

Research on electric kettle temperature control system based on MATLAB/Simulink

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Abstract. Constant temperature control has been widely used in modern agriculture and industry and daily life, control performance affects the safety, the industry productivity and product quality. Based on MATLAB/Simulink software, take the electric kettle as the control object, the simulation model of constant temperature control system is proposed in the paper, the PID controller is used to calibrate the system, and realize constant temperature control of electric kettle. The simulation results show that the PID controller is used to control temperature, which reduces the time of overshooting and adjusting, improves the control accuracy and system reliability, and has practical reference value.

1 Introduction

Temperature control plays a very important role in industrial production and daily life, the temperature control level directly affect the production efficiency, product quality, equipment safety and life security[1-2]. Temperature control has several characteristics like non-linear, heating unidirectional, large inertia, hysteresis and time-varying, which is easy to cause system instability, and the traditional control method is difficult to achieve the ideal control effect[3]. As the earliest developed control strategy, PID control is widely used in industrial control, due to its simple structure, good robustness and high reliability, especially establish the deterministic control system of precise mathematical model[4-5].

Household electric kettle is taken as the research object in the paper, water temperature as input, build the mathematical model of electric kettle temperature control system. The PID controller is used to calibrate the temperature control, thus realize the electric kettle constant temperature control.

2 Electric kettle temperature control system

Constant temperature electric kettle have boiling water function and heat preservation function. The system includes controlled object electric kettle, controller, actuator solid-state relay, temperature sensor and temperature transmitter. Electric kettle is taken as the research object in the system, water temperature is controlled variable. The water temperature is given value, take actual temperature signal detected by the temperature sensor as the feedback signal. In order to control the electric kettle water temperature, the

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PID controller is used to calibrate the temperature. The electric kettle temperature control block diagram is shown in Figure 1.

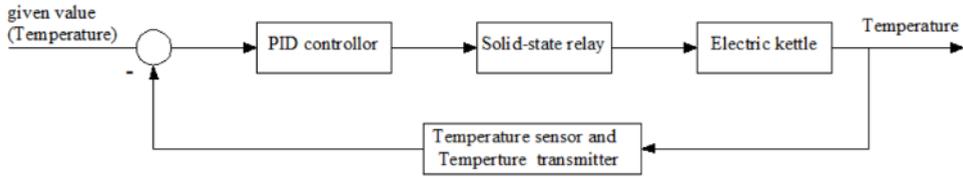


Fig. 1. The electric kettle temperature control system.

3 System model

The electric kettle temperature control model is shown in Figure 2. The model includes temperature setting module, comparison module, PID controller module, solid-state relay module, electric kettle module and temperature sensor module.

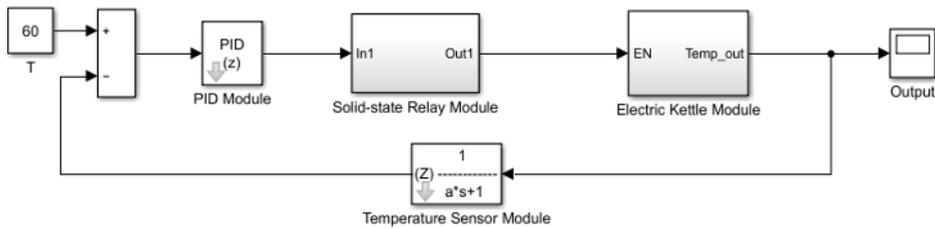


Fig. 2. The electric kettle temperature control model.

3.1 Solid-state relay module

Solid-state relay module subsystem is shown in Figure 3. In the model, the period of triangular wave is used to set relay on-off frequency. The PID output signal is compared with the triangular wave signal, when the comparison value is greater than zero, the relay closed, otherwise the relay open. When closing relay, giving the electric kettle input power, otherwise the electric kettle input is zero. The relay has time delay, replace with delay module, the sampling time of the delay module is set to $5e^{-4}s$, and the delay step is 100, so the relay delay time is $100 * 5e^{-4}s$.

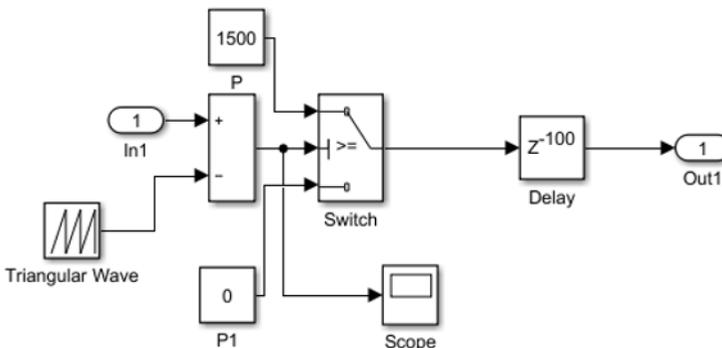


Fig. 3. Solid-state relay module.

3.2 Electric kettle module

Electric kettle module is shown in Figure 4. In the model, '1' represents the electric wire model of the electric kettle. '2' represents water temperature change after water is heated. '3' represents kettle heat dissipation capacity.

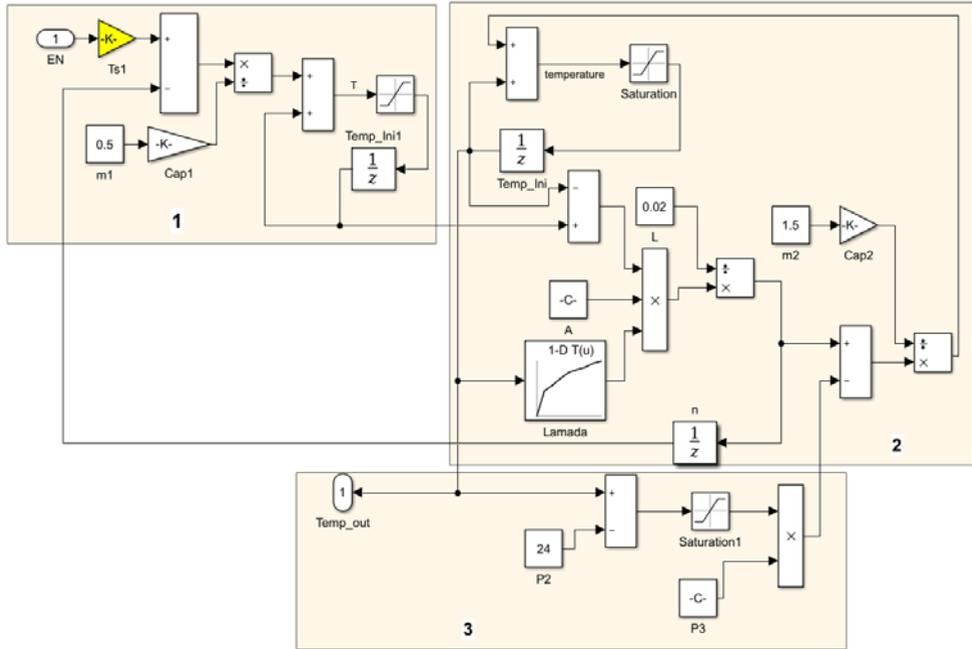


Fig. 4. Electric kettle module.

In the module 1, when closing relay, get the electric kettle input power, convert input power to energy. According to the law of energy conservation $Q = cm\Delta T$ (Q is heat energy, c is electric wire specific heat, m is electric wire mass)[6], get the temperature gat ΔT . The actual temperature of electric wire is obtained by superimposing temperature gat and the initial temperature.

According to the heat balance formula $\frac{E}{t} = \frac{\gamma A(\theta_2 - \theta_1)}{L}$ (γ is thermal conductivity of

water, t is time, A is electric wire area, L is water depth, θ_2 is electric wire temperature, θ_1 is water temperature)[7], calculate water energy in the model 2. Then with the law of energy conservation, get water rising temperature. The water actual temperature is obtained by superimposing water rising temperature and the initial temperature.

4 Model debugging

4.1 Model parameter

In the debugging phase, we first set the model parameters, set the material of electric kettle as stainless steel, input power is 1500W, electric kettle capacity is 1.5L. In the electric wire model, electric wire mass parameter is 0.5, electric wire specific heat is $0.45KJ / C^\circ$. In the water temperature change model, as thermal conductivity of water changes with temperature, module 'Lamada' is used to set the conductivity of different water

temperature, parameter is shown in Figure 5, water mass parameter is 1.5, water specific heat is $4.2\text{KJ}/\text{C}^\circ$.

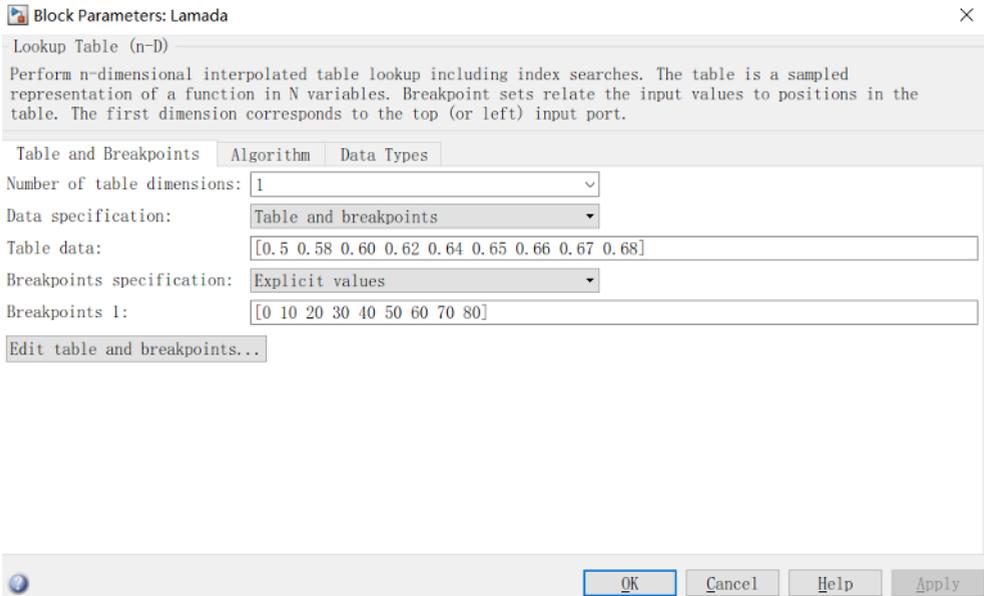


Fig. 5. Lamada parameter.

4.2 PID debugging

In the model correction, use PID controller to calibrate the system, PID correction module is shown in Figure 6. By several experiments, the PID parameter is $K_p = 1.2$,

$$K_i = 0.00005, K_d = 0.001.$$

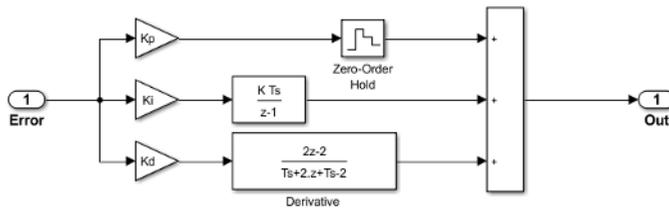


Fig. 6. PID correction module.

4.3 Debugging result

In order to verify the mode effectiveness, we set different water temperature to test the system. Debugging result of water temperature 45C° and 70C° are shown in Figure 7 and Figure 8. From this figure, you can see that system error is very small, whether it is high temperature or low temperature, the errors of 45C° and 70C° are 0.01 and 0.05 respectively.

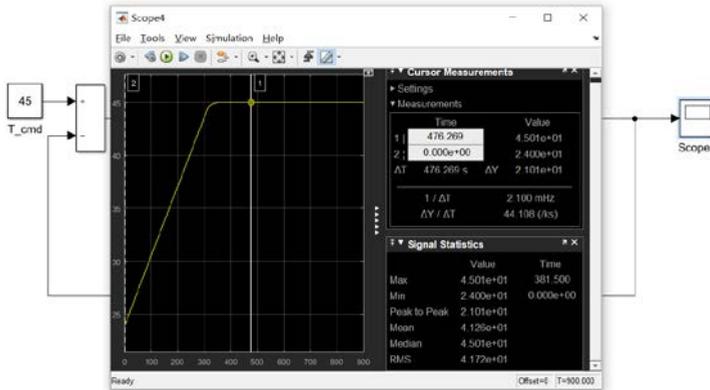


Fig. 7. Debugging result of water temperature 45°C .

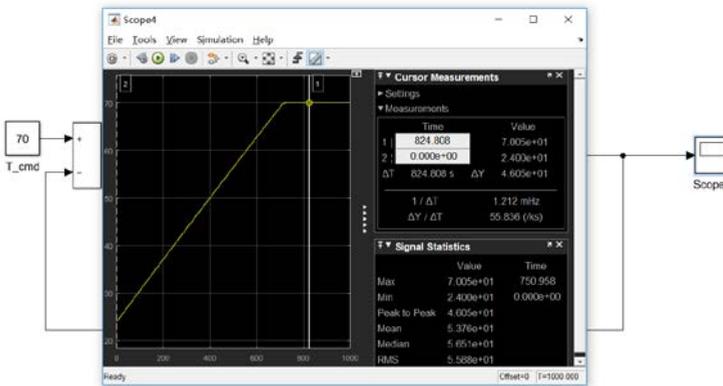


Fig. 8. Debugging result of water temperature 70°C .

5 Conclusion

Constant temperature control system is proposed in the paper, take the electric kettle as the control object. By analysing the structure of the system, the mathematical model of the control system is established. The model is debugged with PID correction method and obtain the PID parameters. The experimental results show that the proposed model error is very small. The debugging results and parameters provide practical reference value for researchers in the model.

In addition, the proposed method take the electric kettle as the control object. It is not limited to this, and the method is also applicable to other control object.

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References

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