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The Stability of the Hydraulic Servo System to Determine Methods based on MATLAB

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***Abstract*—At present most of the design of textbooks and materials are used to stabilize the bode diagram of hydraulic servo control system to determine the stability of; In this paper, using MATLAB to describe the open-loop transfer function, combined with extreme pzmap to analyze the distribution of its open-loop system nyquist maps, and time-domain analysis and comparison of the graphics, graphics, intuitive and very easy to determine the stability of the system. This article describes methods for hydraulic servo control system to promote the**

***Index Terms*—hydraulic servo control system,stability; MATLAB,closed-loop system**

I. INTRODUCTION

In classical control theory, a control system are different from many of the features of the components coupled by way of a certain form. In accordance with the function of these components can be divided into measurement, enlarge the role of the implementation of such components. However, if the view from the mathematical model can be divided into these components or systems composed of a number of links, then summed up in these types of links in a typical type of differential equations were obtained and their transfer function.

Coefficient of linear time-invariant open-loop transfer function, after appropriate transformation, can be written-down

$$G(s)=\frac{\prod_{i=1}^{\chi}K_i\prod_{i=1}^{\mu}(\tau_i s+1)\prod_{i=1}^{\eta}(\tau_i^2 s^2+2\xi_i\tau_i s+1)}{s^v\prod_{j=1}^{\rho}(T_j s+1)\prod_{j=1}^{\sigma}(T_{nj}^2 s^2+2\xi_j T_{nj}s+1)} \qquad (1)$$

Where K_i ——Magnification factor;

τ_i, T_j, T_{nj} ——Time constant;

ξ_i , ξ_j ——Damping ratio。

Determine the stability of the classical system, one using Routh criterion to determine the closed-loop system characteristic equation of the first column of Routh table of all the elements are greater than zero, this method commonly used in the range of system variables, there is no intuitive graphics; Second, hand-painted bode diagram, according to the amplitude margin and phase margin to determine the value of the stability of the system. Bode diagram mapping the general open-loop transfer function will be broken down into type (1) as shown in the transfer function of a typical part of the product, and then the first order, second-order transfer of part of the frequency, the frequency of the transfer in accordance with the order from small to large S in the plot the frequency of the number of axis, the frequency of the link drawn by the handover has been completed, after stacking system bode diagram. In the absence of computer-aided cases it is easier to determine the achievement of stability. But for multi-input / multiple output (MIMO) system, we must have to complete computer-aided. Although the circumstances in MATLAB can draw bode diagram to determine the stability of the closed-loop system, but the margin in accordance with the parameters obtained, it is difficult to accurately determine the stability of the system. In this paper, using MATLAB to describe the open-loop transfer function, combined with extreme pzmap to analyze the distribution of its open-loop system of the nyquist diagram and time-domain analysis and comparison of the graphics, graphics, intuitive and very easy to determine the stability of the system.

Here's an electric hydraulic servo-hydraulic control system as an example to illustrate this.

II OPEN-LOOP TRANSFER FUNCTION MODEL

In engineering practice, power control system for a very wide application, such as material testing machine, fatigue testing machine structures, rolling mill tension control system, the wheel brakes are electric hydraulic control system.

Electric hydraulic control system mainly by the servo amplifier, electro-hydraulic servo valves, hydraulic cylinders and components, such as force sensors [2], As shown in Figure 1.

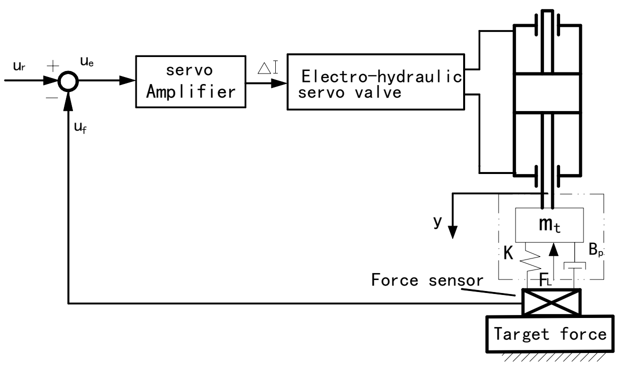

Fig 1 Schematic of hydraulic control system

When the installation instructions issued by the role of command voltage signal to the system, the hydraulic cylinder output force there, the force detected by the sensor signal into a feedback voltage Uf and Ur-phase

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command voltage signal comparison, the bias voltage signal Ue = Ur-U_f . Ue this bias voltage signal amplified by the servo amplifier input to servo valves, servo valves have openings so that the amount of oil pressure in the hydraulic cylinder piston to reduce the error of output force to the direction of change, until the output force command signal equal to So far as the value requirements. In the steady-state cases, the output force is proportional with the deviation signal. Because we want to maintain a certain degree of output power requires a certain degree of servo-valve opening, so this is a zero-based systems are poor. Its open-loop transfer function as follows:

$$G(s)H(s)=\frac{K_0 G_{sv}(s)\left(\frac{s^2}{\omega_m^2}+1\right)}{\left(\frac{s}{\omega_r}+1\right)\left(\frac{s^2}{\omega_0^2}+\frac{2\zeta_0}{\omega_0}s+1\right)} \qquad (2)$$

where ω_m ——The natural frequency of the load，

$$\omega_m=\sqrt{\frac{K}{m_t}}$$

ω_r ——Hydraulic spring in series with the load spring stiffness and damping coefficient of the coupling ratio, $\omega_r \approx \frac{K_{ce}K}{A_P^2}$；

ω_0 ——Hydraulic spring coupled in parallel with the load spring stiffness and load the quality of the formation of the natural frequency, $\omega_0=\sqrt{\frac{4\beta_e A^2{}_p}{V_t m_t}}$;

ζ_0 ——Damping ratio， $\xi_0=\frac{K_{ce}}{4}\sqrt{\frac{\beta_e m_t}{V_t}}$

K_q / K_{ce} ——Gain total pressure.

K_0 —— System open-loop gain ,

$$K_0=K_a K_{sv}\frac{K_q}{K_{ce}}A_P K_{fF}$$

Assumed that the system described in Figure 1, it is designed to keep the system the driving force for the single degree of freedom control system, the maximum load force 88200N, stroke hydraulic cylinder 0.1m, the load spring stiffness 8.8x105N / m, the load weight of 450kg, the time constant for the 10s. According to calculation, the following system of open-loop mathematical model:

$$G(s)H(s)=\frac{\left(\frac{0.05}{1+10s}\right)\left(\frac{s^2}{44.22^2}+1\right)}{\left(\frac{s}{0.024}+1\right)\left(\frac{s^2}{490^2}+\frac{2\times 0.031}{490}s+1\right)} \qquad (3)$$

Programming to achieve the above-mentioned open-loop transfer function description of the MATLAB：

```
num=0.05*[1/44.22^2  0  1];
den=conv(conv([10  1],[1/490^2  2*0.031/490 1]),[1/0.024 1]);
sys=tf(num,den)
sys_close=feedback(sys,1)
```

In the MATLAB command window to run the above command with the system of open-loop transfer function and closed-loop transfer function:

```
Transfer function:
                 2.557e-005 s^2 + 0.05
-------------------------------------------------------------
0.001735 s^4 + 0.05294 s^3 + 416.7 s^2 + 51.67 s + 1
```

（System open-loop transfer function）

```
Transfer function:
                 2.557e-005 s^2 + 0.05
----------------------------------------------------------------
0.001735 s^4 + 0.05294 s^3 + 416.7 s^2 + 51.67 s + 1.05
```

（System closed-loop transfer function）

III STEP-INPUT MEPONSIVE CURVES

A dynamic performance of the system used under a typical input to describe the response. In response to the initial value of zero refers to conditions, a typical input function of the response under the object, the hydraulic servo system commonly used input functions as a unit step function and pulse excitation function (ie impulse function).

In the MATLAB Control System Toolbox to provide input under the two systems in response to the function. Commonly used input functions are unit step function Step (), impulse response function impulse () function and time-domain analysis. Function can call the following format:

y=step(sys_close) and y= impulse (sys_close)

Sys_close system where the closed-loop transfer function.

Closed-loop transfer function for the above-mentioned time-domain analysis of programming:

```
figure(1)
subplot(121)
step(sys_close)
grid
subplot(122)
impulse(sys_close)
grid
```

In the MATLAB command window to run the above procedure has been shown in the graph in Figure 2.

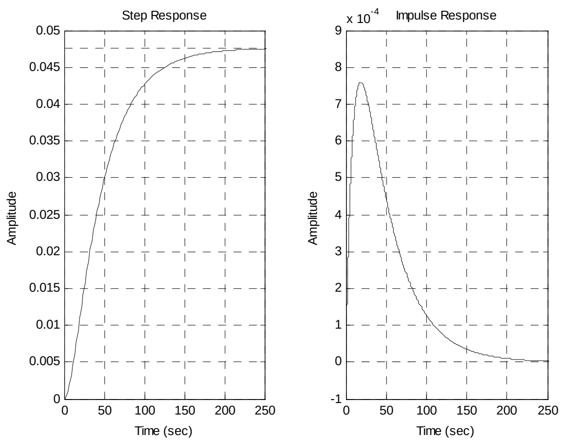


Figure 2 in response to time-domain closed-loop system

Analysis show from figure2: the system is stable.

IV NYQUIST CURVE

Open-loop transfer function using the nyquist curve combined with open-loop transfer function of the zero-pole distribution maps, to determine the stability of the closed-loop system, the criterion is:

（1）If the poles are located in the left side of the imaginary axis, namely the right of most virtual axis points p = 0, then do not surround nyqusit curve (-1, j0);

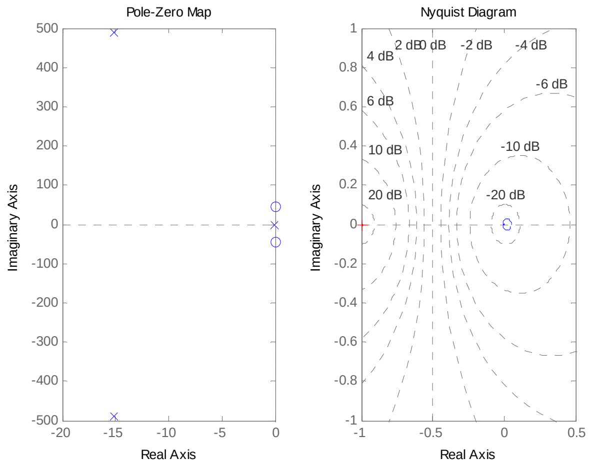
（2）If i were imaginary axis poles are located in the right side, namely the right of most virtual axis points p = i, then surrounded nyqusit curve (-1, j0) i circle.

For the above-mentioned open-loop transfer function programming to determine the stability of the closed-loop system:

```
figure(2)
subplot(121)
pzmap(sys)
subplot(122)
nyquist(sys)
grid
```

After running the above procedure, the system nyquist curve shown in figure 3.

In the MATLAB command window to run the above procedure has been shown in the graph in Figure 3. As can be seen from Figure 3: the right side of the pole virtual axis p = 0, nyquist curve is not surrounded by (-1, j0), therefore the stability of the closed-loop system.



(a) Pole distribution (b) nyquist graph

Figure 3 Distribution of the system poles and nyquist curve

V BODE DIAGRAM

Bode diagram, when the frequency ω as ω_g at the junction phase, $\phi(\omega_g) = 180^o$. Open-loop amplitude-frequency characteristics of the countdown $|G(j\omega)H(j\omega)|$, known as the amplitude margin system, namely:

$$kg = \frac{1}{|G(j\omega)H(j\omega)|} \quad (4)$$

To stabilize the system Kg> 1; for instability in the system Kg <1.

In the Bode diagram, the amplitude margin to the decibel (dB) that

$$20\lg|k_g| = 20\lg\frac{1}{|G(j\omega_g)H(j\omega_g)|} = -20\lg|G(j\omega_g)H(j\omega_g)|$$

to stabilize the system, Kg (dB) must be in the 0dB line, Kg (dB)> 0, at this time is referred to as amplitude margin; for the unstable system, Kg (dB) must be above the 0dB line, Kg (dB) <0, now known as the negative amplitude margin.

Bode diagram, when the frequency ω for the ω_c at the junction phase, the phase-frequency characteristics from the phase-180o line value of γ is called the phase margin.

$$\gamma = 180^o + \phi(\omega_c) \quad (5)$$

In the Bode diagram, γ must be in the above-180^o, γ is positive at this time that the phase margin; for instability in the system, γ must be in the line-180^o, at this time that the value of γ for the phase margin.

Speaking from the control engineering practice, in order for the system has satisfactory stability margin, the general so that

$$\gamma = 30^o \sim 60^o$$
$$kg(dB) > 6dB \text{ 即 } kg > 2 \quad (6)$$

In the MATLAB command window, type:

```
figure(3)
margin(sys)
grid on
```

Be in the graphics window bode diagram shown in Figure 4, we can see from Figure 4: When $\omega_g = 31.4 rad/\sec$, the amplitude margin Gm = 144dB, while the phase margin Pm = inf, in accordance with fuzzy data bode diagram, it is difficult to accurately determine the system stability.

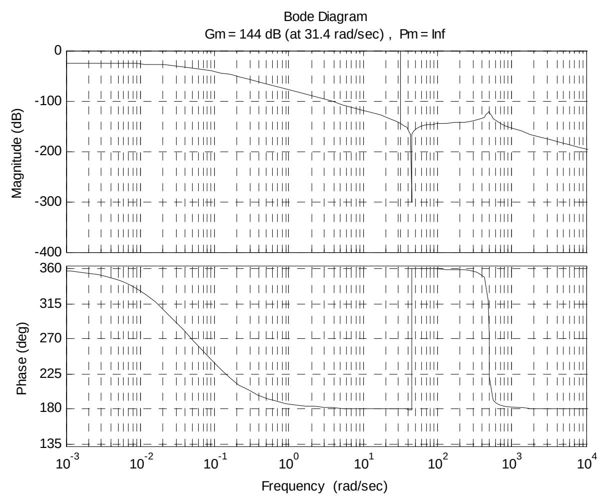


Fig 4 Open-loop system bode diagram

VI CONCLUSION

Hydraulic Servo System Based on concrete examples to introduce the use of MATLAB software to determine the stability of the method. As can be seen in accordance with the stability margin bode very difficult to determine whether the system is stable, while the closed-loop transfer function in accordance with the time-domain analysis and open-loop transfer function of the combination of pole nyquist curve distribution, it is intuitive to determine whether the system is stable. Therefore, to determine the stability of MATLAB-based, it is proposed that we will not bode diagram used to determine the stability of the system.

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