Fuzzy PID based temperature controller for jetting dispenser

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Abstract. In order to reduce the temperature fluctuation of adhesives on jet dispenser, a fuzzy PID temperature controller was designed. An experimental platform was built on the jetting dispenser. The experimental result shows that the stability of the new system is better than that of the classic PID controller, and the temperature fluctuation is reduced by 0.5°C.

Key words: Fuzzy PID; jetting dispenser; Temperature control; Parameter self-tuning

1. Introduction
Dispensing is a common technology in microelectronic packaging [1-3]. With the development of electronic devices to high integration, the requirements for dispensing are increasing [4-6]. The temperature fluctuation of adhesives directly affects the dispensing consistency [7, 8]. Reducing temperature fluctuation is of great significance to dispensing.

The classic PID controller is practical with simple structure, and is widely used in industrial control. However, dispensing equipment tends to high frequency and high integration [9-11]. The disturbance factor and working environment of jetting dispenser is complicated. The new generation of jetting dispenser requires a more stable temperature controller.

Fuzzy controller usually has good performance on nonlinear time-varying systems [12, 13]. Fuzzy PID controller has the advantages of quick response and good robustness [14, 15]. This study built a fuzzy PID controller based on stm32. Contrast experiment with classic controller was executed on dispenser. The stability of the fuzzy PID is better, and it returns to the set temperature without oscillation after being disturbed. The temperature fluctuation of fuzzy PID is within 0.5°C.

2. Fuzzy PID Controller Designing
The fuzzy PID is based on digital PID. The positional digital PID is expressed as below:

\[ u(k) = K_p e(k) + K_i \sum_{j=0}^{k} e(j) + K_D [e(k) - e(k-1)] \]  (1)

The key of fuzzy PID lies in fuzzification, fuzzy reasoning and defuzzification, where fuzzification is based on triangular membership function and defuzzification is based on gravity center method. The
fuzzy inference machine has two inputs: error $e(k)$ and its change rate $ec(k)$ and three outputs: increments of PID parameters $\Delta k_P$, $\Delta k_I$ and $\Delta k_D$. Fig. 1 shows the structure of fuzzy PID controller.

![Figure 1. Fuzzy PID controller structure](image)

The conversions of actual variables and linguistic variables are expressed as follows:

$$E = K_{in} e$$  
$$\Delta k_P = K_{out} \Delta KP$$  
$$K_{in} = \frac{L_f}{L_b}$$  
$$K_{out} = \frac{L_b}{L_f}$$

Where $K_{in}$ is the ratio factor for conversions of $e/ec$ and $E/EC$, $K_{out}$ is the ratio factor for conversions of $\Delta KP/\Delta KI/\Delta KD$ and $\Delta k_P/\Delta k_I/\Delta k_D$, $L_f$ is the length of fuzzy domain, $L_b$ is the length of basic domain. This initialization is used to calculate the order of magnitude of the ratio factors. The ratio factors should be corrected in debugging.

The fuzzy inference machine is based on Mamdani inference method, whose basic reasoning statement is IF A and B THEN C. The experience inference rules are shown in Table 1.

| E  | EC   |  |  |  |  |  |  |
|----|------|---|---|---|---|---|---|
| NB | NB   | PB/NB/NS| PM/NM/NM| PM/NM/NS| PS/NS/NS| PS/NS/NS| ZO/ZO/ZO|
| NM | PM/NM/ZO| PM/NM/NS| PS/NS/NS| ZO/ZO/NS| NS/PS/PS| ZO/ZO/ZO| NS/PS/PS|
| NS | PS/NM/NS| PS/NM/ZO| PS/NS/NS| ZO/ZO/NS| NS/PS/PS| ZO/ZO/NS| NS/PS/PS|
| ZO | PS/NM/NZ| PS/NM/ZO| PS/NS/NS| ZO/ZO/NS| NS/PS/PS| ZO/ZO/NS| NS/PS/PS|
| PS | PS/NM/NS| PS/NM/ZO| PS/NS/NS| ZO/ZO/NS| NS/PS/PS| ZO/ZO/NS| NS/PS/PS|
| PM | PS/ZO/PB| ZO/ZO/NS| NS/PS/PS| NM/PS/NS| NM/PM/PS| NM/PM/PS| NM/PM/PS|
| PB | ZO/ZO/PB| ZO/ZO/NS| NS/PS/PS| NM/PS/NS| NM/PM/PS| NM/PM/PS| NM/PM/PS|

3. Experimental Devices

The circuit is based on stm32 and takes Pt100 as the temperature sensor. The voltage of Pt100 is converted into digital signal by ADC and input to stm32. The PWM output by stm32 controls the power of heater after being amplified. The fuzzy PID and the classic PID method are programmed on stm32. The serial port of the system is connected with the USB of the PC. The temperature is sent to PC in real time. The circuit of the controller are presented in Fig. 2.

The system controls the temperature of the flow channel to rise to the set temperature. When the temperature is $20^\circ$C lower than the set temperature, the resistance heater runs at full power. When the
temperature differs from the set temperature by less than 20°C, the controller starts to adjust the heating power.

Figure 2. Experimental devices: (a) diagram of system; (b) circuit of system.

4. Result and Discussion
The target temperature is set to 70°C. When the temperature exceeds 50°C, the controller adjust the heating power. After reaching the set temperature, a disturbance is applied to the dispenser. The experimental platform is presented in Fig. 3.

The classic PID oscillates after being disturbed and the fluctuation is within 1°C. The fuzzy PID returns to 70°C after being disturbed, and the temperature fluctuates within 0.5°C and does not oscillate. The temperature curves of classic PID and fuzzy PID are presented in Fig. 4.

5. Conclusion
A fuzzy PID based temperature controller on jet dispenser is designed. Comparing with classic PID, the new system improves the stability and reduces fluctuations by 0.5°C. The new temperature controller will improve the dispensing consistency of jetting dispenser.
**Figure 3.** Experimental platform.

**Figure 4.** Temperature curves.

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