Simulation analysis of cooperative motion fuzzy control of distributed lifting units

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Abstract: In the technology of hydraulic lifting system, it is not only necessary to ensure that the displacement and velocity accuracy of each hoist reach a certain value, but also to ensure that under the control of load balance to make each hoist smooth lift. In the conventional method, the PID control method can realize the synchronization of the function. However, the system cannot be controlled and adjusted in real time during the control parameter period, resulting in instability and uncertainty of the system. Aiming at this problem, this paper adds the fuzzy adaptive controller to carry out the master-slave control of the system. AMESim and MATLAB co-simulation were used to model the overall model of the hydraulic system. At the same time, the pressure compensator and variable throttle port model in the hydraulic reservoir were selected to build. The pressure compensator is used to keep the pressure difference of the throttle orifice constant, so as to complete the control and design of the hydraulic lifting system. Finally, the simulation results obtained not only can effectively improve the instability of the hydraulic lifting process, but also greatly improve the operation speed of the system.

1. Introduction

Hydraulic lifting technology is an important engineering technology. The system carries out lifting construction action through adjustment in various environmental conditions. It is composed of steel strand, computer, hydraulic cylinder and various regulating valves\textsuperscript{1}. Operates under reasonable control to lift large and heavy objects Lifting to the designated position to complete the industrial needs. With the continuous development of science and technology, safety and reliability and convenience and flexibility have been improved and developed step by step. It not only has the advantages of saving time, labor and materials, but also has significant economic benefits\textsuperscript{2}.

A key technical index of this research project is: Research on lifting control methods of large tonnage building frame and realization of control system\textsuperscript{3}. A configurable and variable dynamic method is designed and constructed, and various parameters of the components are controlled under the premise of the smooth operation of multiple lifters to ensure that the synchronization error accuracy is within the allowed range and reaches the expected index ±30mm.
2. Control method of hydraulic lift

There are many kinds of synchronous control of hydraulic lifting. In this paper, four hoists are taken as examples to control the stable rise of the system through distributed cooperative control. There are two main control methods, parallel control and master-slave control. The method is described as follows.

2.1 Parallel synchronous control

Parallelism means walking side by side or performing or executing simultaneously. In a hydraulic lifting system, a group of hoists execute at an independent asynchronous speed without overlapping in time\(^4\). At the same time, parallel also refers to the data of multiple lifters is transmitted through movement at the same time, and the transmission rate is greatly improved. Because it is prone to interference in the process of movement, synchronization errors occur between multiple cylinders.

2.2 Master/slave Synchronization control

That is, mapping and non-mapping relationship. The system sends out computer instruction signal to the PID controller, which controls the lifting device to move. During the period, the flow is restricted by the proportional speed regulating valve, and finally transmitted to the hoist for displacement transmission, and the displacement is returned to the system by the feedback adjustment of the displacement sensor. Through the mapping, the slave hand can track the absolute degree of freedom of the master hand through the instruction signal.

3. Fuzzy PID adaptive control for lifting hydraulic system

3.1 Determination of variables

The variation parameters \(K_p, K_i, K_d\) in the algorithm are analyzed. In the operation of a single control invariable variable, according to the principle of fuzzy constant detection, determine the size of error and error variation rule, to meet the positioning displacement input, to achieve good dynamic performance.

\[
e = r(t) - y(t)
\]

\[
e_c = \frac{de}{dt}
\]

Where : \(r(t)\)——the displacement input given by the system;
\(y(t)\)——displacement output of the system.

3.2 Fuzzification of precise quantities

Error variation and error set domain of control rules of \(K_p, K_i, K_d\). Namely take the \(e\) and \(e_c\) = \{1.4, 1.3, 1.2, 1.1, 1.0, 1.1, 1.2, 1.3, 1.4\} corresponding fuzzy set elements \{NB, NM, NS, O, PS, PM, PB\}, reaction fuzzy table for \{small negative, negative, negative, zero, is small, in the middle of, zhengda\}. Suppose \(e\), \(e_c\) and the three coefficients obey normal distribution, so the membership degree of each fuzzy subset can be obtained. According to the membership assignment table of each fuzzy subset and the fuzzy control model of each parameter, the relationship between variables and initial values of variables can be obtained through error and error variation, and the formula is as follows:

\[
K_p = k_p + \{e_i, e_c\}_p
\]

\[
K_i = k_i + \{e_i, e_c\}_i
\]

\[
K_d = k_d + \{e_i, e_c\}_d
\]

On this basis, the increment of the three parameters, the current time of the increment and the real time value of the three parameters are obtained by superposition based on fuzzy reasoning. The triangle membership function is also included, and the formula is as follows:

\[
\mu(x) = \begin{cases} 
0 & x \leq a_n \\
\frac{x-a_n}{b_n-a_n} & a_n < x < b_n \\
\frac{x-c_n}{b_n-c_n} & b_n < x < c_n
\end{cases}
\]

(4)
In which: \( a_n, b_n, c_n \) — \( x \) coordinates of three vertices of a triangle, and \( a_n < b_n < c_n \). The resulting system can be run through Matlab.

4. Simulation analysis of fuzzy PID synchronous Control for lifting Hydraulic System

4.1 Establishment of simulation model of lifting hydraulic system

In this paper, four hoist co-simulation is constructed, the displacement signal of each rod is collected, and the calculated signal of adjusting throttle is input to the four throttle ports respectively. At the same time, in terms of model building, this paper abandons the common HCD library building method, and chooses HD library so as to greatly improve the model calculation and running speed. The co-simulation model in AMESim is shown in the figure 1 below\(^{[5]}\).

![Fig.1 Hydraulic system simulation model](image)

4.2 The establishment of the overall model of fuzzy adaptive PID synchronous control

Using the proportion integral module, the system is jointly constructed by the overall function Simlink module. PID synchronization control model is shown in Figure 2.

During the lifting process, it is important to maintain synchronization. The four hydraulic cylinders are under their own speed control valves, although the load may vary. The four hydraulic cylinders under their own speed control valves, although the load may vary, ensure that the flow into the cylinders is only related to the control signal of the speed control valve, thus synchronizing each lifting point.

During the operation of the hoist, the load is applied to the hydraulic cylinder through the input signal of the force source, which is used to simulate the acting force of the lifting object on the hydraulic cylinder. The internal structure of PID controller is shown in Figure 3.
Displacement curves of four lifters under fuzzy control method are shown in Figure 4. An ideal signal is established to calculate the error and transmit it to the fuzzy controller. Output fuzzy rules $K_p$, $K_i$, $K_d$. Finally, a regulating signal is generated. Set a delay of 1s, after which the curve starts to move, the curve runs an overshoot at the beginning, and gradually approaches stability. The curves of the remaining three lifters almost coincide because the last three lifters have the same ideal input signal as the first lifter. Therefore, their input results are the same, and the adjusted $K_p$, $K_i$, $K_d$ are the same.

Fig.2 Joint simulation diagram of fuzzy adaptive PID synchronous control of hoisting system

Fig.3 Internal structure of PID controller
Fig. 4 Displacement curves of four lifters

Fig. 5 Pressure curves of four lifters

Fig. 6 Speed curves of four lifters
Fig. 7 Throttle flow curves of four lifters

It can be seen from the figure that the displacement, pressure, speed and flow meet the synchronization error within the allowable range under the simulation of the hoist system. With the increase of time, each parameter finally tends to be stable and the lifting effect can be achieved.

5. Conclusion
In this paper, the thought strategy of master-slave control and fuzzy adaptive self-tuning is carried out for multiple hydraulic lift systems, and the system algorithm is analyzed by proportional integral and differential. At the same time, the software is selected to carry on the co-simulation of the lifting of a number of hydraulic hoists, and the displacement, speed, pressure and other parameters are adjusted. Through the choice of the speed regulating valve, and the pressure compensator and variable throttle port, to keep the weight in the process of lifting synchronization. By simulating the lifting force on the hydraulic cylinder through the force source signal, adding the delay link and using the library to build the system greatly improve the running speed of the system, ensure that the error is within the allowed range, and can realize the safe, synchronous and smooth lifting of the system.

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