Temperature Control System for Temperature Sensor Calibration

Chatchaval Pornpatkul[1*] Satean Tanyasrirat[1] and Jongkol Ngamwiwit[2]

[1]Department of Instrumentation and Control Engineering, Faculty of Engineering, Pathumwan Institute of Technology, Bangkok, Thailand

[2]Department of Instrumentation and Control Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

1. Introduction

Temperature is the physical quantity of the heating/cooling that is familiar in everyday life. The temperature measurement has been performed firstly in the medical community by touching a hand to a patient for analysis. In the manufacturing industry, several sensors have also been developed continuously in order to measure the temperature. Recently, the temperature sensors used in the process of temperature measurement are the industrial platinum resistance thermometer (IPRT), resistance temperature detector (RTD), thermocouple (TC) and thermistor, which are commonly employed in the industry. However, the temperature sensors are needed to calibrate by using temperature control calibration. The satisfied qualifications of the calibration compose of evaluation test and accuracy test.

In this paper, a temperature process control for temperature sensor calibration is proposed. The water temperature is controlled not exceed ±0.5°C (expanded uncertainty) in the range of ambient temperature up to 90°C. In accordance with the guidelines of the international temperature scale 1990; ITS-90, the temperature sensor, ie., thermocouple is tested. In order to show the capability of the proposed temperature process control at 40°C and 60°C, the calibration result of TC is compared with the standard platinum resistance thermometer (SPRT).

2 Temperature Source

Temperature Source means a temperature control system for temperature sensor calibration. The temperature sensor calibration in industrial and laboratory calibration can be made in the working standard temperature in the range of ambient temperature up to 90°C using water as the medium. There are two major components of the temperature process control consisting of heating and cooling system.

The temperature process control system in the laboratory is shown in Fig. 1 and it will be used for temperature sensor calibration. In order to design a controller, the transfer function of the temperature process must be known first and it can be obtained from the experiment as shown in Fig. 2.

Fig. 1 Temperature process control experiment.

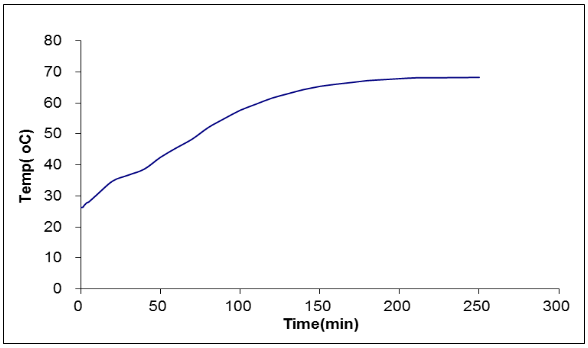

Fig. 2 Reaction curve of temperature process for $60^{\circ}C$.

After drawing the tangent line to the arc of reaction curve, the transfer function of the process is

$$G_p(s) = \frac{K_p \cdot e^{-L_p s}}{(\tau_p s + 1)} \quad (1)$$

where $K_p = 0.932$ is the process dynamic gain, $L_p = 0.75\,\text{min}$ is the effective process dead time (min) and $\tau_p = 160\,\text{min}$ is the effective process time constant (min). These values are summarized in Table 1.

3. Temperature Control System and Its Capability Testing

In this section, the proposed temperature control system and its capability testing will be described.

3.1 Temperature Control System

The proposed temperature control system with PI controller is shown in Fig. 3, where $G_c(s)$ and $G_p(s)$ are the transfer function of PI controller and the temperature process for Fig. 1 respectively.

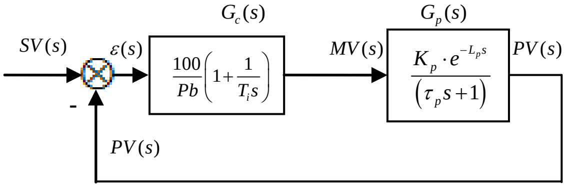

Fig. 3 Temperature control system with PI controller.

The obtained reaction curve shown in Fig. 1 is used find the proportional Pb and integral time T_i of PI controller by Dahlin Algorithm [1].

From Dahlin algorithm, controller gain K_c can be found from $Pb = 100\frac{K_p}{\tau_p}(\tau_c + L_p)$ where τ_c is assigned to be equal to 0.3 sec. Hence, $Pb = 93.38\%$ and $T_i = \tau_p = 160\,\text{min}$.

Table 1 Parameters of the process and controller

Parameter	K_p	τ_p	L_p	Pb =100/K$_c$	T_i
$G_p(s)$	0.938	160	0.75	-	-
$G_c(s)$	-	-	-	93.38%=1.07	160

The responses of PI temperature control system at $40^\circ C$ and $60^\circ C$ are shown in Fig. 4 and Fig. 5 respectively.

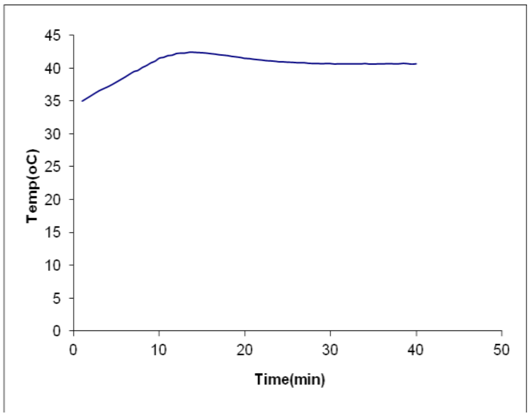

Fig. 4 Response at $40^\circ C$.

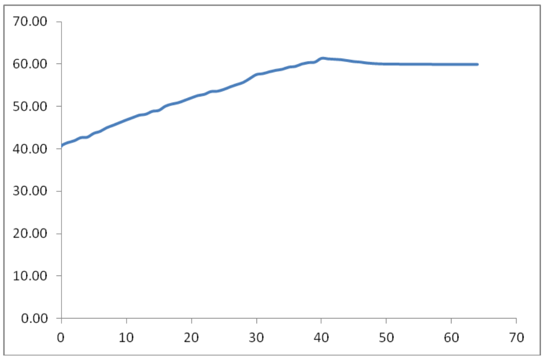

Fig. 5 Response at $60^\circ C$.

3.2 Capability Testing

It is necessary to test the capability of the proposed control system before performing the calibration. There are evaluation test[2] and accuracy test.

3.2.1 Evaluation Test

Two temperature sensors are used for evaluation test. From Fig. 4, the sensor 1 measures temperature at reference point located at the center of process tank and the sensor 2 measures the temperature at test point (6x3 points are measured). Two set of the measured value are summarized in Table 2 and Table 3 for temperature at $40^\circ C$ and $60^\circ C$ respectively. The different values from the reference value are evaluated to find stability and uniformity of temperature source (the calibration capability of the proposed control system).

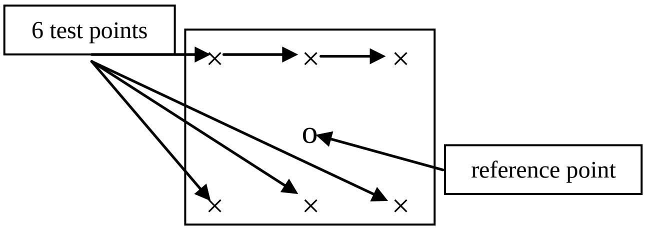

Fig. 6 Evaluation method.

Table 2 Evaluation test at $40^\circ C$

M1	M2	M3	M4	M5	M6
39.9	40.2	40.3	39.3	40.3	40.2
39.9	40.2	40.1	40.3	40.2	40.1
40.0	40.2	40.1	40.2	40.2	40.1

Table 3 Evaluation test at $60^\circ C$

M1	M2	M3	M4	M5	M6
60.2	60.2	60.2	60.2	60.2	60.1
60.3	60.1	60.3	60.4	60.2	60.2
60.2	60.2	60.2	60.3	60.2	60.1

3.2.2 Accuracy Test

In order for temperature controller must be used the Standard Thermometer, in this research we used the Standard Platinum Resistance Thermometer; (SPRT) for determination the characteristic and error of Temperature Controller in this case, diameter of SPRT < 6mm which do not calculated heat conduction [ITS-90]

4. Estimation of the Expanded Uncertainty of Measurement

EURAMET/cg-13/v.01 for guide line to calibration. The repeatability of the predicted temperature values is expressed as the uncertainty. The total expanded at reference temperature (23°C±2°C) associated with the temperature measurement at 95% confidence level for the Temperature Controller for Calibration unit is estimated to be :

$$U = k \cdot u_C \tag{2}$$

From the experimental results and by using equation (2), the calibration for expanded uncertainty[3] not over than $\pm 0.5^\circ C$. Hence, the temperature process control proposed in this paper can be used for calibrating temperature sensors.

5. Conclusions

In this study, temperature control system can be designed that are suitable to be used as a tool for measuring temperature in the calibration of working standard.

References

[1] Zhang Zhi-Gang, Zou Ben-Guo and Bi Zhen-Fu, Dahlin algorithm design and simulation for time-delay system, Proceeding CCDC'09 Proceedings of the 21st annual international conference on Chinese control and decision conference, Pages 5849-5852, IEEE Press Piscataway, NJ, USA ©2009.

[2] EURAMET/cg-13/v.01 for guide line to calibration,2005.

[3] Guide to the Expression of Uncertainty in Measurement (GUM), first edition, 1995, ISBN 92-67-10188-9.