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Neural Network PID Control Application of Hydraulic position Servo System for Precision Improvement

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Abstract. The anti-rolling tank swing bench is a typical hydraulic position servo system. Its function is to simulate the ship roll motion and to verify the performance of the anti-rolling tank. During experiments, the different disturbance torques are generated according to the different dimension scales of the anti-rolling tanks. Changes of the natural characteristics of the system are caused by changes of load. In order to reduce the influences caused by the factors mentioned above, a BP neural network PID control system based on virtual instrument LabVIEW is designed. By simulating the responses of the system in real time control, the verification tests using actual system are avoided. Finally, the experiments of swing bench are carried out. The results show that the controller can ensure the control accuracy and stability. The parameters tuning process efficiency is improved.

Keywords: anti-rolling tank swing bench; hydraulic servo system; BP neural network PID control; LabVIEW.

1 Introduction

In order to verify whether the performance of anti-rolling tank meets the requirements or not, experiments are needed to be carried out. The anti-rolling tank swing bench is an experiment device to verify the requirements. It can simulate the motion of ship in waves.[1-2].

In previous studies, some controllers are designed to improve the accuracy and robustness of the hydraulic position servo system. In reference[3], a PID controller is designed, and the method is easy to be realized, but the control effect is not good when the load changes. In reference[4], in order to compensate interference torque owing to the fluid sloshing in tank, composite controller is designed based on PID disturbance observer and speed feedforward. It expands system bandwidth, but there are some phase lag between the input and output. So it can not meet the experimental requirements of smaller scale anti-rolling tank model. In reference[5], it designs a robust controller to achieve good effect by converting the deviation to the uncertainty of the model. However, it is simulated on a computer and not verified in actual system. In reference[6], a controller based on robust loop shaping is designed to achieve a good control performance. But the control parameters are fixed and are not self-adjusted against the change of load parameters[7].

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The controller is designed in LabVIEW to achieve closed-loop control and data acquisition. When the system parameters change, the controller parameters are adjusted through the simulation program. After it is simulated to achieve the desired objectives, the controller parameters are loaded into the actual system.

2 Hydraulic servo system model

The rolling hydraulic servo system of the swing bench comprises controller, servo valve, swing cylinder, test platform and angular sensor[8].

The rolling hydraulic servo system can be translated by Laplace transformation as follow:

$$Y=\frac{\frac{K_q}{A}X_v-\frac{K_{ce}}{A^2}\left(\frac{V_t}{4\beta_e K_{ce}}s+1\right)F}{\frac{mV_t}{4\beta_e A^2}s^3+\left(\frac{mK_{ce}}{A^2}+\frac{B_cV_t}{4\beta_e A^2}\right)s^2+\left(\frac{KV_t}{4\beta_e A^2}+\frac{B_cK_{ce}}{A^2}+1\right)s+\frac{KK_{ce}}{A^2}} \tag{1}$$

Where： $K_{ce}=K_c+C_{tc}$ is the whole flow-pressure coefficient.

As the load of test bench is inertia load, and elastic load is very small which could be ignored, then it can be regarded as K_c =0 and then $K_{ce}=C_{tc}$. B_c is very small which could be ignored.

The equation (1) is simplified as:

$$Y=\frac{\frac{K_q}{A}X_v-\frac{K_{ce}}{A^2}\left(\frac{V_t}{4\beta_e K_{ce}}s+1\right)F}{s(\frac{s^2}{{\omega_h}^2}+\frac{2\zeta_h}{\omega_h}s+1)} \tag{2}$$

Where： ω_h is the natural frequency of hydraulic pressure. ζ_h is the hydraulic damping ratio.

$$\zeta_h=\frac{K_{ce}}{A}\sqrt{\frac{\beta_e m}{V_t}} \tag{3}$$

$$\omega_h=\sqrt{\frac{4\beta_e A^2}{V_t m}} \tag{4}$$

The open-loop transfer function of rolling system:

$$P_r=K_aK_f\frac{K_Q}{A}\frac{1}{k}\frac{1}{s\left(\frac{s^2}{{\omega_h}^2}+\frac{2\zeta_h}{\omega_h}s+1\right)} \tag{5}$$

Where: k is swinging cylinder’s transmission radius.

3 Controller design

The design steps of BP neural network PID controller are as follows:

(1) Initialize. After the structure of the BP neural network is selected, all of connection weights should be given the initial value. Each initial values of connection weight is a random number.

(2) Obtain the input signal of BP neural network and calculate the output. The output of network is calculated according to the feedforward method.

(3) Calculate the output of controller. Controller output is calculated in accordance with the incremental PID control and the control signal of the controlled object is obtained.

(4) Adjust the weighted coefficient. The connection weights of the network are adjusted.

(5) Repeat steps 2~4.

In order to realize controller design rapidly and effectively, appropriate virtual instrument is needed to make it suitable for hydraulic position system of swing bench. LabVIEW can be convenient for modeling, simulation, data acquisition and processing. Therefore, it can be competent for the work.

The LabVIEW control panel of system is shown in Figure 1.

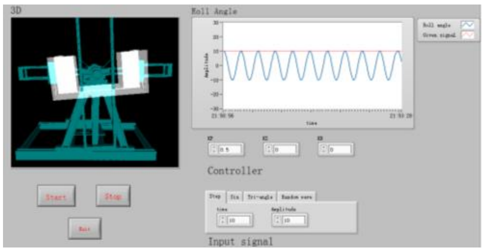

Fig. 1 LabVIEW control panel of system

4 Experiment

To avoid the influence of the scale effect, the swing bench is designed by a certain scale according to resilience and disturbing force of ship and the anti-rolling tank. The maximum achievable rolling range is 30°. As is shown in Figure 2.

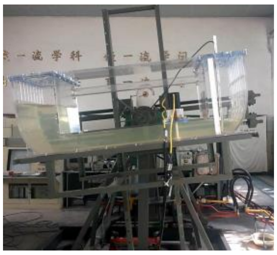

Fig. 2 Anti-rolling tank swing bench

Swing bench is a position servo system, which needs achieve fast and accurate tracking of the dynamic signal and has good robustness. To test the real time control effect, tracking experiments are carried out using the step signal, sinusoidal signal and random rolling angle signal. They are shown in Figure 3. (a) ~ (c) are the three response curves, and (d) ~ (f) are the corresponding controller parameters curves.

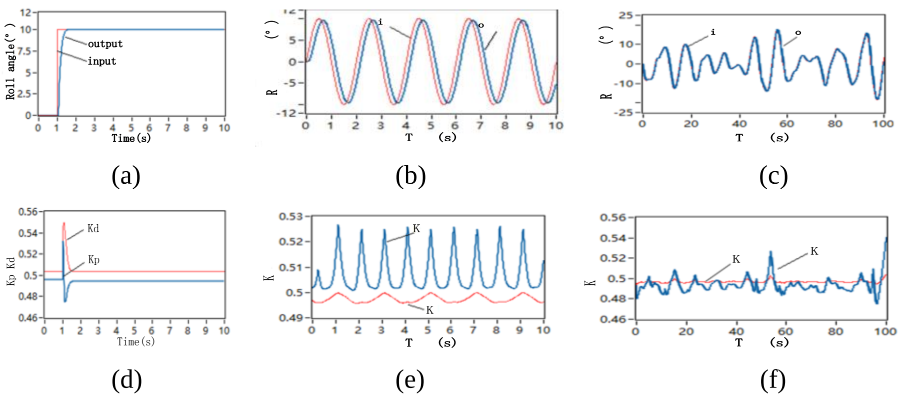

Fig. 3 Response curve and controller parameters curve

It can be obtained from Figure 3 (a) and (d): The system output is no overshoot, fast and stable in 0.5s by using the designed controller. The controller parameters vary all the time. It can be obtained from Figure 3 (b) and (e): The tracking performance of system is also quite good for sinusoidal signal which varies slowly and the parameters are continually changing with the change of deviation. Periodic tracking response has been well verified. It can be concluded from the results that the system can quickly and accurately track for the simulation in real sea off random rolling signal. The controller parameters are continuously adjusted in the dynamic tracking of input signal. It can meet the requirements of actual system.

5 Conclusion

Aimed at the uncertainty problems of swing bench, this paper designs a controller using BP neural network PID method based on LabVIEW to improve the servo system's adaptability and possess the performance of approaching any continuous bounded nonlinear function. The controller parameters are adjusted by BP neural network automatically, and the favourable stability and tracking accuracy are able to be provided.

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