UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Uncertainty Evaluation for the Measurement of Gauge Block by Micrometer.

Thesis submitted in accordance with the requirements of the Universiti Teknikal Malaysia Melaka for the Degree of Bachelor of Engineering (Honors) Manufacturing (Process)

By

Mohamad Zubaidi Bin Aziz

Faculty of Manufacturing Engineering

Mei 2008

UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM)

BORANG PENGESAHAN STATUS TESIS*

JUDUL: <u>UNCERTAINTY EVALUATION FOR THE MEASUREMENT OF GAUGE BLOCK BY MICROMETER.</u>

SESI PENGAJIAN: <u>2007/2008</u>
Saya <u>MOHAMAD ZUBAIDI BIN AZIZ</u>

mengaku membenarkan tesis (PSM/Sarjana/Doktor Falsafah) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hak milik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia yang termaktub di dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Disahkan oleh:

_____
(TANDATANGAN PENULIS)

Alamat Tetap:
<u>Lot 5781 Jln Alor Lit, Bukit Payong,</u>
<u>21400 Marang,</u>
<u>Terengganu Darul Iman.</u>

Tarikh: <u>12/05/2008</u>

_____
(TANDATANGAN PENYELIA)

Cop Rasmi:

Tarikh: _____

* Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.

APPROVAL

This thesis submitted to the senate of UTeM and has been accepted as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process). The members of the supervisory committee are as follow:

……………………………………………….

Supervisor

(Official Stamp & Date)

DECLARATION

I hereby, declare this thesis entitled "Uncertainty Evaluation for the Measurement of Gauge Block by Micrometer" is the results of my own research except as cited in the reference.

Signature   :   ………………………………………………………………

Author's Name   :   MOHAMAD ZUBAIDI BIN AZIZ……………………

Date   :   12/05/2008……………………………………………

ABSTRACT

The purpose of this study was to assess the uncertainty in measurement of gauge block by micrometer. The study focused on the data collecting from the measurement of gauge block using micrometer in Metrology Laboratory at Fasa B workshop, Universiti Teknikal Malaysia Melaka, UTeM in conjunction to achieve their objectives to find uncertainties and parameters that influence measurement. Uncertainty analysis can be used to provide a meaningful analysis of a massive set of length measurement data. The uncertainty of measurement is a parameter, associated with the result of a measurement, which characterizes the dispersion of the values that could reasonably be attributed to the measurand. The measurands are the particular quantities subject to measurement. A recording data form was constructing to collect the data from the metrology laboratory that consists of parameter data value that used to evaluate the uncertainty in length measurement using micrometer. In this study, it focused on identify the parameter that contributes to the uncertainty in gauge block measurement. The factor that influences the success of any method of evaluating and expressing uncertainty also includes in this study. This thesis also gives a brief explanation about the uncertainty categories that divide into two type which is type A and type B which will describe in next chapter.

ABSTRAK

Tujuan kajian ini adalah untuk menilai ketidakpastian dalam pengukuran tolok bongkah oleh mikrometer. Kajian tertumpu pada data hasil dari pengukuran tolok bongkah menggunakan mikrometer dalam Makmal Metrologi di bengkel Fasa B, Universiti Teknikal Malaysia Melaka, UTeM. Ini adalah bertujuan untuk mencapai objektif-objektif bagi mencari ketidakpastian dan parameter yang memberi kesan kepada pengukuran. Analisis ketidakpastian boleh digunakan untuk menyediakan satu analisis yang berguna bagi suatu data pengukuran panjang. Ketidakpastian ukuran merupakan satu parameter, bersekutu dengan hasil satu ukuran yang menggambarkan sifat-sifat sebaran nilai-nilai yang boleh menjadi munasabah dianggap berpunca daripada bahan ukur. Nilai ukuran adalah perkara kuantiti tertentu untuk sesuatu pengukuran. Satu borang merekod data digunakan untuk mengumpul dan merekod data daripada makmal metrologi yang mengandungi nilai data parameter yang digunakan untuk menilai ketidakpastian dalam ukuran panjang menggunakan mikrometer. Kajian tertumpu pada penilaian ketidakpastian untuk pengukuran tolok bongkah oleh mikrometer. Dalam kajian ini, ia tertumpu untuk mengenal pasti parameter yang menyumbang kepada ketidakpastian dalam pengukuran bongkah tolok. Faktor pengaruh untuk sebarang cara bagi menilai dan mempenjelaskan ketidakpastian juga termasuk di dalam kajian ini. Tesis ini juga memberi satu penjelasan ringkas mengenai kategori-kategori ketidakpastian iaitu jenis A dan jenis B yang akan dihuraikan dalam bab lain. Sepanjang proses menilai ketidakpastian, matlamat utama adalah untuk membuat suatu penilaian realistik ketidakpastian dan supaya tidak terlalu mentaksir secara berlebihan sesuatu ketidakpastian itu.

ACKNOWLEDGEMENTS

Alhamdulillah, thank to Allah the Almighty God for giving me the strength and patience to work on this final year project report.

A report about uncertainty evaluation for the measurement of gauge block by micrometer cannot be written by one person. There are so many aspects of uncertainty, measurement, and procedure that one person can't possibly learn everything there is to know proper understanding about uncertainty evaluation in measurement. For this reason, the insights and research of many people dedicated to the people who have gone into the making of this report.

I would like to take this opportunity to express my sincere and deepest gratitude to my project supervisor, Dr Mohd Rizal Salleh for his guidance and opinion in order completion this report. He has provided a wealth of information to help anyone who concern with measurement in engineering field to understand what uncertainty is about. Most of the information in the report is from his guide about uncertainty. I also would like to thank Dr. Mohd Rizal Salleh again for his concern and carefully reading this report and giving many useful comments.

Lastly, I thank my friend for their moral and support and valuable help that they have provide to make this report possible. Without their support and love, I would not be able to complete this report successfully.

TABLE OF CONTENTS

CHAPTER 3

List of Tables

List of Figures

List of Abbreviations

UTeM - University Technical Malaysia Melaka

GUM   - Guide to the Expression of Uncertainty in Measurement

CHAPTER 1

Introduction

1.0   Background of Measurement and Uncertainty

All measurements of physical quantities are subject to uncertainties in the measurements. Variability in the results of repeated measurements arises because variables that can affect the measurement result are impossible to hold constant. Even if the circumstances could be precisely controlled, the result would still have an error associated with it. Uncertainties exist in every aspect of a design process such as in the model structure and parameters due to the abstractions of the realities, assumptions, lack of knowledge, and random physical properties.

The measurement uncertainty narrows down the difference between the actually measured value of a physical quantity and the true value of the same physical quantity. The result of a physical measurement comprises two parts: an estimate of the true value of the measurand and the uncertainty of this estimate. The observed value may be considered as an estimate which may be greater or smaller than the true value. This measurement uncertainty is not a mistake in the common usage but is rather an inherent part of any measurement.

The calculation of uncertainty for a measurement is an effort to set reasonable bounds for the measurement result according to standardized rules. Since every measurement produces only an estimate of the answer, the primary requisite of an uncertainty statement is to inform the reader of how sure that the answer is in a certain range.

1.1   Problem Statement

The problem regarding the measuring process influences uncertainty in measurement process. In an ideal world, measurements are always perfect. For example, wooden boards can be cut to exactly two meters in length and a block of steel can have a mass of exactly three kilograms. However, we live in the real world, and here measurements are never perfect. In our world, measuring devices have limitations however the uncertainty of the result of a test may need to be taken into account by a customer when interpreting data in order to obtain a good result.

This report was carried out to find the contribution of certain parameter toward uncertainty in the measurement of gauge block by micrometer. There are several considerations why this report was carried out which are:

- Gauge as a specific instrument used for calibration as well as measurement.
  As a calibration instrument, gauge block should require a standard or checking device at least ten times as accurate as the item being checked. This is why gauge block has been choosing as a sample in this study to evaluate the uncertainty using micrometer.
- Quantify the influence quantities
  Estimate the value of each input quantity either by the statistical analysis of repeated observations or by other means such as taking the uncertainty of a reference standard from a calibration certificate, estimating temperature effects on test or calibration results based on theoretical predictions, estimating the uncertainty of physical constants based on data in reference books and so on

2

1.2   Aims and Objectives

In conjunction to carried out this report, there is aims and objectives has been set up as a guide line in order to make sure their work become effectives and systematic. Main objectives of this study is to evaluate the uncertainty in measurement of gauge block using one of measuring equipment which is micrometer. In this study, student will also look at the parameter that influences the uncertainty in measuring gauge block. Furthermore, this study also includes the research about uncertainty equation. This report also provides a worked example of a typical evaluation of measurement uncertainty for the case of the measurement of gauges block by micrometer. Here listed an objectives that student ought to gain.

- To evaluate uncertainty in measurement of gauge block by micrometer.
- To identify parameter that influences the uncertainty in measurement of gauge block by micrometer.
- List assumptions and their impact or influence on the measurement.

One of the important purposes why this thesis carried out is to identify the parameters that influence the uncertainty in measurement of gauge block by micrometer. Factor influencing this measurement is contributed to evaluate uncertainty in measurement gauge block by micrometer.

The length calibration of the standard, factors inherent in the comparator equipment used to measure the length difference such as scale linearity and reading capability, gauge geometry with respect to its effect on probing the length difference, the temperature of the environment as it influences the gauge temperatures, which is in turn influences by the gauge materials and so forth is examples of factor that student will consider in this study.

3

1.3   Scope of Study

In this studies, student was going to evaluate uncertainy for the measurement of gauge block by using micrometer. In this thesis, student was focused to identify the parameter that influence the uncertainy in gauge block measurement. Student also need to understand the factor that must be considered in order to evaluate uncertainy in gauge block measurement. To gain the data for analysis, student have to construct a form and then conduct preliminary experiment in metrology laboratory using the related equipment.

The aim is to identify as many sources of uncertainty as possible and account for them by appropriate precision and trueness studies. Any additional sources of uncertainty can be evaluated by other means such as calibration certificates or published data. It may not be necessary to evaluate every source of uncertainty if they are deemed insignificant, unless there are a large number of them. Uncertainty components that are less than one third of the largest component need not be evaluated in detail.

A preliminary estimate of the contribution of each component or combination of components to the uncertainy should be made and those that are not significant eliminated. The uncertainy contributions need to be expressed as standard deviations, and combined according to the appropriate rules, to give a combined standard uncertainy. Generally, this thesis is about the evaluation uncertainy in measurement.

CHAPTER 2

Literature Review

2.1 Background to Measurement and Uncertainty

2.1.1 Measurement and Uncertainty

The process of evaluating this uncertainty associated with a measurement result is often called uncertainty analysis or error analysis. The complete statement of a measured value should include an estimate of the level of confidence associated with the value. Properly reporting an experimental result along with its uncertainty allows other people to make judgments about the quality of the experiment, and it facilitates meaningful comparisons with other similar values or a theoretical prediction.

When make a measurement, generally that some exact or true value exists based on how we define what is being measured was assumed. While it may never know this true value exactly or not, finding this ideal quantity to the best of ability with the time and resources available.

When making measurements by different methods, or even when making multiple measurements using the same method, slightly different results obtained. So how do to report for the best estimate of this elusive true value? The most common way to show the range of values that can accepted may include the true value is:

Measurement = best estimate ± uncertainty (units)

5

© Universiti Teknikal Malaysia Melaka

In order to understand uncertainty, firstly the terms accuracy and precision must be defined.

Accuracy

Accuracy is the closeness of agreement between a measured value and a true or accepted value. Measurement error is the amount of inaccuracy.

Precision

Precision is a measure of how well a result can be determined without reference to a theoretical or true value. It is the degree of consistency and agreement among independent measurements of the same quantity; also the reliability or reproducibility of the result. The statement of uncertainty associated with a measurement should include factors that affect both the accuracy and precision of the measurement.

For the example with the gold ring, there is no accepted value with which to compare, and both measured values have the same precision, it have no reason to believe one more than the other. The only way to assess the accuracy of the measurement is to compare with a known standard. For this situation, it may be possible to calibrate the balances with a standard mass that is accurate within a narrow tolerance and is traceable to a primary mass standard at the National Institute of Standards and Technology (NIST). Calibrating the balances should eliminate the discrepancy between the readings and provide a more *accurate* mass measurement.

Precision is often reported quantitatively by using relative or fractional uncertainty:

$$\text{Relative Uncertainty} = \left| \frac{\text{Uncertainty}}{\text{Measured Quantity}} \right| \tag{2.1}$$

For example, $m = 75.5 \pm 0.5$ g has a fractional uncertainty of:

$$\frac{0.5 \, g}{75.5 \, g} = 0.0066 = 0.66\%$$

Accuracy is often reported quantitatively by using relative error:

$$\text{Relative Error} = \left| \frac{\text{Measured value} - \text{expected value}}{\text{Expected Value}} \right| \qquad (2.2)$$

The minus sign indicates that the measured value is *less* than the expected value.

When analyzing experimental data, it is important that you understand the difference between precision and accuracy. Precision indicates the quality of the measurement, without any guarantee that the measurement is correct. Accuracy, on the other hand, assumes that there is an ideal value, and tells how far your answer is from that ideal, right answer. These concepts are directly related to random and systematic measurement errors.

2.2 Measurement and Uncertainty

Recent exciting research raises the possibility that the speed of light in a vacuum, which until now has been assumed to be constant, has been changing slowly with time since the universe was created.

This controversial (and yet to be confirmed) finding, stems in part from work done on spectral lines of light emitted from metal atoms in quasars 1 situated at different distances from the earth. In particular, researchers have measured the fine structure constant α, (which depends on the speed of light) and have concluded from their data that α was smaller in the distant past than it is today. If this finding *is* supported by the work of independent researchers, it is no exaggeration to say that physics books will need to be rewritten, so profound are the implications.

The researchers who carried out the work have carefully examined all aspects of their experimental technique in order to establish the size of the errors associated with their measurements. Their conclusion at this stage is that, even accounting for sources of error, they have strong evidence for an increase in the fine structure constant over time.

2.3   The Concept of Uncertainty

Uncertainty as currently defined in the GUM and the International Vocabulary of Basic and General Terms in Metrology (VIM) is a parameter, associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand.

This definition is consistent with the well-established concept that an uncertainty statement assigns credible limits to the accuracy of a reported value stating to what extent that value may differ from its reference value

Uncertainty is basically a measure of the goodness of the measurement result. In practice it quantifies the magnitude of any possible discrepancy between the value actually obtained from a measurement of a defined quantity and the value which would be attained by the highest level reference laboratory for the same quantity or by some other agreed upon authority.

The estimation of possible discrepancy takes into accounts both random error and bias in the measurement process. The distinction to keep in mind with regard to random error and bias is that random errors cannot be corrected, and biases can, theoretically at least, be corrected or eliminated from the measurement result, at least in situations where there is a defined reference value. The GUM procedures are based on the assumption that all biases are corrected for and that the only uncertainty from this source is the uncertainty of the correction.

2.4   Type of Uncertainty

Uncertainty in a measurement can arise from three possible origins: the measuring device, the procedure of how you measure, and the observed quantity itself. Usually the largest of these will determine the uncertainty in your data.

There are two basically different types of uncertainties: systematic and random uncertainties.

2.4.1 Systematic Uncertainties

Systematic uncertainties or systematic errors always bias results in one specific direction. The result will consistently be too high or too low.

An example of a systematic error follows. Assume you want to measure the length of table in cm using a meter stick. But suppose the meter stick has been manufactured incorrectly or the stick is made of metal that has contracted due to the temperature in the room, so that the stick is less than one meter long. Clearly all the calibrations on the stick are smaller than they should be. The numerical value for the length of the table will then always be too large no matter how often or how carefully you measure.

Another example might be reading temperature from a mercury thermometer in which a bubble is present in the mercury column. Systematical errors are usually due to imperfections in the equipment, improper or biased observation, or by the presence of additional physical effects you did not take into account.

In performing experiments, try to estimate the effects of as many systematic errors as you can, and then remove or correct for the most important. By being aware of the sources of systematic error beforehand, it is often possible to perform experiments with sufficient care to compensate for weaknesses in the equipment.

2.4.2 Random Uncertainties

In contrast to systematic uncertainties, random uncertainties are unbiased -- meaning it is equally likely that an individual measurement is too high or too low. Random uncertainty means that several measurements of a quantity will not always come out the same but will spread around a mean value. The mean value will be much closer to the real value than any individual measurement.

From everyday experience, somebody might now say, "Stop! Whenever I measure the length of a table with a meter stick I get exactly the same value no matter how often I measure it!" This may happen if the meter stick is insensitive to random measurements, because of a coarse scale (like mm) and always read the length to the nearest mm. But if with meter stick with a finer scale would use or if interpolating to fractions of an mm, it would definitely see the spread. As a general rule, if the value does not get a spread in values, the measurements can improve by using a finer scale or by interpolating between the finest scale marks on the ruler.

How can one reduce the effect of random uncertainties? Consider the following example. Ten people measure the time of a sprinter using stopwatches. It is very unlikely that each of the ten stopwatches will show exactly the same result. Its will observe a spread in the results. Even if each started their watch at exactly the same time (unlikely) some persons will have stopped the watch early, some of them late. In general, making multiple measurements and averaging can reduce the effect of random uncertainty.