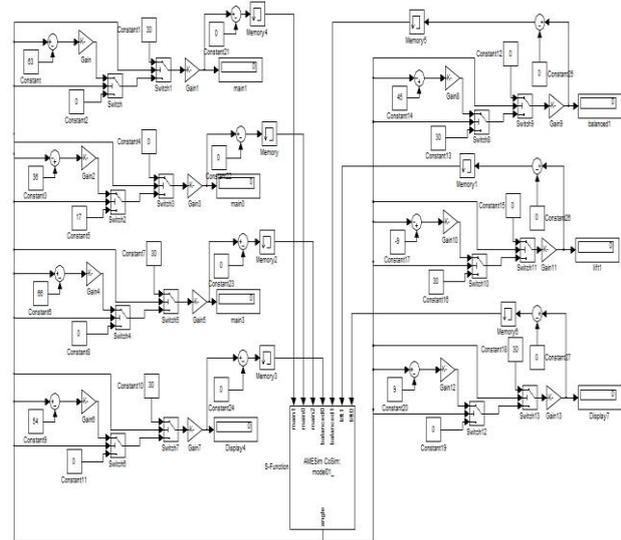


Figure4. Simulink model of opening control function

Because there are 16 hydraulic cylinder in this hydraulic system, it cause the system model becomes complicated and low computational efficiency, thus we need simplify the hydraulic cylinder according to the cross-sectional area of the equivalent principle of system, hydraulic system simulation model is shown in Figure 3, the valve opening control function model is established in the simulink software as shown in Figure 4

4.2 Theoretical verification of simulation model

According to the characteristics of the numerical simulation, the veracity and reliability of system model is uncertain. The Hydraulic press in the process of “virtual travel to lifting” was taken as object, the hydraulic impact of theoretical analysis and calculation based on the theorem of momentum compared with the results of simulation, the numerical simulation model can be verified.

Take the cam angle conversion time (valve action time) for $\Delta t = 0.1s$, using the formula (6) can be calculated the pressure of the pipeline at this time is 28.82MPa, that is, 288.2Bar; Then, under same conditions and the valve closed within 0.1second begin at the 2th seconds, the pressure curve of hydraulic system based on the numerical simulation model shown in Figure 5:

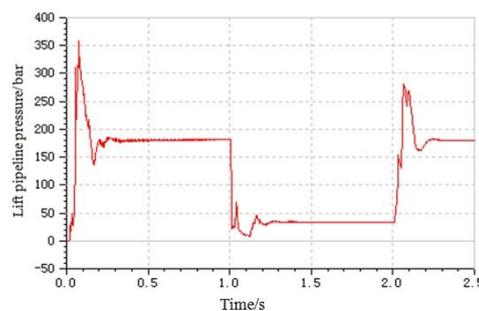


Figure 5. the pressure curve of virtual travel to lifting process

Comparing the theoretical calculation (288.2 bar) and the simulation results (278.4 bar) shows that the error between the simulation and theoretical calculation is only 9.8bar, and the error rate of 3.4% ,the error be in the permitted range, so we can determined that the simulation model is Accurate and reliable.

4.3 The simulation analysis for dynamic characteristics of hydraulic system

The process of “forging to mold collision” is a dangerous action of the hydraulic press work, while, there are high pressure in the work cylinder and valve have no action, the change of forging deformation resistance leads to mold collision, the movable beam stopped suddenly. The influence law of leakage gap, air content, emulsion temperature, and the diameter of pipeline for the dynamic characteristics under this conditions have been founded based on simulation.

As the reciprocating motion of valve stem, the gap is inevitable exist in the valve, cause the internal leaks especially serious under the background of high pressure. The pressure peak of working cylinder as shown in Figure 6, it shows that the leakage of the valve body effect the cylinder pressure very obviously, especially when the leakage gap reached more than 1.5mm.

Set the emulsion air content of 0.1% to 0.1% in 11 sets of data for simulation analysis, the working cylinder pressure as shown in Figure 7.

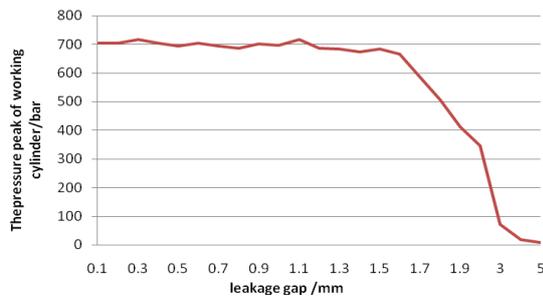


Figure 6. The pressure curve with leakage gap

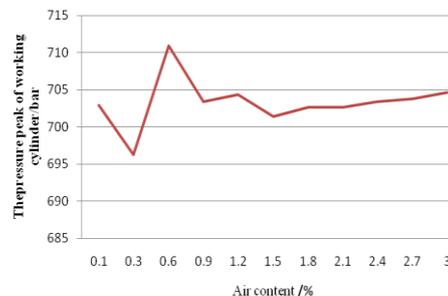


Figure 7. The pressure curve with air content

The figure 7 shows that the air content is between 0.1% to 3%, the impact on the work in cylinder pressure amplitude is not very big, when the air content reach to 1.5%, the effect tends to stability and gradually increase.

Due to the existence of energy conversion and consumption in the work process, the emulsion medium inevitably will be warming, based on the analysis of emulsion temperature is 5°C-70°C in 14 groups of data, obtained the pressure curve as shown in Figure 8:

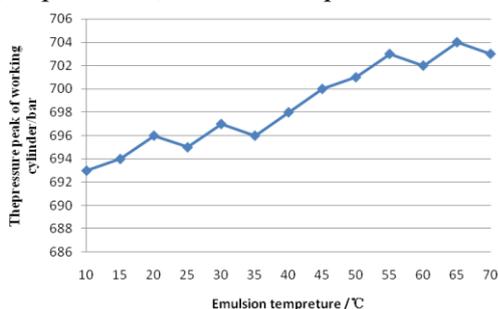


Figure 8. The pressure curve with temperature diameter

The figure 8 shows that the pressure peak in working cylinder is increasing with the temperature's rising, And similar to the linear relationship. In the scene, it is necessary to keep the emulsion temperature under 40°C;

Set the inner diameter of working cylinder pipeline for 9 sets of data in the 64 mm-154mm, and then obtained the pressure curve after simulation and analysis, as shown in Figure 9, it shows that the

cylinder pipe diameter is smaller, the impact of the pressure peak of the cylinder is smaller, and more than 124mm, the effect for the pressure peak is tend to stability.

5. Conclusions

The fault phenomenon and hydraulic impact mechanism of 300MN die-forging hydraulic press were analyzed, the co-simulation model of hydraulic system was established based on AMESim and Simulink software, the dynamic characteristics of hydraulic system during “forging stroke changing to mold collision” have been founded, studies show that this method is effective and credible. Then the influence law of leakage gap, air content, emulsion temperature, and the diameter of pipeline for the dynamic characteristics under have been founded based on simulation. This results can be applied to the design and maintenance of hydraulic system with high pressure large flow.

Acknowledgments

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