Modeling and Simulation of Force Control System of Triaxial Testing Machine Based on AMESim/Simulink

JIAPING LI, MINGFU YIN, ZHENHONG ZHAO and ZHENGAO WANG

ABSTRACT

A servo force control system based on iterative learning control algorithm is proposed for the characteristics of nonlinear, strong cross coupling and parameter uncertainty of triaxial loading hydraulic servo system. Through the mathematical modeling of hydraulic servo force control system to determine the control parameters of the iterative algorithm, finally, the AMESim/Simulink is used to model and combine the simulation. The simulation results show that the control method can effectively improve the control accuracy of the three-axis loading servo-control system and improve the response speed of the system. The simulation results show that the control method can effectively improve the control accuracy of the three-axis loading servo-control system and improve the response speed of the system.

INTRODUCTION

The rotary triaxial loading test system is designed to simulate the deep environment of the stratum in the laboratory environment and to reproduce the physical conditions of the deep rock under formation pressure and groundwater power (hydrodynamic seepage), and to design a mechanical system for studying the comprehensive mechanical properties of rock. The core of the system is the hydraulic servo system, and its performance characteristic has great influence on the design of the control system.

Because of the non-linear, time-varying, uncertain parameters and disturbances of the hydraulic servo system, the traditional PID control strategy can not meet the requirements of the system. In view of the Rotary triaxial loading test force control system, a method of AMESim/Simulink combined simulation is presented to verify the performance of iterative learning control and to obtain good control effect.
ITERATIVE LEARNING CONTROL

The main idea of iterative learning control algorithm is to make use of existing experience and real-time tracking error, to revise the input of the next control model through iterative iteration through some learning law, so that the actual output of the system is approaching the desired output. This control method has a good effect on the force control system with nonlinear, strong cross coupling, difficult modeling and high parameter uncertainty.

The dynamic process of setting the controlled object is:
\[
\begin{align*}
\dot{x}(t) &= f[x(t), u(t), t] \\
y(t) &= g[x(t), u(t), t]
\end{align*}
\]

The K time is:
\[
\begin{align*}
\dot{x}_k(t) &= f[x_k(t), u_k(t), t] \\
y_k(t) &= g[x_k(t), u_k(t), t]
\end{align*}
\]

The error at the kth time is:
\[
u_{k+1}(t) = L(u_k(t), e_{k+1}(t))
\]

Its learning Control law is:
\[
u_{k+1}(t) = u_k(t) + P e_{k+1}(t) + I \int_0^t e_{k+1}(\tau) d\tau + D \dot{e}_{k+1}(t)
\]

where \(P, I\) and \(D\) is the learning gain matrix.

SIMULATION ANALYSIS

AMESim Simulation Model

In this paper, we use the AMESim and Simulink to combine the simulation, both of which are compiled by S function and parameter processing, which can give full play to its powerful digital processing ability to get more accurate control system model to complete the simulation. The whole model of loading system can be established according to the standard component library provided by AMESim. The overall model of the load system built is shown in Figure 1.
Simulink Simulation Model

According to the algorithm calculation flow of iterative control learning, the Simulink Force control model is established according to the process of the joint simulation. The iterative process of the iterative learning control algorithm requires the application of "To Workplace" and "From Workplace" to complete the task of storing, reading and calling parameters such as intermediate variables, input and output of the system during simulation. The Simulink simulation model based on iterative learning controller is shown in Figure 2, where $t$ is the control system simulation time, Fcn module, after the iterative learning end loop, stores the coefficient $K + 1$ in the to workplace. Postion Transform, Postion Transform1, Postion Transform2 and Force Transform are the role of displacement and load voltage command signal into the corresponding actual displacement and load and output to the corresponding oscilloscope display.
Simulation Results

The test waveform of servo hydraulic cylinder force control is mainly oblique wave signal, sine signal, triangular wave and composite signal, and the test force loading rate is 0.01kN/s ~100kN/s. The test force control accuracy requirement is less than ±4KN. In order to test the dynamic performance of hydraulic loading servo system, the sample loading load rate is taken as 100kN/s, the sampling period is 1 ms, and the number of iterations is 2 times.

Ramp Signal Simulation

The control mode is load constant load, the maximum value of the ramp signal is 400kN, and the simulation time is 4s. Hydraulic cylinder force control tracking ramp signal simulation results shown in Figure 3. It can be seen from Figure 3, the servo system control error can meet the accuracy requirements. In the initial stage, the tracking error of the system is large, but still within the control error range. In 3.5-4 seconds, because the stiffness of the specimen before the failure of a large drop, resulting in servo hydraulic cylinder piston control instability, tracking error has increased.

Figure 3. Target track and tracking error of the ramp signal.

Figure 4. Target track and tracking error of the sinusoidal signal.
Sinusoidal Signal Simulation

The maximum value of sinusoidal signal is 400KN, the specimen deformation loading rate is about 100kN/s, and the simulation time is 24s. Hydraulic cylinder force control tracking sinusoidal signal simulation results shown in Figure 4. It can be seen from the graph that the sinusoidal signal tracking error has some fluctuation in the whole phase, and its fluctuation is within the allowable range of error.

Triangle Wave Signal Simulation

The control mode is equal-speed loading, constant loading, equal speed load-reducing, maximum oblique-wave composite signal is 400kN, the simulation time is 30s (loading 4s, constant loading 2s, load-reducing 4s). Simulation Results of triangle wave composite signal in hydraulic cylinder force control and tracking as shown in Figure 5, in the whole loading process, the fluctuation appears in the place of loading state transformation, but it is still within the controllable range.

CONCLUSION

Aiming at the characteristics of nonlinear, time-varying, uncertain parameters and disturbances of hydraulic servo force control system, a servo force control system based on iterative learning control algorithm is proposed. Based on the model of hydraulic servo system established by AMESim and the iterative learning control model established by Simulink, the control system is simulated, and the simulation results validate the good control effect of the iterative learning control in this hydraulic pressure control system.

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