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Research Article

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Mechanism analysis and solve of the hydraulic fault of drill power unit

Zhao Guohua

Mechanical Engineering College of Hubei University of Automotive Technology, Shiyan, Hubei, PR China

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ABSTRACT

To has built mathematical modeling of system, in order to solve fibrillation not regularly appeared even crawl phenomenon in the feed phase of the hydraulic cylinder in HCZW5072 machine tool, on this basis, we analyzed the failure mechanism, thus established the ways to solve the fault, and better solved the fault. According to the actual situation, therefore, to can establish a mathematical model of system, we can analyze the further cause of the failure, and more likely obtain the method to solve the problem. It is an effective way to solve the problem of the mechanical engineering.

Key words: The hydraulic system; machine tool failure; mathematical modeling; mechanism analysis

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INTRODUCTION

The machine tool is drilling, expanding and reaming machine, used for processing Φ50*85 hole—workpiece material is casting HT20. In the process of feeding stage, tremor not regularly appeared even crawl phenomenon, and affects the processing quality and production. After a comprehensive inspection and maintenance of machine tool, that the fault was in the hydraulic system of the transmission part of the feed movement of the hydraulic cylinder was determined. Therefore, the hydraulic drive system of the equipment had been tested and analyzed, the reason of the failure was found out, and the flutter and the crawling was solved finally.

MATHEMATIC MODEL OF THE SYSTEM

The three parts is included in the hydraulic system of the machine tool,1) the driving part of the power head to realize feed movement, 2) the part of the drive wheel rotation to implement dividing movement, 3) the part of positioning and clamping workpiece. The action sequence is: dividing, positioning clamping and feeding, its dividing and positioning clamping movement do not influence the feed movement. The feed movement work cycle is: quick feed, working feed and quick retraction. The Failure occurs in the working feed, therefore , to analyze the cause of failure, the working performance of this hydraulic circuit is analyzed mainly.

Fig.1 is schematic diagram of the simplified working feed after removing irrelevant parts, it is an inlet throttling speed-regulating circuit consist of the quantitative pump, throttle valve, relief valve and hydraulic cylinder. The system dynamics differential equation [1, 2] is as follows, the parameters is as shown in Fig.1.

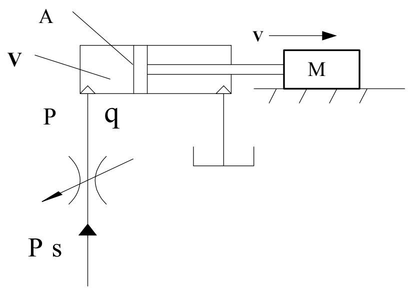

Fig. 1: the simplified hydraulic circuits of feed stage

The force balance equation in position is

$$m \frac{dv}{dt} + Bv + F_L = Ap \tag{1}$$

The flow balance equation in cylinder is

$$Av + K_l p + \frac{V}{K}\frac{dp}{dt} = q \tag{2}$$

And the flow into the throttle orifice is

$$q = C_d A_T \sqrt{\frac{2(p_s - p)}{\rho}} \tag{3}$$

Where, m is removable parts quality, v is hydraulic cylinder speed, B is the viscous damping coefficient of hydraulic cylinder at motion, V is the inlet cavity volume of hydraulic cylinder and tubing, F_L is the external load, A is working area of hydraulic cylinder, K_l is leakage coefficient of hydraulic cylinder, p_s is hydraulic pressure of the system—to remain unchanged by the overflow valve, K is bulk modulus of the hydraulic, p is hydraulic pressure of working chamber of the hydraulic cylinder, ρ is oil density.

The above Eqn.3 is transformed into incremental form, that is

$$\Delta q = q - q_0 = -\frac{1}{2} C_d A_T \sqrt{\frac{2}{\rho_0}} (p_s - p_0)^{-1/2} (p - p_0)$$

Letting

$$K_p = \frac{1}{2} C_d A_T \sqrt{\frac{2}{\rho_0}} (p_s - p_0)^{-1/2}, \quad \Delta p = p - p_0,$$

Yields

$$\Delta q = -K_p \Delta p \tag{4}$$

The Eqn.1 and Eqn.2 are transformed into incremental form, and "Δ" is omitted, then taking Laplace yields

$$\begin{cases} msv(s) + Bv(s) + F_L(s) = Ap(s) \\ Av(s) + K_l p(s) + \dfrac{V}{K} sp(s) = q(s) \\ q(s) = -K_p p(s) \end{cases} \tag{5}$$

Among Eqn.5, parameter values at the balance are v_0,q_0,p_{L0} and F_{L0},by Eqn.5 yielding

$$= -\frac{1}{B(K_l + K_p) + A^2} \frac{(K_l + K_p + \frac{V}{K}s)\omega_n{}^2}{s^2 + 2\xi\omega_n s + 1} \tag{6}$$

In Equ. 7, the natural frequency and damping ratio are

$$\omega_n^2 = \sqrt{\frac{(A^2 + B(K_l + K_p))K}{Vm}} \tag{7}$$

$$\xi = \frac{\omega_n}{2K} \frac{Km(K_l + K_p) + VB}{A^2 + B(K_l + K_p)} \tag{8}$$

MECHANISM ANALYSIS AND RESOLUTION OF FAULT

There may be Loose parts for workpiece are casting , when processing in this area, there will be the phenomenon that a feed cutting force suddenly decrease and increase over time τ , in the meantime two step excitation signals(F_{0l} and $F\tau_L$) in the opposite direction is applied Successively on the hydraulic cylinder.

$$F_{0L} = \begin{cases} -F_{L0} & 0 \le t < \tau \\ 0 & t \ge \tau \end{cases} \tag{9}$$

$$F_{\tau L} = \begin{cases} F_{L0} & t \ge \tau \\ 0 & t < \tau \end{cases} \tag{10}$$

That is $F_{\tau l} = -F_{0l}(t - \tau)$,to Equ. 9 and Equ.10 taking Laplace yields

$$F_{0l}(s) = -\frac{1}{s}F_{L0} \quad , \quad F_{\tau l} = e^{-\tau s}\frac{1}{s}F_{L0}$$

To Equ.8 application of superposition theorem yields

$$v(s) = G_F(s).F_{0l}(s) + G_F(s).F_{\tau l}(s) = -G_F(s).\frac{1}{s}.F_{L0} + G_F(s).e^{-\tau s}.\frac{1}{s}F_{L0} \tag{11}$$

To Equ.11 taking inverse Laplace yields

$$\Delta v(t) = \Delta v_0(t) + \Delta v_\tau(t) \tag{12}$$

In Equ. 12,that is

$$\Delta v_0(t) = \frac{F_{L0}(K_l + K_p)}{A^2 + (K_l + K_p)B}\left[1 - \frac{1}{\sqrt{1-\zeta^2}} e^{-\xi\omega_n t} \sin(\omega_n + \sqrt{1-\xi}\ t + \arcsin\sqrt{1-\xi^2})\right] +$$

$$\frac{F_{L0}}{A^2+(K_l+K_p)B}\frac{V}{K}\frac{\omega_n}{\sqrt{1-\xi^2}}e^{-\xi\omega_n t}\sin(\omega_n\sqrt{1-\xi^2}t) \tag{13}$$

$$\Delta v_\tau(t) = -\Delta v_0(t-\tau) \tag{14}$$

$$v(t) = v_0 + \Delta v(t) = v_0 + \Delta v_0(t) - \Delta v_0(t-\tau) \tag{15}$$

The simulation results are shown in Fig.2,according to Equ,13,14,15 (v_0=0.2mm/s, τ =0.4s)

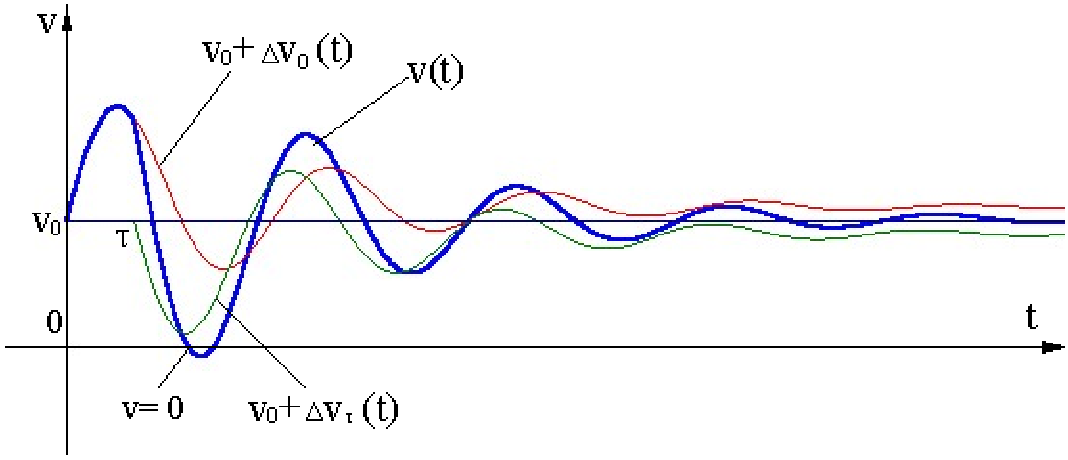

Fig.2: simulation results of speed in the corresponding phase

As shown in Fig.2, for load changes, speed fluctuation is caused, and decay to zero in the 0.34s < τ < 0.81s, thus chatter vibration and crawl of the hydraulic cylinder is caused. By analysis on the time-domain response of the system in reference[3], the wave peak of system dynamic response mainly depends on the damping ratio ξ, the greater the ξ is, The smaller the peak is, whereas The greater, so to reduce or eliminate the tremor and crawl phenomenon, ξ can be increased. Based on the analysis of Equ.9 and Equ.10, V, B and m increase and K and A decrease, Then ξ increase, Whereas ξ decrease. In these factors affecting ξ, for the existing system only to increase V is easy to implement, so eventually an accumulator increased in hydraulic cylinder inlet[4, 5]. In the working operation speed fluctuation was reduced greatly, tremor phenomenon was not obvious. So basically the desired effect was achieved.

CONCLUSION

From the above analysis available, by the establishment of the mathematical model of equipment with the hydraulic system, according to the actual situation, it is an effective way that the input signal is abstracted firstly (in this system, Successively input signals is the two step-function signal in the opposite direction), then the malfunction cause of random instability of speed is judge, and finally ways to solve fault is found out.

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