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# Dynamic Simulation on Quadrangular leveling System under Proportional Technology

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**Abstract:** According to the special requirements of Sheet Molding Compound (SMC) a set of quadrangular leveling system is designed, whose leveling precision is controlled by electro-hydraulic proportional technology. Based on analyzing the components and working principle of the quadrangular leveling system, the mathematical model of this system is established. The dynamic characteristics of stability and anti-interference are simulated and analyzed. The results show that the main factors that can affect the dynamic characteristics of system are obtained and the system completely meets technical requirement after being corrected, the work in this paper can provide a high guidance for presses of similar kinds.

**Keywords:** Quadrangular leveling, Proportional technology, Dynamic simulation

## 1 Introduction

Because of the difference of geometric shapes and surrounding temperature or other factors, when the Sheet Molding Compound (SMC) hydraulic press is working, the deformation resistance of activities beams deviates the center of the compressor, as a result the activities beams bear from the overturning. In case the torque overturning is not balanced, most of it is transferred to hydraulic frame beams, which will cause the activities inclined and make leveling precision declining [1]. In order to produce high precision work-pieces, the overturning must be balanced to make tilt angle of the activity beams in a precision scope, then the stress of the compressor machine framework is improved and the service life of mould and ontology can be prolonged. In recent years, the electro-hydraulic proportional technology is used in the quadrangular leveling process of the SMC hydraulic press, which can realize horizontal adjustment of the activities beam in the press. It has many advantages such as simple structure, quick response speed, and high control precision, strong ability to provide against pollution and so on. This method can realize direct computer control and has good prospects in the application [2].

## 2 Control strategy design

The quadrangular leveling hydraulic system of SMC hydraulic press provides two functions in the leveling process: Leveling in the downward pressure and supporting active beams in the process while the mould is opened slightly [3]. In order to realize effectively these two functions, leveling system sets a benchmark cylinder, in which three other cylinders follow-up. when the low of slider is on the side of benchmark cylinder, the force that benchmark cylinder generates achieves a top leveling effect when the benchmark cylinder is down with the follow-up cylinder without the function on the slide block; When the lows of slider are on the side of the follow-up cylinders, the cylinder is in touch with the slider first with no force on the slider by the benchmark cylinder, and the tracking control system still remains detecting position of the benchmark cylinder to make the down chamber of follow-up cylinders to product press to lift up the side, which can achieve leveling effect. After completing the leveling, leveling cylinder descend passively as the resistance loading of slider. These two kinds of conditions appear alternately, which is the dynamic leveling process of the electro-hydraulic proportional valve which has the function of high-frequency reversed, this process in the low speed loading stages can get high leveling accuracy[4]. Leveling measurement system diagram is shown in figure 1:

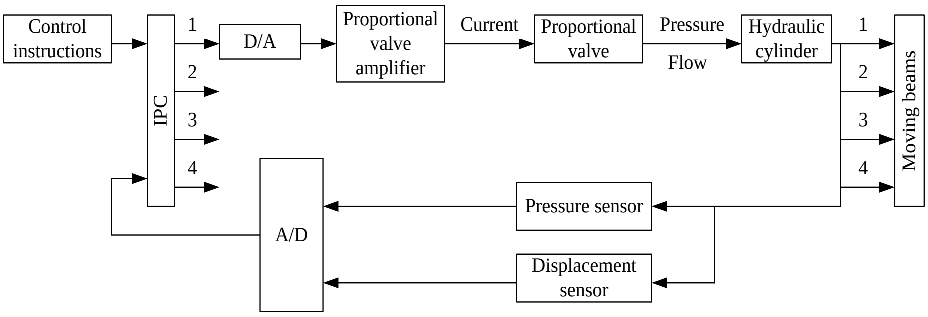


Fig .1 Block diagram of leveling measurement system

## 3 Mathematical models

The dynamic characteristic of hydraulic cylinder depends on valve, hydraulic cylinder and the load. Assuming system is a single-degree-of-freedom system, which is composed of mass, spring and viscous damper. Due to the differential equation of some dynamic mechanism nonlinear, the linear analysis method is used in order to facilitate analysis, namely research the characteristics of trace movement in a steady working condition [5].

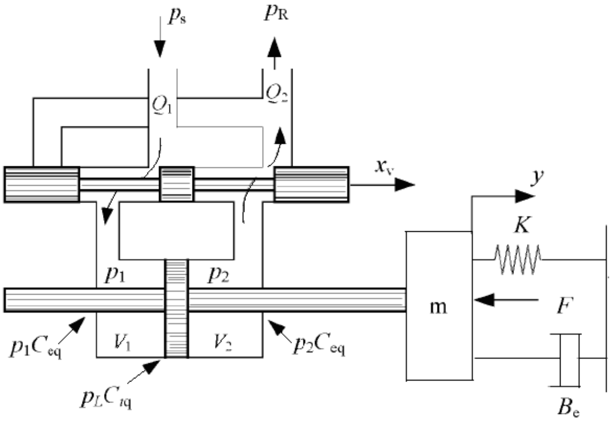


Fig.2 The load diagram of valve controlling cylinder

The load flow of proportional valve and flow continuity equation of Hydraulic cylinder is

$$Q_L = A_p \frac{dx_p}{dt} + C_{tp} p_L + \frac{V_t}{4\beta_e} \frac{dp_L}{dt} = k_q x_v - k_c P_L \qquad (3.1)$$

Where $Q_L$ is load flow, $A_p$ is effective area of piston, $x_p$ is piston displacement, $C_{tp}$ is total leakage coefficient of hydraulic cylinder, $\beta_e$ is composite elastic modulus of system, including liquid and structure stiffness. The force balance equation for the piston of the cylinder under load can be expressed as,

$$F_g = A_p(p_1 - p_2) = A_p p_L = M_t \frac{d^2 x_p}{dt^2} + B_p \frac{dx_p}{dt} + Kx_p + F_L \qquad (3.2)$$

where Mt is the total quality of piston and load, $B_p$ is the viscous damping coefficient of piston and load, $K$ is elastic stiffness of Load, $F_L$ is external load acting on the piston. $F_g$ is hydraulic cylinder pressure effect on the driving force. The transfer function of amplifier is

$$W_I(S) = \frac{I(S)}{U(S)} = K_a \qquad (3.3)$$

The transfer function of electro-hydraulic proportional valve is

$$W_s(S) = \frac{X_v(S)}{I(S)} = \frac{K_{sc}}{\dfrac{S^2}{\omega_s^2} + \dfrac{2\varepsilon_s}{\omega_s} S + 1} \qquad (3.4)$$

where $K_{sc}$ is the gain of proportional valve, $w_s$ is the natural frequency of the proportional valve, $\xi_s$ is damping ratio. The total output displacements of hydraulic cylinder for piston after Laplace transform is

$$x_p(s) = \frac{\dfrac{k_q}{A_p} x_v(s) - \dfrac{k_{ce}}{A_p^2}(1 + \dfrac{V_t}{4\beta_e k_{ce}} S) F_L(s)}{\dfrac{V_t M_t}{4\beta_e A_p^2} S^3 + (\dfrac{M_t k_{ce}}{A_p^2} + \dfrac{B_p V_t}{4\beta_e A_p^2}) S^2 + (1 + \dfrac{B_p k_{ce}}{A_p^2} + \dfrac{KV_t}{4\beta_e A_p^2}) S + \dfrac{Kk_{ce}}{A_p^2}} \qquad (3.5)$$

where $k_{ce}$ is the flow-pressure coefficient. Drawing the transfer function diagram by the formula of 3.5, as shown in figure 3:

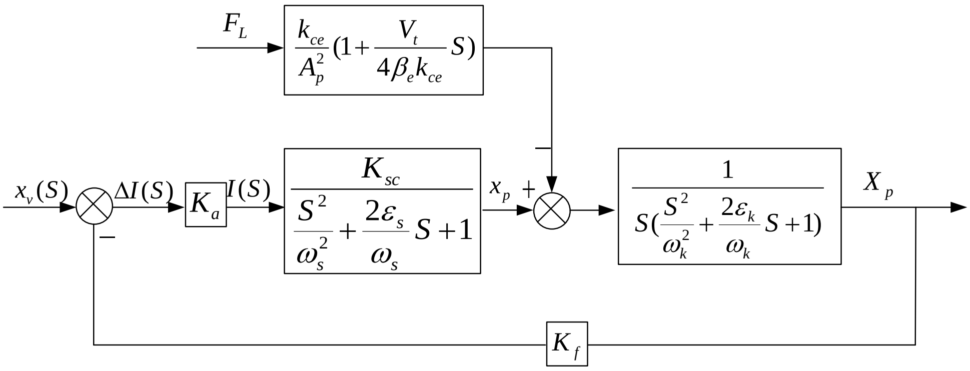


Fig.3. Block diagram of transfer function

According to the (3.3) (3.4) (3.5), the open-loop transfer function of system gotten is as follow:

$$\mathrm{W}(S)=\frac{K_v}{S(\frac{S^2}{\omega_s^2}+\frac{2\varepsilon_s}{\omega_s}S+1)(\frac{S^2}{\omega_k^2}+\frac{2\varepsilon_k}{\omega_k}S+1)} \tag{3.6}$$

where $K_v$ is open-loop gain, $w_k$ is hydraulic inherent frequency, $\xi_k$ is hydraulic damping ratio.

## 4 Simulation and analysis of the dynamic characteristics

In the circumstance except the load disturbance, the input parameters of model can get the unit step response figure of the system and the open-loop Bode curve, which is shown in figure 4:

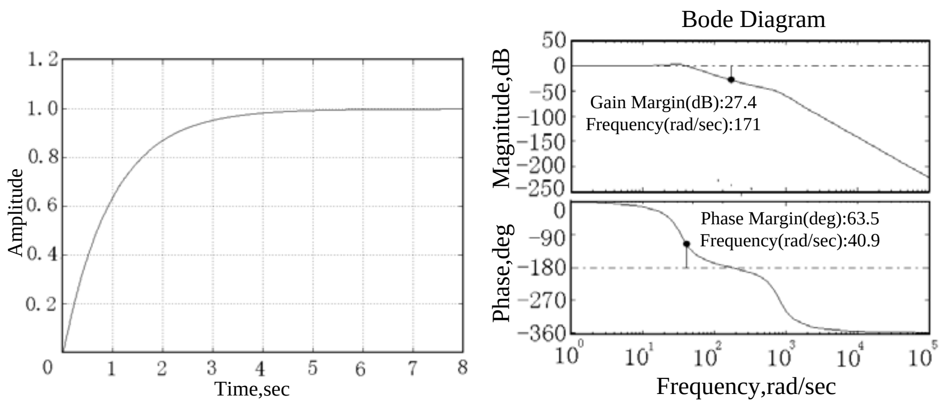


Fig.4 The unit step response of the system and the open-loop Bode curve

Fig.4 shows the amplitude margin of the system $K_g$ is 27.4 dB and the phase margin $\gamma$ is 63.5 º. Because the different parameters of hydraulic system for dynamic quality is mutual influence and restriction, reasonably selecting parameters of the system optimal performance becomes the focus of research, therefore a series of simulation can be used to research the influence of different parameters on the performance for the hydraulic system[6]. The impact amplifier and hydraulic inherent frequency have on the system characteristic is shown in figure 5:

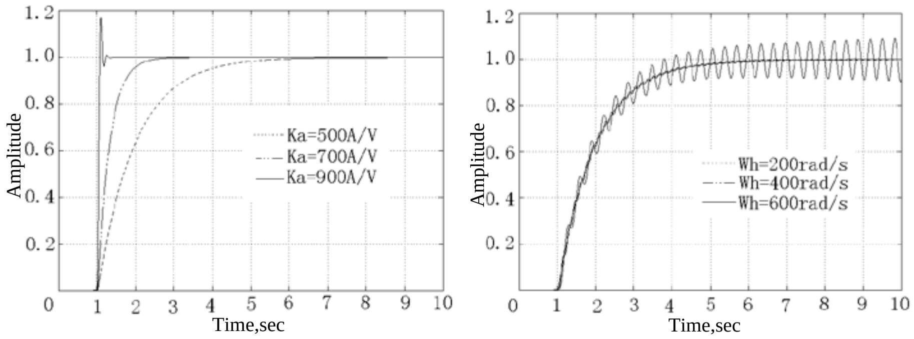


Fig.5 Amplifier on system performance and natural frequency on system performance

According to the analysis of the factors affecting the characteristics of system, using Design Tool can get the optimization of unit step response curve and open-loop Bode curve of the hydraulic system by the theory of control system for stable condition: $K_g$ (dB) $\geqslant$6dB, $\gamma$=30° ~60° , the results are shown in figure 6:

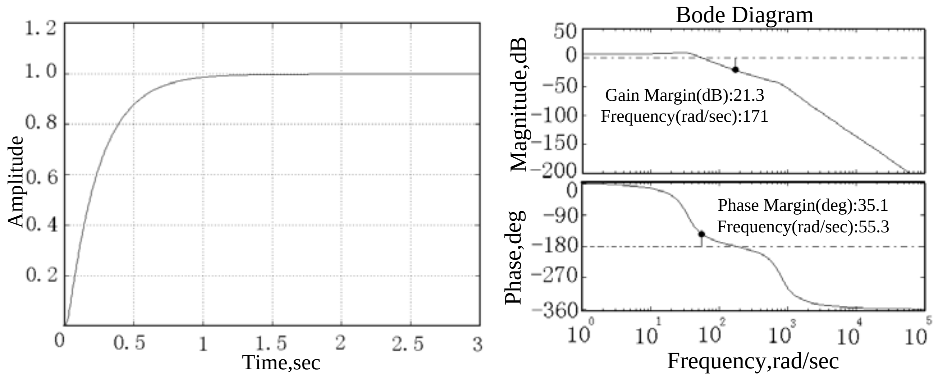


Fig.6 The unit step response curve and the open -loop Bode figure after correction

From Fig.6 it can be seen that the system response speed is accelerated after correction, adjusted time is 1.8s, overshoots and steady-state error is very small, amplitude margin $K_g$ is 21.3 dB, phase margin $\gamma$ is 55.3 °, which satisfy the requirement of system stability.

## 5 Conclusions

The amplifier can affect the dynamic quality of system, increasing the value of amplifier can increase the response speed of the system, but it is easy to produce oscillation and even divergent. Hydraulic inherent frequency for the stability of system have a certain effect, if this value reduced, it can make system produce overshoot and oscillation, increasing hydraulic inherent frequency can improve the oscillation of system to a certain extent, but not obvious oscillations. Simulation results show that the system completely meets technical requirement after being corrected. The quadrangular leveling technology in the article is in good validation, which can provide a high guidance for presses of similar kinds.

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