

Research on Electro-hydraulic Control of Spreader Loading based on Variable Speed Integral PID Algorithm

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Abstract

Aiming at the spreader loading machine using other PID control algorithm in the set value, the integral will cause a large overshoot, and it even cause system oscillation problems, algorithm utilizing the proportional relief valve for variable integral PID control scheme is proposed. Through the establishment of mathematical model of the proportional overflow valve, The block diagram of the valve transfer function is obtained, and the static and dynamic characteristics of the valve are analyzed. Through the cone valve pilot level transfer function block diagram of the control object characteristics of high gain low frequency, provide the basis for the design of the control system. Finally, the feasibility of applying the variable speed integral PID control algorithm to the loading control of the flexible specimen loading machine is determined by the joint simulation of Matlab and AMESim. The result shows that the variable integral PID control algorithm can keep good control performance in a small deviation and large deviation, not only there is no overshoot or oscillation, and the loading process is more gentle, further improve the performance of the controller.

Keywords

Electro-hydraulic proportional relief valve;variable speed integral PID;static loading.

1. Introduction

With the continuous development of the transportation industry, the number of newly built and expanded port terminals is increasing day by day, and the loading and unloading workload of the port is also rising linearly. At the same time, safe loading and unloading is often neglected in the task of grabbing tasks, capturing targets, striving for advancement, and completing loading and unloading tasks ahead of schedule and in excess. Wire ropes are commonly used as traction parts in port spreaders. Wire ropes for various purposes (such as wire rope slings, etc.) will have various damages after being used for a period of time. In order to prolong the service life of the wire rope and prevent accidents, the wire rope should be routinely inspected, especially the wire rope that has not been used for a long time. , It should be identified before use. The stress of the steel wire rope is more complicated, and it is still impossible to use strict mathematical formulas for accurate calculation [2]. Therefore, whether the wire rope is qualified or not, the manufacturer should use a loading test machine to load test it. The mechanical structure and hydraulic system of the loader have a certain influence on the loading accuracy, but the key factor affecting the accuracy is the performance of the control system. Static loading testing machines mostly use PID control methods. PID control has been widely used in the industrial field. After years of research, PID control algorithms for different problems have been produced. This chapter will establish the model of the controlled object [1-2], and select the appropriate PID control algorithm for the control of the static loading test machine according to the characteristics of the controlled object.

2. Model of Electro-Hydraulic Proportional Control System

The static loading test machine adopts the hydraulic loading method, and the loading load is output by the loading hydraulic cylinder and adjusted by the proportional relief valve. The controller changes the input current of the electro-hydraulic proportional relief valve, thereby changing the pressure of the loading hydraulic circuit, and then changing the input force of the loading hydraulic cylinder.

There are three controlled objects, namely proportional relief valve, hydraulic cylinder and test piece. During the entire loading process, the dynamic characteristics of the loading hydraulic cylinder can be disregarded. It can be regarded as only one proportional link, so the characteristics during the entire loading process are determined by the proportional relief valve. The control links of the proportional solenoid, pilot valve and main valve of the valve are carefully analyzed, and the structure diagram of the pilot proportional relief valve can be obtained, as shown in Figure 1. To establish a mathematical model of the valve to analyze its dynamic and static characteristics.

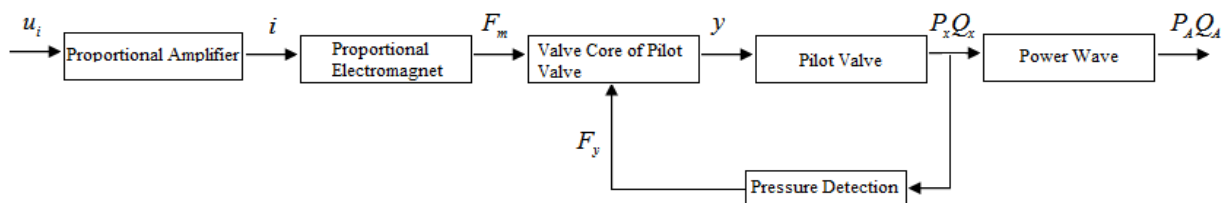


Figure 1. Structure diagram of pilot proportional relief valve

By deriving and consulting reference materials, the overall transfer function block diagram is obtained, as shown in Figure 2.

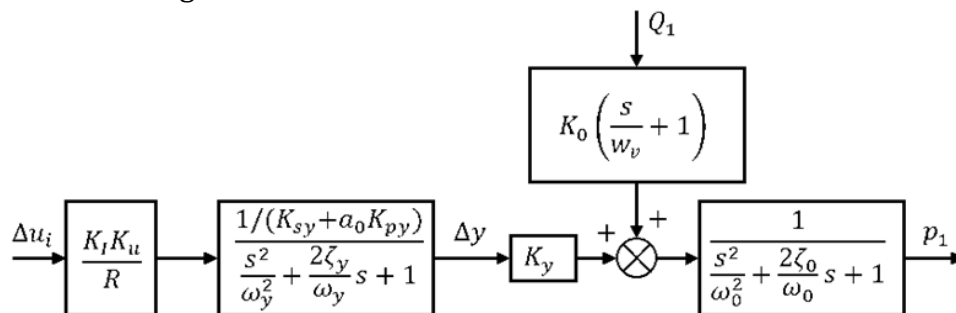


Figure 2. Block diagram of overall transfer function of proportional relief valve

3. PID Algorithm

The pressure adjustment range of the pilot proportional relief valve does not start from zero, and in the low pressure stage, when the static loading test machine uses the pilot electro-hydraulic proportional relief valve to adjust the loading load, it may not be possible for the lower test load. The realization or control accuracy is poor. At the same time, different set pressures are affected by the input flow rate of the overflow valve, and the change of the flow rate will cause the pressure adjustment deviation of the proportional overflow valve.

In order to eliminate the static error of the system, the integration link is usually introduced in the ordinary control algorithm, which can improve the control accuracy of the system. However, the introduction of points will also bring some disadvantages. When the loading system starts or ends, in these two cases, because the time is short, there will be a large output deviation at this time. During the calculation, the integral will accumulate and the system may experience

oscillation or large Overshoot, this situation is unwilling to see in the control process, and it must be avoided. Aiming at the loading control of the static loading test machine, this paper selects the variable speed integral PID control algorithm to control the proportional relief valve. When other PID control algorithms have a large deviation between the set value and the controlled variable, the integral link will cause a large overshoot and even cause system oscillation. The variable speed integral PID control algorithm is proposed for this problem. The variable speed integral PID algorithm is a further improvement of the integral separation PID control algorithm on a certain theoretical basis. Its basic realization principle is to change the speed of the integral term in the accumulation process according to the change of the deviation: when the deviation is large, the integral is slower, The effect is relatively weak at this time; the integration is faster when the deviation is small, and the effect is relatively strong at this time [3-5] to avoid overshooting of the system. The specific algorithm is as follows:

According to the loading control situation, set the coefficient $f[e(k)]$ artificially, which is a function of $e(k)$. The function $f[e(k)]$ satisfies the following relationship, when $|e(k)|$ increases, $f[e(k)]$ decreases, and vice versa. The expression of variable speed integral PID integral term is:

$$u_i(t + \Delta t) = u_i(t) + k_i f(e(t)) e(t) \Delta t \quad (1)$$

Where $u_i(t)$ is the output control amount of the integral link; $e(t)$ is the system deviation; $f(e(t))$ is the integral coefficient function.

The relationship between the coefficient function and the deviation can be linear, such as a linear decreasing function, or non-linear, such as a negative exponential function. The integral coefficient function should satisfy:

$$f[e(k)] = \begin{cases} 1 & |e(k)| \leq B \\ (A - |e(k)| + B) / A & B < |e(k)| < A + B \\ 0 & |e(k)| > A + B \end{cases} \quad (2)$$

In the integral coefficient function of PID, the requirements for A and B are not accurate, so it is enough to select appropriate parameters in simulation and practical application. Therefore, this article combines the actual loading system and initially defines as:

$$f(e(t)) = 0.8 \{1 - [u_i(t + \Delta t) - u_i(t)] / u_i(t)\} + 0.2 \quad (3)$$

4. PID Algorithm Simulation

In order to verify the performance of the variable speed integral PID control algorithm in the static loading test machine, this paper uses Matlab and AMESim co-simulation to test the performance of the variable speed integral algorithm controller. In order to reduce the amount of calculation in the simulation, only the loading circuit part of the hydraulic system is used in the co-simulation, and a certain simplification is carried out. The simulation models of Matlab and AMESim are shown in Figure 3 and Figure 4 respectively.

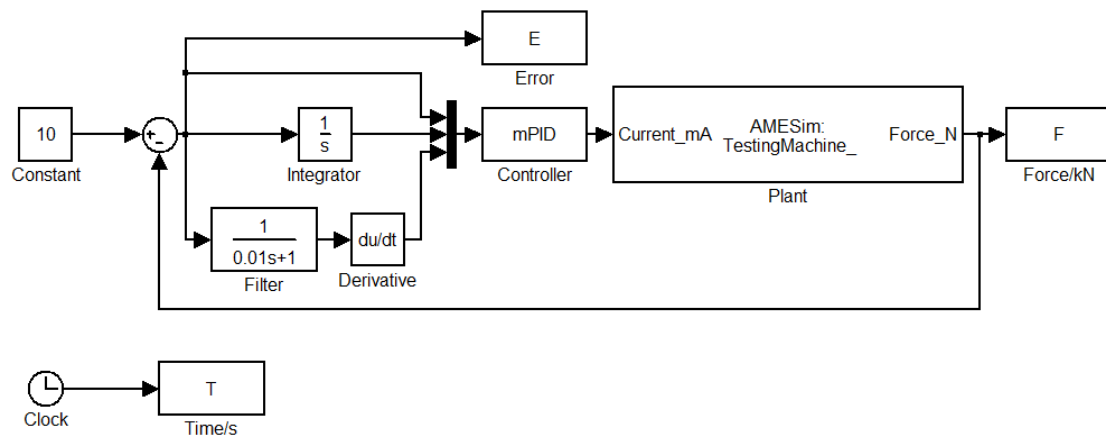


Figure 3. The control system model in Matlab

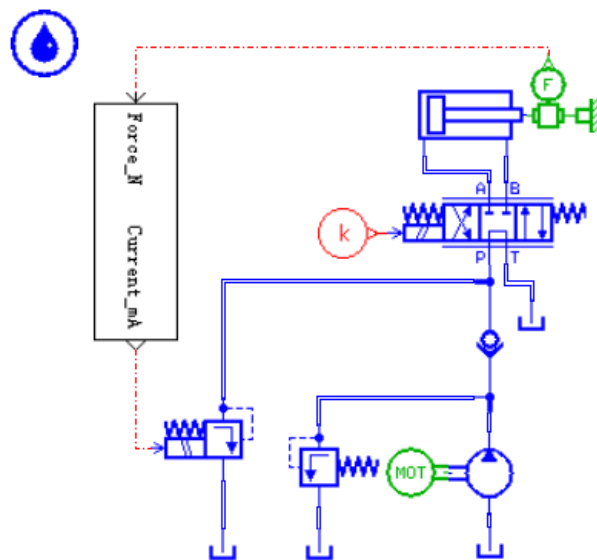


Figure 4. Hydraulic system model in AMESim

For flexible specimens such as wire ropes used on spreaders, in order to verify the performance of the variable speed integral PID algorithm in the loading control of flexible specimens, the model of the hydraulic system was modified, and the piston of the loading hydraulic cylinder was fixed to one end. Connect the other end of the steel wire rope to simulate the tensile test of the flexible specimen.

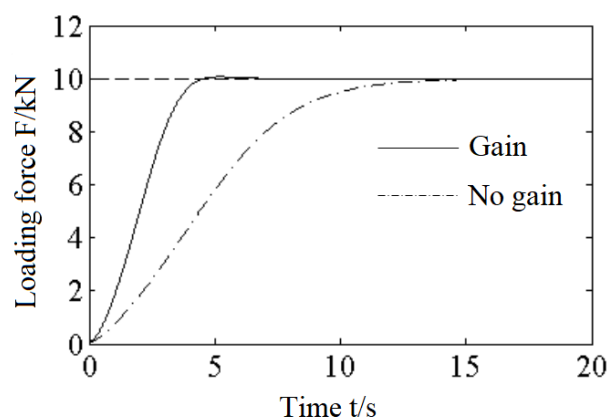


Figure 5. Variable speed integral during loading of flexible specimen

From the simulation results shown in Figure 5, it can be seen that the variable speed integral PID control algorithm shows good control performance in the control of the flexible test piece loading. When increasing the proportional link with a gain of 2.57, the system has a slight overshoot, but it is still within the allowable error range. When the proportional link is not increased, there is no overshoot phenomenon, but the adjustment time has been greatly increased, so that the load application process becomes smooth. For the loading of flexible specimens such as steel wire ropes, the gentle loading time can avoid impact. Conducive to the test. In order to reduce the amount of calculation in the simulation, only the loading circuit part of the hydraulic system is used in the co-simulation, and a certain simplification is carried out. The simulation results show that the variable speed integral PID control has good control performance in the control task, and there should be no overshoot or oscillation in actual work, and the loading process is smoother and simple to implement. It is suitable for flexible specimen loading control.

5. Experiment and Analysis

According to the control requirements of the static loading test machine, the electronic control system should adopt a computer as the upper computer and PLC as the lower computer. The industrial computer uses EVOC industrial panel PC PPC-1261V series C00, and the PLC uses ifm expandable controller CR0232, and the corresponding programming software is CoDeSys2.3.

In the test, the loader performs a preset load of 10kN, and performs a flexibility test at 10kN and processes the collected data to obtain the following loading curve. From the loading curve graph, it can be found that during the process of loading to 10kN, the curve performance is relatively stable, the control effect is relatively ideal, and the load control basically meets the accuracy requirements.

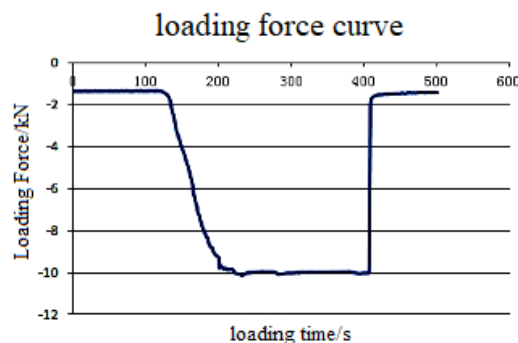


Figure 6. Loading curve under the condition of 10KN tension

The above experiment is to carry out tensile loading under a specific 10kN condition. In addition, 20kN, 50kN, and 100kN are also loaded during the experiment. During the test, it was found that when the load increases, the proportional relief valve has a higher control accuracy for the load, and the control accuracy is within 1%.

6. Conclusion

It can be concluded that the variable-speed integral PID algorithm controls the proportional relief valve, which is ideal for improving the control accuracy of the spreader loading test machine. Therefore, the variable-speed integral PID control algorithm can be applied to static loading of the loading test platform. But for tests that require higher loading characteristics, such as precise loading rates or switching between different control modes, it is necessary to try to use model reference or fuzzy adaptive control algorithms to solve them.

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