KOLEJ UNIVERSITI TEKNIKAL KEBANGSAAN MALAYSIA

Universal Measuring Machine: A Study on Potential Error and Common Error in Calibration Process (Gage Block)

Thesis submitted in accordance with the requirements of the Kolej Universiti Teknikal Kebangsaan Malaysia for the Bachelor Degree of Manufacturing Engineering in Manufacturing Process

By

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DEDICATION

For My Beloved Father, Mother, All My Siblings and Friends.

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ABSTRACT

Calibration is the most important thing in measurement field since human technology requires accuracy and precision in life. This is proved when it is always stated that calibration could enhance business competitiveness by averting the unnecessary costs caused by errors in equipment readings. However, when dealing with calibration and measurement process, human tendency to make an error is cannot be prevented. But human is still find the best way try to eliminate all the possible errors that might occurred to increase the accuracy and precision for nowadays and future purposes. This paper study is about to study and analyze potential error and common error done by human that arise during calibrating 100 mm gage block using high precision machine as UMM. Apart from finding the error, the study is also aimed to find the best method to calibrating the 100 mm gage block using UMM by analyzing the collected data from experiment among selected individuals. All the data were collected in the Metrology Laboratory in KUTKM. Results that come out from the experiments data were grouped and compared to each other in case to be used as the finding to achieve the study goals.

ABSTRAK

Penentukuran adalah perkara terpenting di dalam bidang pengukuran semenjak teknologi buatan manusia memerlukan ketepatan dan kejituan di dalam kehidupan. Ini dibuktikan apabila penentukuran sering kali dinyatakan sebagai mampu untuk meningkatkan persaingan di dalam perniagaan dengan mengelakkan penggunaan kos yang hanya disebabkan oleh ralat bacaan pada peralatan. Bagaimanapun, apabila manusia menjalankan proses penentukuran dan pengukuran, kesilapan dan ralat tidak dapat dielakkan. Namun begitu, manusia masih mencari kaedah terbaik untuk menghapuskan sebarang ralat yang mungkin timbul untuk meningkatkan ketepatan dan kejituan pada bacaan untuk kegunaan pada hari ini dan juga masa hadapan. Kertas kajian ini adalah merangkumi kajian dan analisa mengenai *'potential error'* dan *'common error'* yang dilakukan oleh manusia semasa melakukan penentukuran keatas *'gage block'* yang berukuran 100 mm dengan menggunakan mesin berkejituan tinggi seperti mesin UMM. Selain dari menentukan ralat, kajian ini juga mensasarkan untuk mencari kaedah terbaik bagi melakukan proses penentukuran ke atas *'gage block'* yang berukuran 100 mm dengan menggunakan mesin UMM. Ini dilakukan dengan menganalisa kesemua data yang dikumpul dari individu yang melakukan eksperimen. Kesemua data yang dikumpul telah diambil ketika eksperimen di dalam makmal metrologi di KUTKM. Data dari hasil eksperimen yang dilakukan akan dikumpul dan dibandingkan sesama sendiri sebagai satu penemuan untuk mencapai sasaran kajian ini.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

DYN. Button	- Dynamic measurement button
KUTKM	- Kolej Universiti Teknikal Kebangsaan Malaysia
mm	- Milimeter
UMM	- Universal Measuring Machine
μin	- Microinch
μm	- Micrometer

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

This study is all about to discuss and discover the 100 mm gage block calibration process using UMM, common and potential error that possibly will occur and the influence of these error in metrology world. Recommendations for reducing the errors are discussed in Chapter 7.

The degree to which a measurement meets the national, or other generally accepted standard, depends on how well the measuring instrument or process is calibrated. The quality of calibration in turn depends on the choice and use of a stable standard, its traceability, reliability, and stability of compliance to an accepted standard. In dimensional metrology, management's ultimate tool for technologically assuring precision in measurement through the calibration is the use of gage as an example.

High technology manufacturing rooted in automated processes, robotics, group technology, flexible manufacturing and computer integration has assumed increased significance as a determinant of global competitive pressures, managing the precision of product components and their assembly remains a primary concern for management. Developments in high tech manufacturing mean that industrial measuring processes must ensure precision. Precision is here defined as the degree of agreement among independent measurements of a quality under strictly specified conditions (Babbar, 1992).

The need to ensure precision in measurement when managing for quality must be underscored. While the degree of precision in measurement may vary between manufacturers and locations, the significance of the need for precision in calibration and measurement is universally recognized.

1.2 THE GROSS ERRORS

Gross errors are the result of human mistakes, equipment fault, and the like. Human errors may occur in the process of observation or during the recording and interpretation of experimental results (Dyer, 2001). Potential errors and common errors that are generated by human will be determined in order to reduce variance in calibration data. Even though UMM is the high precision machine, there will be errors made by human contributed by several factors. One of these factors is environment factor since this factor is uncontrollable as the condition of calibration room; hot or cold, crowded or spacious and so on.

1.2.1 Potential Error

According to Thompson (1995) potential is capable of coming into being or action; latent. It also defined as the capacity for use or development; possibility. Potential error as it term, is a type of error that highly possible will occur during the measurement or calibration process using UMM. The causes is not only raises from human, it also may involve the environment factor such as temperature and relative humidity that surrounding the area. These factors affected the size of gage block and as a result, the reading from measurement is unpredictable as it highly influenced by this type of error and usually has an alternate method to control the outcome from the experiment. But only human error will be taken under consideration since environmental factor is specified as constant along this study.

1.2.2 Common Error

According to Thompson (1995), common is defined as occurring often (a common mistake), ordinary; of ordinary qualities; without special rank or position. Differ with potential error, common error is an error that frequently will occur because of human tendency to make an error. In the other words, common error is an error that normally arises to affecting the measurement or calibration process caused by human, it hardly to prevent or demolish cause of human nature that always stick with mistake or error in whatever situation they are, especially when dealing with machine like UMM. Careless is the main reason that always contributing to the common error. However, this can be reducing by increasing the level of concentration and cautious when performing this process.

1.3 CALIBRATION

Calibration is an essential process for the equipment before it can be use in lab or machine. This is because there is no machine or equipment that truly precise and accurate due to environment and human factor. The calibration of all instruments is essential for checking their performances against known standards. This provides consistency in readings and reduces errors, thus validating the measurements universally. After an instrument is calibrated, future operation is deemed to be error-bounded for a given period of time for similar operational conditions. The calibration procedure involves comparison of the instruments against primary or secondary standards. In some cases, it may be adequate to calibrate a device against another one with a known accuracy.

1.4 CALIBRATION EQUIPMENTS

This study involves several equipments to achieve the objective consisted of 100 mm gage block and Universal Measuring Machine (UMM).

Gage block is regularly used in the lab as a measuring reference for calibration almost measuring equipment as example micrometer and vernier caliper. This block is in rectangular shape with lapped and flat surface. 100 mm gage block is used during this study because only this size is available for master gage block provided by supplier with UMM.

Universal Measuring Machine (UMM) is the machine that fully used to achieve the project objectives for both semesters. It is beneficially for measuring and calibration purpose of almost equipment and object. The other tasks that also can perform by this machine is free measurement, measuring bores, measuring plain gage, measuring threads, measuring micrometer screws, measuring snap gages and measuring dial gages.

1.5 BACKGROUND PROBLEMS

In the determination to have an accuracy and precision of measurements, calibration process is the fundamental and essential process. This thing is very important in case to find and counter the inaccuracy and imprecise data collected. UMM is the new machine with high precision technology and this machine will be used as the machine to calibrate the 100 mm gage block. Error always arise especially when human are dealing with machine that manually handled by them. Through this study, the human errors would be identified as common error and potential error. It also defined as gross error. The study may show the variation between experience individual and non experience individual. Non experience individual may have bigger data variance compare to experience individual in operating this high precision machine, UMM.

1.6 OBJECTIVES OF STUDY

The objectives of this study are:

i) To identify the potential error and common error that might occur during the calibration process.
ii) To reduce variance in the calibration data of 100 mm gage block.
iii) To estimate the number of contact points on the gage blocks in the calibration process by using UMM.

1.7 SCOPE OF STUDY

The potential errors and common errors are identified based on the calibration results of 100 mm gage block by using Universal Measuring Machine 828 CiM. Human error is taken as the sources of these errors. The experiments data are limited to four individual who have experience in using UMM and another 4 individual who have not experience in using UMM.

1.8 THE EXPECTED OUTCOMES

The 100 mm gage block calibration process will smoothly perform with minor errors by using a standard operating procedure with a specific number of contact points. Therefore, the variation of calibration data is smaller.

CHAPTER 2

LITERATURE REVIEW

2.1 THE CALIBRATION

Calibration indicated as a process to find an exact value from its nominal value by using a specific equipment or machine resulted by related factors as environment or human. Calibration defined as adjusting or setting an instrument to give readings that are accurate within a reference standard. (Kalpakjian, Schmid, 2000).

As an addition, Lipták (1999) had mentioned calibrate is purposing to ascertain output of advice corresponding to a series of values of a quantity which the device is to measure, receive or transmit. Data so obtained are used to:

i. Determine the locations to which scale graduations are to be placed.
ii. Adjust the output, to bring it to the desired value, within a specified tolerance.
iii. Ascertain the error by comparing the device output reading against a standard.

Calibration is the process of putting marks on a display or checking a measuring system against a standard when transducer is in a defined environment (Bolton, 2000).

Dyer (2001) explained that the calibration of all instruments is essential for checking their performances against known standards. This provides consistency in readings and reduces errors, thus validating the measurements universally. He also mentioned that the rule of thumb is that each calibrated variable must have a traceable ladder starting from laboratory standards and secondary standards leading to primary standards. This is known as the linear calibration model or traceability.

He added that most instrument manufacturers supply calibrated instruments and reliable information about their products. But their claims of accuracy and reliability must be taken at face value. Therefore, in many cases, application-specific calibrations must be made periodically within the recommended calibration intervals.

Usually, manufacturers supply calibration programs. In the absence of such programs, it is advisable to conduct frequent calibrations in the early stages of installation and lengthen the period between calibrations as the confidence builds based of satisfactory performance. Recently, with the wide applications of digital systems, computers can make automatic and self calibrations as in the case of many intelligence instruments. In these cases, post measurement corrections are made, and the magnitudes of various errors are stored in the memory to be recalled and used in laboratory and field applications (Dyer, 2001)

Calibration can be simplified from the findings as a process to make an adjustment to equipment's nominal value by using specific method and equipment. Sometimes, this value is slightly different from measured value during calibration process. In this case, the measured value is taken as a new value to the equipment. As an example, the nominal value of gage block is declared as 50 mm in width. After the calibration process with certain temperature and condition, the value changed to 50.0005mm. This value is taken as a new value under the same temperature and condition for any measurement process using the same gage block after this.

2.2 TYPES OF ERROR

The ideal or perfect instrument would have perfect sensitivity, reliability, and repeatability without any spread of values and would be within the applicable standards. However in many measurements, there will be imprecise and inaccurate results due to many internal and external factors. The departure from the expected perfection is called the error. When determining the performance of an instrument, it is essential to appreciate how errors arise.

There may be many sources of error; therefore, it is important to identify these sources and draw up an error budget. In the error budget, there may be many factors, such as imperfections in electrical and mechanical components (e.g., high tolerances and noise or offset voltages), changes in component performances (e.g., shift in gains, changes in chemistry, aging, and drifts in offsets), external and ambient influences (e.g., temperature, pressure, and humidity), and inherent physical fundamental laws (e.g., thermal and other electrical noises, Brownian motion in materials and radiation). In instrumentation systems, error can be broadly classified as systematic, random, or gross (Dyer, 2001).

Errors can be classified as being either random or systematic errors. Random errors are ones which can vary in a random manner between successive readings of the same quantity. Systematic errors are errors which do not vary from one reading to another (Bolton, 2000).

2.2.1 Systematic Error

Systematic errors remain constant with repeated measurements. They can be divided into two basic groups: the instrumental errors and the environmental errors. Instrumental errors are inherent within the instrument, arising because of the mechanical structure, electronic design, improper adjustments, wrong applications, and so on. They can be also sub classified as loading errors, scale error, zero error, and response time error. The environmental errors are caused by environmental factors such as temperature and humidity. Systematic errors can be also viewed as static or dynamic errors (Dyer, 2001).

Bolton (2000) has mentioned that under systematic error, there lying 4 factors that contributing to this type of error.

i. *Construction errors*

These occur in the manufacture of an instrument and arise from such causes as tolerances on the dimensions of components and on the values of electrical components used.

ii. *Approximation errors*

These arise from the assumptions made regarding relationships between quantities, e.g., a linear relationship between two quantities is often assumed and may in practice only be an approximation to the true relationship.

iii. *Ageing errors*

These are errors resulting from the instruments getting older, e.g. components deteriorating and their values changing, a build up deposits on surfaces affecting contact resistances and insulation.

iv. Insertion errors

These are errors which result from the insertion of the instrument into the position to measure a quantity affecting its value, e.g. inserting an ammeter into a circuit to measure the current thus changing the value of the current due to the ammeter's own resistance.

Supported by Lipták (1999), systematic error is an error which, in the course of a number of measurements made under the same conditions of the same value of a given quantity; either remains constant in absolute value and sin or varies according to a definite law when the conditions change.

2.2.2 Random Error

Random errors appear as a result of rounding of reading, noise and interference, backlash and ambient influences, and so on. In experiments, the random errors vary by small amounts around a mean value. Therefore, the future value of any individual measurement cannot be predicted in a deterministic manner.

Random errors may not easily be offset electronically; therefore, in the analysis and compensation, stochastic approaches are adapted by using the laws of probability (Dyer, 2001).

According to Bolton (2000), random errors can be divided into several numbers of sources as operating errors. These can result from variety of causes, e.g. errors in reading the position of a pointer not being in the same plane, the reading obtained then depending on the angle at which the pointer is viewed against the scale (the so called parallax error). Also there are errors due to the uncertainty that exist in estimating readings between scale markings on an instrument's display. Other than that are environmental errors. These are errors which can arise as a result of environmental effects, such as a change in temperature or electromagnetic interference. And the last one is stochastic errors. These result from stochastic processes such as noise. A stochastic process is one which results in random signals.

2.2.3 Gross Error

Gross errors are the result of human mistakes, equipment fault, and the like. Human errors may occur in the process of observation or during the recording and interpretation of experimental results. A large number of errors can be attributes to carelessness, the improper adjustment of instruments, the lack of knowledge about the instrument and the process, and so on. These errors cannot be treated mathematically and cannot be eliminated completely, but they can be minimized by having different observers repeat the experiments (Dyer, 2001).

2.2.4 Simplification of Errors

By refer to findings mentioned before it can be conclude that random errors are actually the errors that arise from the environment and current situation. It mostly affected when the environment or current situation is change.

As an example, temperature and level of sound would affect the result of one's experiment value. Random error also makes the reading vary from each other in random manner from the successive reading of the same quantity and would be seems to give a random data to the experiment result.

Different with random error, systematic error is the type of error that remains do not vary from one reading to another obviously. This is because of the factor that contributes to crop up this error is not affected by the environment or current situation as random error. It is naturally errors occur as machine constructions that originally deliver to the customer with the error, or the ageing factor to the machine that make it slightly give the incorrect reading. Operators that also make an earlier roundup to the results were also the contributor to the systematic error.

2.3 GAGE BLOCK

Gage blocks are rectangular in shape and come in sets of 81-88 blocks of different length. The hierarchy in the levels of gage blocks is given by the grand master set, the master set, the reference set and finally the working set. The importance of precision in the calibration of gage blocks especially the master blocks becomes even more critical owing to their hierarchical level. An error at one level of the block hierarchy can easily compound, as blocks at this level are used to calibrate lower level blocks. The cumulative error then ultimately transfers on to manufactured components and products through devices calibrated for use on the shopfloor (Babbar, 1992).

Babbar (1992) has also mentioned that there is four values are associated with the length specification of a gage block. These are the nominal, true, measured, and accepted values. He added that the nominal value is the length value assigned to the block at the time of it manufacture. Reference to a block as "2.000-inch block" constitutes its nominal length specification. The true value, on the other hand, is the actual length value of the block at given point in time. Supporting his statement is measured value simply reflects the reading generated by a measuring instrument at a point in time.