Level Control Study of Two-link Tank on Double Baroceptors

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ABSTRACT

The level of two-link tank was controlled for THKGK-1 advanced process control device based on double baroceptors. The method of PID control and fuzzy control were used respectively to control liquid level on the existing experiment equipment and software environment. During the experiment, firstly, PID control experiment was done on single baroceptor. Then the experiment was repeated on double baroceptors, and observation and analysis control effect was done according to the actual control results. Secondly, fuzzy control method was put forward and a fuzzy controller was designed by analysis experimental results to find the shortages, and then experimental verification work was done. Finally, the real-time curve of level control and real-time data were displayed in the MCGS configuration software. The two experimental results show that PID Control can control the level of two-link tank, but the effect is a bit poor. It can be improved the performance using PID control based on double baroceptors. The fuzzy control improves the dynamic performance and steady-state performance and obtains better control effect.

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INTRODUCTION

The THKGK-1 Advanced Process Control Experiment Device is an experimental plat consisting of a controlled object and a control computer. The device can finish the experimental project such as liquid level, temperature, pressure and flow control. These experimental projects can be used to simulate the measurement and control such as petroleum, chemical and sewage treatment and other areas. As a typical experiment representative of process control, level control study of two-link tank which is studied by numerous process control specialists is one of the hotspots. Because of the features of its own lag, nonlinear characteristics and complex control system status, system parameters and control algorithm directly affect the control precision.

Most of current process control systems use pressure transducer to detect the tank level with the traditional PID control methods, improved PID control and fuzzy control & neural network control [1-4]. The experimental project can make the experimenter understand the experimental principle, know well the process, verify different control methods, thus strengthen the understanding of the control algorithm and applied it. So the research of the process control system has very important theoretical significance and practical application value.

EXPERIMENTAL SYSTEM

Experimental device principle and diagram. Level control principle and diagram of two-link tank on the experimental device is shown in Figure 1.

Baroceptor. The baroceptor is a kind of instrument, it is used to measure the absolute pressure of air. The basic principle that the baroceptor detects the level of the water tank is to detect the level by inserting the plastic hose at the bottom of the tank. When the liquid level rises, the water level in the hose goes up and air is compressed increasingly causing the pressure to increase. When the liquid level is lowered, the water level in the hose is reduced and the air is compressed decreasingly causing the pressure to reduce. Finally, the height of the water level into the hose is converted into the actual height of the tank level. The detail is shown in Figure 2. Since the hose can not absolutely contact the bottom of the tank, there is certain error for the detection. In order to reduce the detection error, this study uses the double baroceptor to detect liquid level.
Data Processing of double baroceptors detection. According to the principle of the experimental device, the output information of two baroceptors is transmitted and processed by A/D conversion in order to obtain the digital information. Then the digital information is transmitted to the host computer through RS-232. The host computer determines whether the sensor data is normal by reference to the setting value of the computer software (configuration software) and the upper and lower bounds of the liquid level control. If both of them are normal, the average of the two data is regarded as the final detection value. If one of them is failed, another data is regarded as the final detection value. If both of them are failed, the operation is stopped and an alarm is given.

**CONTROL ALGORITHM DESIGN**

PID control. PID control is a control law based on the proportion, integral and differential of the error. The control algorithm includes [5]. Position control algorithm:
\[ u(k) = k_p [e(k) + \frac{T}{T_i} \sum_{j=0}^{k} e(j) + T_d \frac{e(k) - e(k-1)}{T}] + u_0 \]  

(1)

Incremental control algorithm:

\[ \Delta u(k) = k_p [e(k) - e(k-1)] + k_p \frac{T}{T_i} e(k) + k_p \frac{T_d}{T} [e(k) - 2e(k-1) + e(k-2)] \]  

(2)

Design of fuzzy controller for water tank level. Generally, PID control requires the establishment of the precise mathematical model or empirical parameters of the controlled object. Fuzzy control [6-8] is a kind of intelligent control which reflects the human thinking, which has good robustness, good construction and is easy to be accepted and no need to know the exact mathematical model of the controlled object. The fuzzy controller works according to certain language rules which are based on summarizing the experience of operator, and most fuzzy logic inference methods adopt max-min inference method. Therefore, in order to design a fuzzy controller, the input and output variables of the fuzzy controller must be fuzzed.

Ensure the input and output variables of the fuzzy controller. The fuzzy controller selects error e of the system level and change rate of the error ec as the input language variable, and output u as the output language variable. So, a two-dimension fuzzy controller is constituted.

Determine the range of input and output variables. According to the characteristics and the actual parameters of the experimental device, the domain of discourse of the error e is set as [-6 6], the domain of discourse of error change rate ec is set as [-12 12], the domain of discourse of control output u is set as [-6 6]. And the fuzzy quantities of the error e can be set as "NB", "NM", "NS", "ZE", "PS", "PM", "PB". The fuzzy quantities of error change rate ec and control output u can be set as "NB", "NM", "NS", "ZE", "PS", "PM", "PB". Input and output are used triangular membership function to proceed fuzzy inference to get the membership function of the error e as shown in Figure 3. The membership function of the error change rate ec is similar to the membership function of the output u, of course, the domain of discourse of error change rate ec has been set as [-12 12]. According to the fuzzy quantities above-mentioned, the fuzzy control rules can be obtained as shown in TABLE I. Anti-fuzzy method adopts the method of the centroid method, and finally calculates the input value after the quantitative calculation. Then the controlled quantity is gained.

**EXPERIMENTAL STUDY AND RESULTS**

PID control experiment and result. Experiment of PID Control under Single Baroceptor. Before the experiment, according to the characteristics of the device, the valve opening is adjusted initially, and zero calibration and gain calibration are
proceed three times. And then the PID control parameters are setted for experiment in order to complete the level control. The result of the liquid level control with a target water level of 4.0 cm and an initial water level of 0 cm under a single baroceptor is shown in Figure 4. From Figure 4, the dynamic time of the system is about 25min, and the overshoot is close to 50%. It shows that the dynamic performance is not very good. After the system is stabilized, the water level is about 4cm. There is static error in comparison with the target water level. So the error is large, and the control accuracy is not high.

![Figure 3. The membership function of error e.](image)

Note: The system initialization phase "delay" is due to the hysteresis characteristics of the control system.

In order to compare with PID experiment based on the single baroceptor, PID control experiment based on the double baroceptors was done under parameters and procedures are the same, but the effect is not. The result is shown in Figure 5.

| TABLE 1. TABLE OF FUZZY CONTROL RULES. |
|---|---|---|---|---|---|---|---|
| $e$ | NB | NM | NS | ZE | PS | PM | PB |
| NB | PB | PB | PM | PM | PS | ZO | ZO |
| NM | PB | PB | PM | PS | PS | ZO | NS |
| NS | PM | PM | PM | PS | ZO | NS | NM |
| ZO | PM | PM | PS | ZO | NS | NM | NM |
| PS | PS | PS | ZO | NS | NS | NM | NM |
| PM | PS | ZO | NS | NM | NM | NM | NB |
| PB | ZO | ZO | NM | NM | NM | NB | NB |

Note: The system initialization phase "delay" is due to the hysteresis characteristics of the control system.
It can be seen from Figure 5 that the water level of the stabilization system is very close to 4cm. The error is close to 0 in comparison with the target water level. The dynamic time of the system is about 19min and the overshoot is about 30%, so the dynamic performance is improved. Therefore, PID control based on the double baroceptors, not only improves the dynamic performance of the system, but also improves the system's steady-state performance, especially the accuracy was clearly improved in the late period of the stabilization.

Fuzzy control experiment and result. According to the designed fuzzy control method, the experiment was carried out under the same parameter setup (a target water level of 4.0 cm and an initial water level of 0 cm) and the same experimental conditions (double sensors, zero calibration, gain calibration and valve opening). The result is shown in Figure 6.

It can be seen from Figure 6 that the water level of the stabilization system is very close to 4cm. The error is close to 0 in comparison with the target water level, the dynamic time of the system is about 5min and the overshoot is about 3%, so the dynamic performance is improved obviously. Therefore, the fuzzy control based on the double baroceptors, not only improves the dynamic performance of the system, but also improves the system's steady-state performance, especially the dynamic process is significantly accelerated.
CONCLUSIONS

On the basis of the THKGK-1 advanced process control device, two methods of PID control and fuzzy control were used to study the liquid level control of the Two-link Tank. From the results, both experimental methods can achieve the level control for the same device and set value, and achieve better control effect. But the comparison shows that the effect of single baroceptor PID control is somewhat poor, the double baroceptors PID control is better than single baroceptor PID control, and the fuzzy control can greatly correct deficiency of the PID control and can further improve the control effect for the tank level.

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REFERENCES