EVALUATION OF DYNAMIC CHARACTERISTICS ON PRT AND THERMOCOUPLE SENSORS IN AN AUTOMATED TEMPERATURE CALIBRATION SYSTEM

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Laporan ini dikemukakan sebagai
memenuhi sebahagian daripada syarat penganugerahan
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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in term of scope and quality for the award of degree of Bachelor of Mechanical Engineering (Design & Innovation)".

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

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Khas buat

Ayah dan Ibu tersayang

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ABSTRACT

` It is important to identify the static and dynamic characteristic of temperature transducer in order to get a precise measurement in temperature calibration. Most of the previous studies in temperature calibration system only focus on static characteristic of the transducer. While the diameter of temperature probe does not affect the steady state temperature, it is important factor when considering the dynamic characteristic of the transducer. Different sizes probe diameter may alter the time response of the systems due to different loading error. When dealing with dynamic analysis of temperature transducer, it is necessary to design a measurement system that having as small as possible time constant to reduce the error cause by the dynamic characteristic of the system. This dynamic characteristic of temperature transducer is studied using an automated temperature calibration system. An automated calibration system is different from manual temperature calibration by utilizing computer interface in calibration process. LabVIEW is used to develop the computer interface that control the calibration parameters precisely and display the result. From the calibration result obtain, the uncertainty analysis of the measured data is carried out including the population of mean and variant of the data.

ABTRAK

Adalah penting untuk mengenal pasti ciri-ciri statik dan dinamik transduser suhu untuk mendapatkan ukuran yang tepat dalam penentukuran suhu. Kebanyakan kajian sebelumnya dalam sistem penentukuran suhu hanya memberi tumpuan kepada ciri-ciri statik penderia. Walaupun diameter pengukur suhu tidak menjejaskan suhu keadaan mantap, ia adalah faktor penting apabila mempertimbangkan ciri-ciri dinamik transduser. Diameter pengukur yang berbeza boleh mengubah masa tindak balas sistem kerana ralat muatan yang berbeza. Apabila berurusan dengan analisis dinamik transduser suhu, adalah perlu untuk mereka bentuk sistem pengukuran yang mempunyai sekecil mungkin pemalar masa untuk mengurangkan ralat yang disebabkan oleh ciri-ciri dinamik sistem. Ciri-ciri dinamik transduser suhu dikaji menggunakan penentukuran suhu sistem automatik. Satu sistem penentukuran automatik adalah berbeza dari penentukuran suhu manual kerana menggunakan antara muka komputer dalam proses penentukuran. LabVIEW digunakan untuk membangunkan antara muka komputer yang mengawal parameter penentukuran dengan tepat dan memaparkan keputusannya. Dari hasil penentukuran yang diperolehi, analisis ketidakpastian data yang diukur dijalankan termasuk populasi purata dan taburan data.

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LIST OF ABBREVIATIONS

PRT	=	Platinum resistive thermometer
TC	=	Thermocouple
MMSL	=	Microgravity Materials Science Laboratory
NASA	=	National Aeronautics and Space Administration
PID	=	Proportional integral derivative
ITS	=	International temperature scale
RTD	=	Resistance temperature detectors
ISA	=	Instrument Society of America
FYP	=	Final year project

LIST OF SYMBOLS

τ@ $\frac{dT_t}{dt}$	=	Time constant
I	=	Current (A)
E@e.m.f	=	Electromotive force (V)
T	=	Temperature(°C)
m	=	Bulb mass
c	=	Bulb specific heat
y/ye	=	Step input
R	=	Resistance (Ω)
α	=	Dominant constant ($/^0C$)
δ	=	Constant
β	=	Constant
U	=	Thermoelectric voltage (V)
ΔT	=	Temperature different (°C)
$\propto$	=	Seebeck coefficient ($Wm^{-2}K^{-1}$) @ (μV/°C)

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CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

Those objectives evaluated are to assist and complete this study:

- To measure and analyze the transient response of temperature probe characteristic.
- To study the effect of loading error due to the change of probe diameter for PRT and Thermocouple probes.

1.2 PROBLEM STATEMENT

Temperature transducers range from different types of diameters made of PRTs, Thermistors, Thermocouple and infrared thermometers. Each of this probes has different characteristics due to the types of sensors and diameters of the probes. Most of the calibration system only focus on the steady - state temperature characteristics but the change of probe diameters also may alter the dynamic response of the transducer. Therefore, it is necessary to measure the effect of these factor in order to obtain precise measurement in temperature calibration.

1.3 SCOPE OF STUDY

The scope of this study has been identified. The thermocouple itself can be treated as first order system and serve to demonstrate the application of first order dynamic analysis. The probe characteristics will be measured using an automated temperature calibrator to estimate the time constant, τ for the temperature probes. The effect of using different diameter of temperature probe also will be studied to measure the effect of probe diameter on the temperature calibration. At the end of the study, the uncertainty analysis will be carried out including the population of mean and variant of the data.

CHAPTER 2

LITERATURE REVIEW

2.1 PREVIOUS STUDIES ON TEMPERATURE CALIBRATION

.

Temperature calibration has been focused in industries as an indicator to maintain the quality of products especially in steel and food processing industries. Therefore, many studies on temperature calibration were conducted by previous researchers such as Mark D. Bethea, Bruce N. Rosenthal, Janko Drnovisek, Jovan B Djkovski, Igor Pusnik, Tanasko Tasic, Jie Chen, Xuejun Hu, Lixin Xu for thermocouples (TC), Platinum Resistive Thermometers (PRT) and thermistors.

An automated calibration system has been started by Bethea and Rosenthal (1992) which developed an automated thermocouple calibration system for use in the Microgravity Materials Science Laboratory (MMSL) at the NASA LeRC. There is capable of calibrating a large number of thermocouples simultaneously up to 60 thermocouples. On the other hand it also reduce the calibration time significantly while maintaining accuracy of ± 0.7 ℃.

The method of automated temperature calibration systems using PC based controller systems also applied by Drnovisek et al. (1999) in their research, that emphasize the reliability of measurements, repeatability and minimization of various influences, which are likely the cause of gross measurements errors, as basic requirements for performance of the work in every precision calibration laboratory. However, the automation calibration systems require a suitable hardware and software which might be very costly due to their performance and quality.

Recently, a new thermocouple auto-calibration system then have been develop by Chen et al. (2008) by applying fuzzy-PID controller based system. It can improve the accuracy and eliminate the self-oscillation of the system. This control module is developed using LabVIEW that capable to control the calibration temperatures precisely and also to manage data and display the result.

2.2 STATIC AND DYNAMIC CHARACTERISTIC OF TEMPERATURE TRANSDUCER

2.2.1 Static Characteristic of Temperature transducer

Every equipment and transducer has their own static characteristics consist of accuracy, resolution, and sensitivity. The characteristics probably change due to the aging or thermal stress in applications.

2.2.1.1 Accuracy

Accuracy is defined as the closeness of agreement between a measured value and the true value. It is a quantified in terms of measurement error, i.e. the difference between the measured value and the true value. Thus the accuracy of a laboratory standard PRT is the closeness of the reading to the true value of temperature. This brings us back to the problem, of how to establish the true value of a variable. The true value of temperature often referred to primary standard which is International Temperature Scale of 1990 (ITS-90). (Bentley, 2005)

Generally, manufacturer specifications of accuracy describe residual uncertainty that exists when a device has been properly adjusted and calibrated and is used in specified manner. Accuracy specifications generally include residual systematic and random errors in the measuring systems itself.

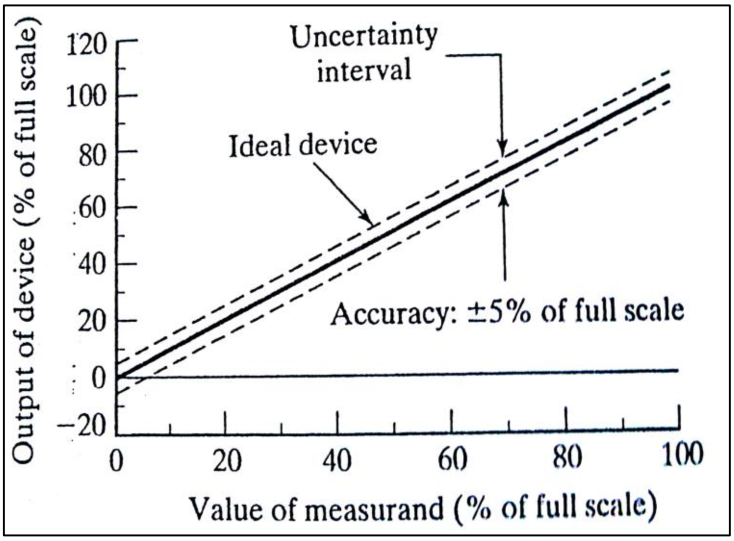

Figure 2.1: Accuracy as a percentage of full scale

(Source: Wheeler, Ganji, 2010)

As shown in Figure 2.1, a typical measuring device with an accuracy of ±5% of full scale, at reading below full scale, the percent of uncertainty in the reading will be greater than 5%. At reading towards the lower end of the range, the percent uncertainty might be completely unsatisfactory. This problem with high uncertainty at the low end of the range is a major concern in selecting a measuring system. To minimize uncertainty, the experimenter should select measuring systems so that important readings will fall in the middle to upper portions of the range.

2.2.1.2 Resolution

Some elements are characterised by the output increasing in a series of discrete steps or jumps in response to a continuous increase in input (Figure 2.2). Resolution is defined as the largest change in input that can occur without any corresponding change in output.