Proceedings of the 7th JFPS International
Symposium on Fluid Power, TOYAMA 2008
September 15-18, 2008

P1-03

STUDY ON FAST FORGING PROCESS CHARACTERAISTICS OF 20MN FORGING PRESS

Yao Jing*, Kong Xiangdong*, Gao Yingjie*, He long*, Quan Lingxiao*, Li Nan*

* Department of Mechanical Engineering, Faculty of Electromechanical Engineering
Yanshan University
Qinhuangdao, 066004 China
(E-mail: jyao@ysu.edu.cn)

ABSTRACT

The E/H servo cartridge valve is adopted to control the system of 20MN Forging Hydraulic Press. Its characteristics ,such as short response time, high control accuracy and so on, are extremely fit for forging hydraulic press. As a result the high forging times and accuracy can be achieved. A new saving-energy fast forging press using accumulator is presented for the problem of power waste during forging process. The model of proportional cartridge and accumulator are found, then the mathematical model of the whole fast forging circuit is found and simulated, the results show that it performs perfect for the fast forging press by using accumulator. Finally, base on the fast forging press test with accumulator, the model validity and feasibility of this fast forging circuit are validated.

KEY WORDS

Fast forging, accumulator, forging curve, saving-energy

NOMENCLATURE

A : the cross-sectional area of the accumulator.
A_1 : the plunger piston area of the main cylinder..
A_2 : the plunger piston area of the retracting cylinder..
a : proportional cartridge valve choke area...
B : oil viscous damping coefficient
c_a : gasses coefficient of damping of the accumulator
C_d : proportional cartridge valve flow coefficient
d : proportional cartridge valve choke diameter
K_a : gasses rigidity coefficient of accumulator
K_{vx}: proportional cartridge valve gain
M : the moving part mass
m_a : liquid equivalent mass of accumulator
P_{sa} : the inlet pressure of accumulator
P_1 : the pressure of the main cylinder
P_2 : the pressure of the retracting cylinder
P_s : the pressure of the pump
Q_1 : the flow of the main cylinder
Q_2 : the flow of the retracting cylinder
Q_x : the flow of the accumulator
P_s : the pressure of the pump
V_1 : the initial volume of the main cylinder
V_2 : the initial volume of the retracting cylinder
ω_{vx} : proportional cartridge valve frequency
V_2 : the initial volume of the retracting cylinder

INTRODUCTION

Forging industry is closely linked with national war industry, nuclear energy, airspace, electric power generation, traffic, fossil oil, heavy machinery etc. Forging press capacity tonnage represent a national strength, the advanced forging equipment is also one important symbol for a state industry modernization[1].

With the development of industry modernization, the forging precision and forging velocity are requested more and more high. Because it not only can increase productivity, but also can reduce the loss of the workpiece and economize in raw materials[2]. Due to some characteristics such as high pressure, large flow, heavy moving inertia and so on, the forging hydraulic press often has poor rapidity, large shock during pressure relief and flow relief, low control accuracy and high accident rate. To overcome the negative influence and improve forging press performance, 20MN fast forging hydraulic press have obvious improvement with respect to hydraulic system design, control method and control software.

FAST FORGING PROCESS CONTROL

Fast forging work is mainly used to finishing operation, its forging stroke is not exceed 30mm, the amount of deformation is generally controlled less than 5mm. The simplification schematic diagram of 20MN hydraulic press fast forging system with accumulator is shown in Figure 1.

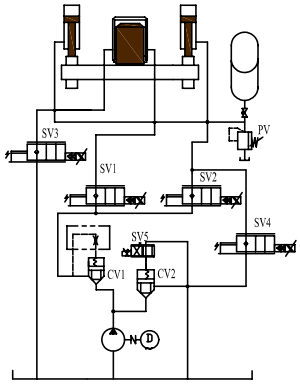


Figure 1 The simplified accumulator fast forging circuit

During fast forging process, SV4 is all along closed, the chamber of return cylinder form close and maintain pressure. Decompression stage，SV1 turns on and high-pressure oil comes into master cylinder, the moving beam go down, oil from return cylinder enter into accumulator and the energy is stored, supporting-valve PV serve for security. During return-stroke hour，SV1 is closed and SV3 is turning on, master cylinder pressure is releasing and SV5 open up instantaneously and main pump unload, at the same time accumulators release, high-pressure oil comes into return cylinder, moving beam is lifted, after running up to upper set point, next working cycle is coming immediately.

FAST FORGING PROCESS MATHEMATIC MODEL

The rapidity and control precision is pursuing goal for hydraulic press, it is important to study on dynamic characteristics of fast forging process.

The E/H proportional cartridge model

20MN fast forging hydraulic press adopts Parker E/H proportional cartridge, its response time is less than 20ms, from Figure 1, SV1，SV3 is this type valve. When hydraulic system natural frequency is less than 50 Hz, the E/H proportional cartridge model can be represented as:

$$\frac{x_v}{I_c} = \frac{K_{vx}}{1 + s/\omega_{vx}} \tag{1}$$

The flow equation of the master cylinder's input proportional cartridge valve is：

$$Q_1 = C_d a \sqrt{\frac{2}{\rho}(P_s - P_1)} \tag{2}$$

The flow equation of the master cylinder's pressure relief proportional cartridge valve is：

$$Q_t = C_d a \sqrt{\frac{2}{\rho}(P_1 - P_0)} \tag{3}$$

The throttle area of proportional cartridge valve is：

$$a = x_v \pi d \sin\alpha \tag{4}$$

The accumulator model

Supposing state 0(P_{X0} , V_{X0})is the pressure and volume state of initial working point in the air cavity, state a(P_a , V_a)is random working mode of the air cavity. In the fast forging course of hydraulic press, the working frequency of the accumulator is about 1.3Hz，the inflation and deflation time of the accumulator is less than 1min, it can be regard as adiabatic condition, so $k = 1.4$.

Accumulator is a gasses spring-damp model[4]，Accumulator motion equation:

$$(P_{sa} - P_a) = \frac{m_a \ddot{V}_a + B\dot{V}_a + c_a \dot{V}_a + k_a V_a}{A^2} \tag{5}$$

According to gas equation, where is

$$p_{x0} V_{x0}^k = p_a V_a^k \tag{6}$$

from above Eq.(6) :

$$p_{\mathrm{a}} = p_{\mathrm{x0}} V_{\mathrm{x0}}^{k} V_{\mathrm{a}}^{-k} \tag{7}$$

Then accumulator from state 0 to state a, pressure increment is :

$$\Delta P = P_a - P_{x0} = p_{\mathrm{x0}} V_{\mathrm{x0}}^{k} V_{\mathrm{a}}^{-k} - P_{x0} \tag{8}$$

The accumulator state of pressure equation is:

$$\dot{P}_a = \frac{\Delta P}{\Delta t} = -\frac{k p_{\mathrm{x0}} V_{\mathrm{x0}}^{k}}{V_a^{k+1}} \dot{V}_a \tag{9}$$

The cylinder model

The controlled actuator of the E/H servo system consists of one main cylinder and two return cylinders in 20MN fast forging hydraulic press. Those cylinders work together to realize forging press framework motion. To model such system, the reciprocating motion cylinders are regarded as a double-acting cylinder with a noticeable difference that is the reciprocating motion cylinders have no internal leakage.

The flow continuous equation in main cylinder:

$$Q_1 = \frac{V_1}{\beta_e} \dot{P}_1 + A_1 \dot{y} - Q_x \tag{10}$$

The flow continuous equation in return cylinder:

$$Q_2 = -\frac{V_2}{\beta_e} \dot{P}_2 + A_2 \dot{y} \tag{11}$$

Owing to oil condensability smallness, hydraulic spring stiffness which is caused by the oil condensability is much larger than accumulator loading system [5], so the syntheses spring stiffness of forging system is mostly decided by accumulator.

Neglecting pipeline influence, the flow variation of return cylinder is equal to accumulators', the pressure change of return cylinder is correspondence with the accumulators'.

so

$$Q_2 = A_2 \dot{y} = \dot{V}_1 \tag{12}$$

$$P_2 = P_{sa} \tag{13}$$

The moving framework model

Ignoring friction force, the framework motion equation is expressed as follows:

$$P_1 A_1 - P_2 A_2 - B\dot{y} - F_z + G = M\ddot{y} \tag{14}$$

SIMULATION ANALYSIS

simulation parameter

Master cylinder diameter of 20MN fast forging press is 820mm, return cylinder diameter is 250mm, the weight of moving beam is 200t, balancing deadweight needs for 14.5MPa system pressure, the max flow of compression is 3600L/min, the frequency of fast forging is 80 times/min, stroke is 30mm, gauge reduction is 5mm, accuracy of displacement is $\pm$1mm. Supposing maximum external load is 10MN, practical external load has certain relation with deformation of forging workpiece. Setting the basic parameters of accumulator is very important, selected V_{x0}=40L, P_{x0}=14.5MPa.

simulation analysis

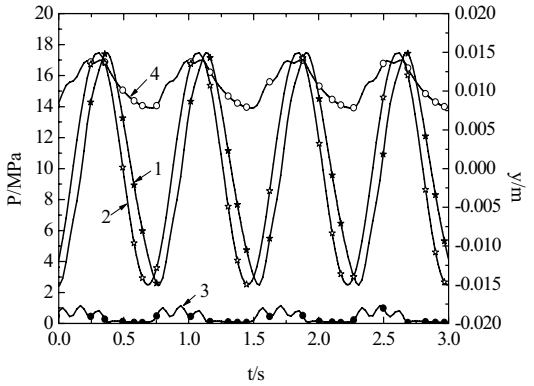
The simulation model is found and simulated by Matlab/Simulink®. Figure 2 shows the fast process pressure and displacement curve of the forging press without load. The displacement curve is smooth and no overshot, and the forging press has high position precision, during compression course, pressure of main cylinder P_1 rises, the pressure P_2 of accumulator also goes up because of absorbing energy. There is one slowdown process near lower-most point, both master cylinder and return cylinder pressure appear wave trough; during upstroke course, main cylinder releases through SV3, pressure decreases to zero, accumulator releases energy, pressure gradually reduces. The pressure fluctuation of main cylinder is due to moving beam quality, hydraulic spring and damping effect together.

The forging press with external load fast process pressure and displacement curves are shown in Figure 3, loaded instant, the moving beam is at once slowdown and displacement curve appears fluctuation, but control accuracy is not affected, the pressure of main cylinder rapidly rises, the pressure of accumulator are also higher than that of no-load. Figure 4 shows the external load input curve.

CONCLUSION

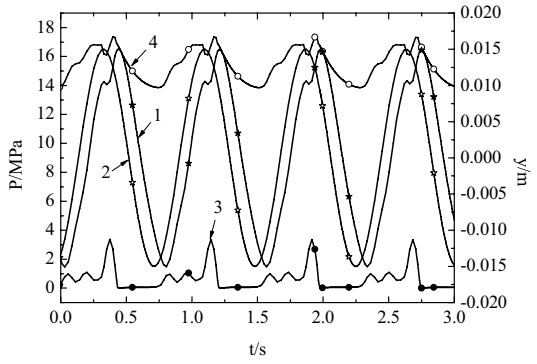
a) 20MN fast forging press adopts advanced electro-hydraulic control system, the simulation results approve that its forging curve is approaching to sine curve.

b) The accumulator fast forging circuit is a new energy saving mode, if only the accumulator parameters are rationally designed and selected, the simulation results



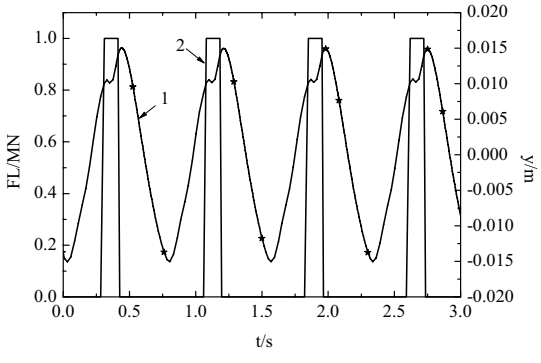
1. forging press displacement 2.input displacement
3. main cylinder pressure 4.return cylinder pressure

Figure 2 The displacement and pressure curve without Load



1. forging press displacement 2.input displacement
3. main cylinder pressure 4.return cylinder pressure

Figure 3 The displacement and pressure curve with load



1. external load 2.displacement

Figure 4. The external load curve

prove that it is feasible to use accumulator to realize fast forging.

c)Establishing kinematic equation of accumulator, and supply the gist of fast forging circuit design and accumulator select.

d)Establishing mathematic model of fast forging circuit with accumulator, hydraulic press dynamic characteristics is researched by simulation, which provides theoretical foundation for fast forging press design and application.

ACKNOWLEDGEMENT

This work is supported by the National Natural Science Foundation of China (NO.50575196).

REFERENCES

1. G.H.Zhang, Study of 80MN isothermal forging hydraulic press control system.(Master degree dissertation),Tianjin University,2005,pp.1-5
2. F.R.Biglari. Optimum design of forging dies using fuzzy logic in conjunction with backward deformation method. International Journal of Machine Tools＆Manufacture, 1998,38,pp.981-1000
3. X.L.Yue, “Hydraulic Press”, China Mechanical Press, 1982,pp.
4. L.X.Quan. the Therory and Experiment study on Accumulator Absorbing Pressure Pulsation without Entrance.[J].Chinese Journal of Mechanical Engineering ,2007,43-9,pp.28_32
5 N.L.Wu,.Accumulator Loading System Stiffness Analysis.[J].Engineering mechanie.2003,10,pp.20~23