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SIMULATION EXPERIMENT RESEARCH ON SIX DEGREES OF FREEDOM TEST BENCH BASED ON FUZZY PID CONTROL STRATEGY

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ИМИТАЦИОННОЕ ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ НА ИСПЫТАТЕЛЬНОМ СТЕНДЕ С ШЕСТЬЮ СТЕПЕНЯМИ СВОБОДЫ НА ОСНОВЕ СТРАТЕГИИ НЕЧЕТКОГО ПИД УПРАВЛЕНИЯ

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Abstract. The quality of the control system depends on various factors such as the characteristics of the controlled object, the control scheme, the form and size of interference, etc. In a control system where the characteristics of the object and the hardware and software have been basically determined, the control quality of the system depends on the control algorithm. The control algorithm will make the motion process control have better speed, accuracy and stability. The study of control law is an important part of the control system design of the entire six-degree-of-freedom test bench. The characteristics of the controlled object and the existence of interference in this control system require the designed control law to have the characteristics of strong robustness, certain intelligence, and easy implementation, so as to achieve stable and precise control of the system and achieve the control indicators required by the system. The control strategy of this six-degree-of-freedom test bench adopts Fuzzy PID control, which combines fuzzy theory with the mature traditional PID control theory and uses fuzzy theory to tune the three control parameters of PID to form a parameter self-tuning Fuzzy PID control Device. The Fuzzy PID control strategy is simulated by MATLAB simulation software.

Аннотация. Качество системы управления зависит от различных факторов, таких как характеристики управляемого объекта, схема управления, форма и размер помех и т. д. В системе управления, в которой характеристики объекта и аппаратного и программного обеспечения были в основном определены, качество управления системой зависит от алгоритма управления. Алгоритм управления повысит скорость, точность и стабильность управления процессом движения. Изучение закона управления — важная часть проектирования системы управления всего испытательного стенда с шестью степенями свободы. Характеристики управляемого объекта и наличие помех в этой системе управления требуют, чтобы разработанный закон управления обладал такими характеристиками, как высокая надежность, определенный интеллект и простота реализации, чтобы обеспечить стабильное и точное управление системой и достичь показателей управления, требуемых системой. Стратегия управления этого испытательного стенда с шестью степенями свободы использует нечеткое ПИД управление, которое объединяет нечеткую теорию со зрелой традиционной теорией ПИД управления, и использует нечеткую теорию для настройки трех параметров ПИД управления для формирования параметра самонастраивающегося устройства нечеткого ПИД управления. Стратегия нечеткого ПИД управления моделируется с помощью программного обеспечения для моделирования MATLAB.

Keywords: Fuzzy control, Fuzzy PID controller, six degrees of freedom test bench, MATLAB simulation experiment.

Ключевые слова: нечеткое управление, нечеткий ПИД регулятор, испытательный стенд с шестью степенями свободы, имитационный эксперимент MATLAB.

Research Background and Theoretical Research

The attributes of things and the connections between things are vague, and people's observation and understanding of things are rough. For example, "high temperature" is the amount of blur, and "fuzzy" has more information and richer content. Therefore, "fuzzy concepts" are suitable for people to observe and understand things. L. A. Zadeh believes that classical cybernetics emphasizes accuracy too much and cannot handle complex systems. Therefore, a different kind of mathematics is needed to deal with biological systems. This mathematics is fuzzy mathematics, that is, fuzzy sets [1], which is a kind of fuzzy language A tool that is transformed into a mathematical language and can be recognized by a computer. Based on fuzzy set theory, L. A. Zadeh established fuzzy theory. Fuzzy theory mainly includes fuzzy logic, fuzzy sets, fuzzy control and fuzzy reasoning [2]. The basic idea of fuzzy theory can be understood as: admit the existence of fuzzy phenomena, to deal with uncertain things as the research goal, and convert it into information that can be processed by the computer, without complicated mathematical analysis to solve the problem. In recent years, with the development of fuzzy theory, fuzzy control has developed rapidly and is widely used.

After the automatic control theory experienced classic control theory and modern control theory, intelligent control theory appeared again. Intelligent control does not require manual intervention under normal circumstances, and the machine can realize control autonomously. The fuzzy control is a component of intelligent control [3], so it has the following advantages [4]: fast response speed; fuzzy control system does not change with the change of parameters and has good performance for objects with time-varying and hysteresis characteristics Control effect, but also has a certain anti-interference ability; Based on rules, fuzzy control has a good control effect for controlled objects that do not need to establish a precise mathematical model. Its control principles and strategies are easy to accept and understand; In many controls Among the rules, fuzzy control can switch well, and the control performance is better; the fuzzy control algorithm can simulate the manual operation control process and has the characteristics of intelligence.

L. A. Zadeh introduced fuzzy logic in the 1960s to express and use fuzzy and uncertain knowledge. In 1974, fuzzy logic was used to implement the fuzzy control experiment of a steam engine for the first time [5]. Fuzzy control is a control method based on fuzzy sets, fuzzy language and fuzzy reasoning. It compiles the knowledge and control experience expressed by operators or experts in natural language into fuzzy rules [6], and then fuzzifies real-time signals from sensors. The fuzzified signal is used as the input of the fuzzy rule to complete the fuzzy inference, and the output obtained after the inference is added to the actuator. It is a computer control technology based on natural language control rules and fuzzy logic inference. It does not depend on the mathematical model of the control system. On the contrary, it relies on "fuzzy rules" transformed from practical engineering experience and expressed knowledge, which is a kind of intelligent control.

In 1974, E. H. Mamdani applied fuzzy controller to the operation control process of boiler and steam turbine for the first time, and achieved better control quality in the laboratory, marking the birth of fuzzy control [7]. In 1977, fuzzy control was first applied to a multivariable control system. Since the late 1980s, the application of fuzzy control has gradually expanded. For example, in the fields of coal mining, obstacle avoidance fuzzy control of mobile robots, automatic parking of cars [8] and food processing [9], fuzzy control has been obtained. Application, and achieved good results [10]. In 1984, R. M. Tong first proposed an expert fuzzy controller [11]. The expert fuzzy control system introduces the expert system into the fuzzy control and combines the characteristics of the expert system to further improve the intelligent level of the fuzzy controller.

Experimental Research

Figure 1 is the control block diagram of the six-degree-of-freedom test bench for Fuzzy PID control. The given value of the rod length of the hydraulic cylinder is compared with the actual value of the rod length fed back by the displacement sensor to obtain the deviation E and the deviation change rate EC after differentiation as the Fuzzy PID control. The input variable and output variable of the controller are the control signal u of the electro-hydraulic servo valve. This signal determines the opening degree of the electro-hydraulic servo valve, which in turn determines the expansion and contraction of the hydraulic cylinder piston, so that the platform can achieve various expectations Space attitude.

Figure 2 is a schematic diagram of fuzzy logic control. A 2–3-dimensional fuzzy logic control with two inputs and three outputs is designed. Deviation E and deviation change rate EC are used as inputs, and the output is three control parameters of the PID controller. △Kp, △Ki, △Kd. The process of fuzzy control is to convert the input deviation E and the deviation change rate EC from the precise quantity into the fuzzy quantity accepted by the fuzzy rules by the fuzzer to obtain the fuzzy subset of the input quantity E and EC. The designed fuzzy rules make a reasoning budget for the input and obtain the output, that is, the fuzzy values of the three control parameters of the PID controller △Kp, △Ki, and △Kd. After de-fuzzification, △Kp, △Ki, the precise amount of △Kd [12], thereby changing the parameters of the PID controller.

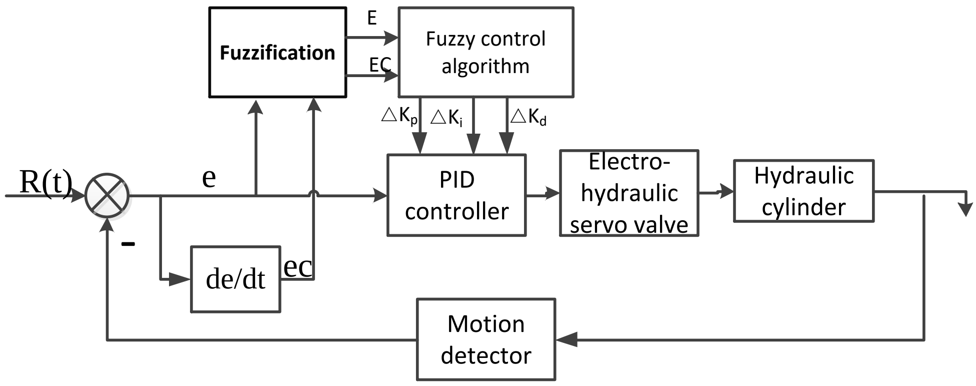

Figure 1. System schematic of Fuzzy PID control.

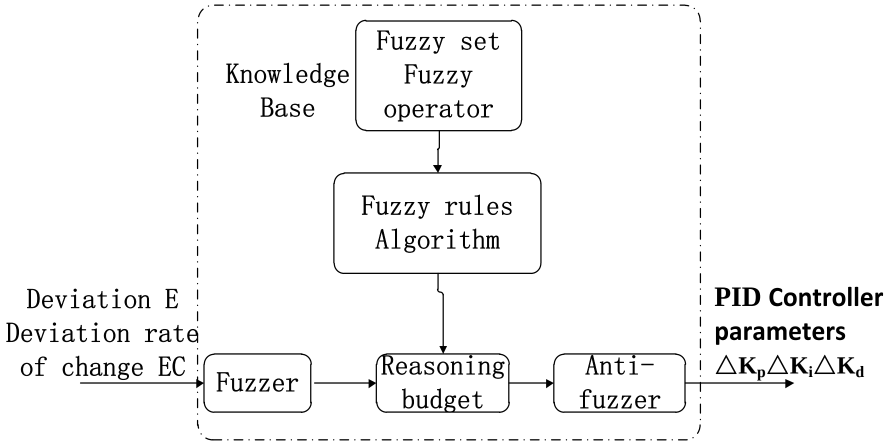

Figure 2. Fuzzy logic control principle.

Fuzzy rules are the basis of fuzzy inference and the key to the controller. Fuzzy language is used to describe the control rules obtained by experts and operators in their long-term work practice [13]. Therefore, it is necessary to summarize the corresponding influence of the three parameters KpKiKd of the PID controller on the system. Combining the PID parameter tuning experience summarized by predecessors and the actual debugging situation of the system, the relationship between deviation E, deviation change rate EC and output △Kp, △Ki, △Kd is as follows:

1) At the beginning of control, |e(t)| is larger. In order to obtain a larger voltage and spool opening, make the hydraulic cylinder expand and contract quickly and speed up the response speed of the system, a larger Kp value should be used, so that Reduce the time constant and damping coefficient of the system, and too large may cause the system to be unstable.

2) When |e(t)| is an intermediate value, a smaller Kp value can avoid excessive system overshoot; a smaller Ki can reduce the steady-state error.

3) When |e(t)| is small, Kp should be small and Ki can be large to achieve better steady-state performance.

In order to meet the requirements of different operating conditions for control parameters, the system has better control quality, that is, better speed, accuracy and stability. On the basis of fully understanding the control theory and learning the actual engineering experience, according to the deviation E, the deviation change rate EC and the relationship between the output △Kp, △Ki, △Kd and the PID parameter tuning experience, the platform is comprehensively debugged. In the case, sum up the fuzzy rules between E, EC and △Kp, △Ki, △Kd.

The Rule View of the Fuzzy toolbox in MATLAB shows the important part of the whole fuzzy myopia reasoning, explains all the fuzzy reasoning process, can observe the reasoning results after changing the membership function and fuzzy rules, and debugs and corrects the whole fuzzy control logic to achieve Better control effect. The reasoning result of Fuzzy PID controller is shown in Figure 3.

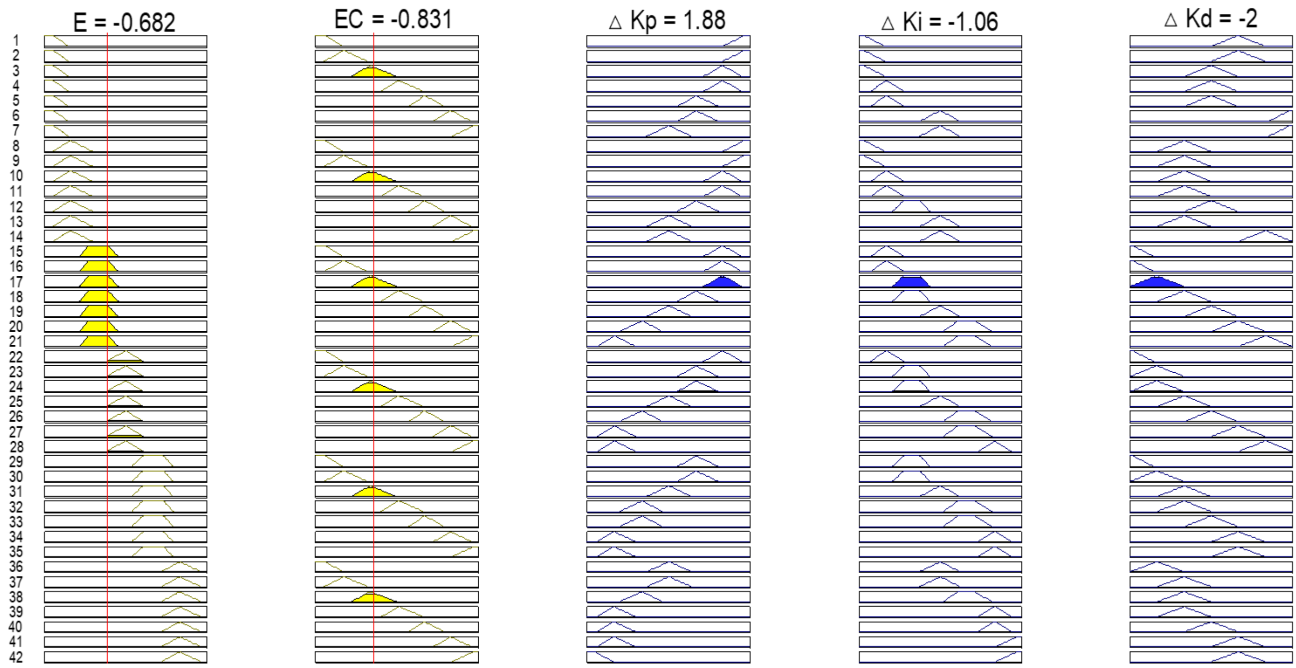

Figure 3. Reasoning results of the Fuzzy PID controller.

Since the actual controlled object can only accept precise control quantities, it is necessary to convert the fuzzy control quantities obtained by fuzzy inference into precise quantities. The entire input area corresponding to the entire output interval of the fuzzy inference system is obtained, as shown in Figure 4.

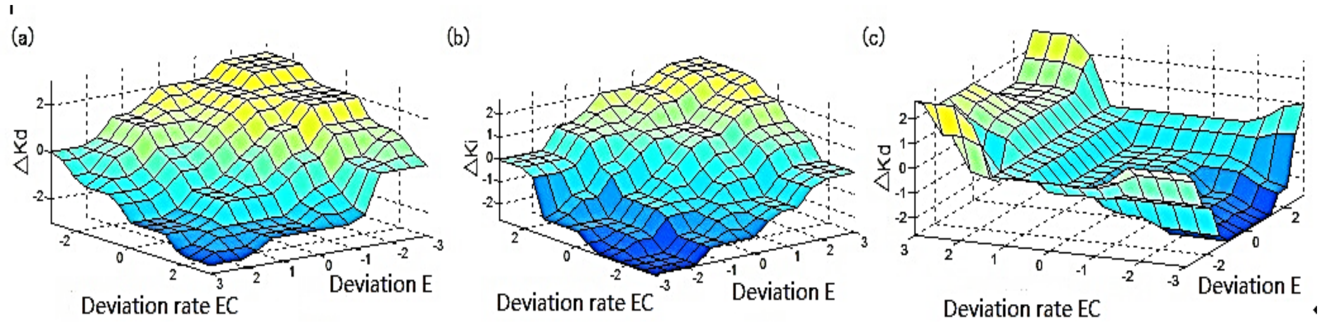

Figure 4. Fuzzy logic output surface.

According to the design of the Fuzzy-PID controller, a single-cylinder simulation model of the experimental bench control system based on the Fuzzy PID controller and the traditional PID controller is established in MATLAB as shown in Figure 5.

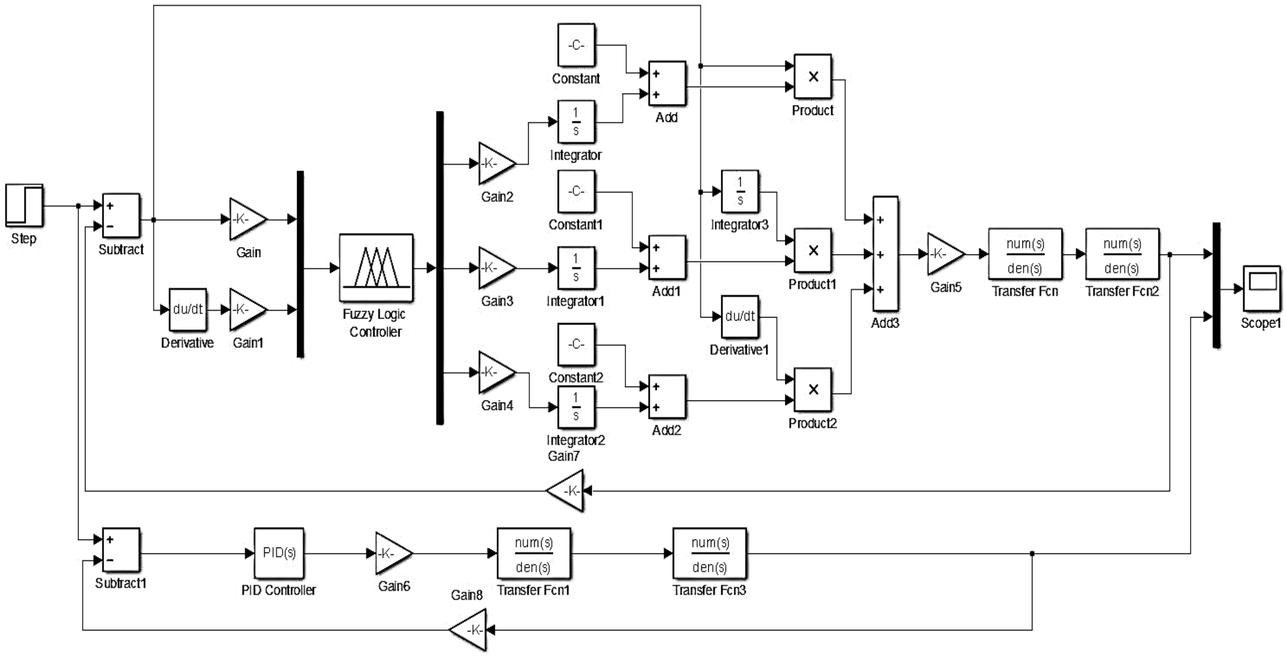

Figure 5. System single cylinder simulation model.

Analysis of test results

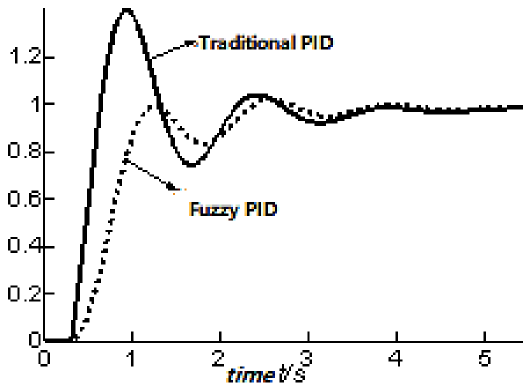

Figure 6. System single cylinder step response.

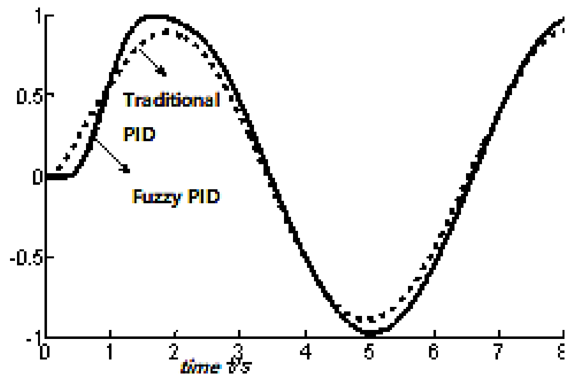

Figure 7. System single cylinder sinusoidal response.

Figure 6 shows the single-cylinder response of the hydraulic parallel six-degree-of-freedom test bench under a step input with an amplitude of 1. It is compared with the traditional PID controller, and the Fuzzy PID control and the traditional PID control are calculated by MATLAB. Performance. It can be seen from the figure that the overshoot of single cylinder response under traditional PID control is 40%, and the adjustment time (take 5% of the bar) is 2.82 s. The overshoot of single cylinder response under fuzzy adaptive PID control. The adjustment volume drops to 16%, and the adjustment time (take 5% of the bar) is 2.21s. Compared with traditional PID control, Fuzzy PID controller reduces the overshoot of system response and speeds up the response time of the system.

Carry on the sine tracking simulation to the system, the input amplitude is 1, the frequency is 0.1 sine signal, the single cylinder response curve is shown as in Fig. 6. It can be seen from the figure that the single-cylinder response under the Fuzzy PID controller has higher steady-state accuracy. Therefore, Fuzzy PID control strategy can make the system have better control quality.

Conclusion

In order to obtain better control quality of the system, a fuzzy PID control strategy combining fuzzy control and traditional PID control is adopted to overcome the shortcomings of traditional PID parameters fixed and fuzzy control with steady-state errors; according to the actual situation of the experiment, a fuzzy PID control strategy is designed. PID control strategy, adjust the PID control parameters in real time according to the position feedback, establish a single-cylinder simulation model of the experimental bench control system based on the Fuzzy PID controller and the traditional PID controller, and carry out step input and sinusoidal input response simulation and simulation The result verifies the feasibility of Fuzzy PID control strategy, improves the dynamic characteristics and steady-state accuracy of the system, and its control performance is better than traditional PID control.

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