UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EVALUATION OF CMM'S UNCERTAINTY BY USING EXCEL

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons.). The member of the supervisory is as follow:

_____

ABSTRAK

Seperti yang diketahui, penilaian *uncertainty* untuk Mesin Pengukuran Koordinat (MPK) bukan satu tugas yang mudah. Kebanyakan penilaian *uncertainty* bagi pengukuran adalah dijalankan dengan menggunakan piawaian yang dikenali sebagai *Guide to the expression of Uncertainty Measurement* (GUM). Walau bagaimanapun, formula yang digunakan untuk menilai uncertainty adalah rumit dan tidak mudah untuk dihafal. Kajian ini dijalankan untuk mengatasi kesukaran dalam penilaian *uncertainty* dengan menggunakan fungsi-fungsi yang diperkenalkan oleh Excel. Terdapat banyak faktor-faktor yang boleh menyebabkan *uncertainty* dalam pengukuran MPK. Namun begitu, faktor-faktor yang akan dibincangkan dalam kajian ini adalah panjang *stylus*, diameter bebola, dan kelajuan kuar sentuh yang menghala komponen yang hendak diukur . Untuk mencapai objektif kajian ini, artifak yang berbentuk sfera digunakan untuk mendapatkan bacaan bulatannya. *Uncertainty* dalam pengukuran MPK dinilai dengan Excel yang telah dikaji. Akhirnya, keputusan untuk penilaian *uncertainty* akan dibandingkan dengan kajian-kajian yang pernah dijalankan.

ABSTRACT

Uncertainty evaluation for the Coordinate Measuring Machine (CMM) is not an easy task. Mostly, the evaluation of CMM measurement will be carried out by using the Guide to the expression of Uncertainty Measurement (GUM). However, the complicated equations involved in the evaluations are not easy to be memorised and calculated. This study is carried out to overcome the difficulties of the CMM measurement evaluation by applying the functions of Excel to build up an uncertainty evaluation tool. There are a number of sources that may contribute to the measurement errors and uncertainty. However, the factors that taking part in this styudy are stylus length, ball diameter and touch speed. In order to evaluate the uncertainty in CMM measurement, a probe calibration artefact which is a ceramic sphere was measured and the uncertainty of CMM measurements were evaluated by using the evaluation tool created. This uncertainty evaluation tool was created by using the application of Excel accordance with GUM. Finally, the results of evaluation uncertainty were validated by comparing with the previous researchs.

DEDICATION

To my beloved grandparents, parents, sisters and brother

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LIST OF ABBREVIATION, SYMBOLS AND NOMENCLATURE

AMC	-	Advance Machining Centre
ANSI	-	American National Standards Institute
ASME	-	American Society of Mechanical Engineers
CAD	-	Computer Aided Drawing
CMM	-	Coordinate Measuring Machine
DOE	-	Design of Experiment
GUM	-	Guide to the expression of Uncertainty Measurement
ISO	-	International Organization for Standardization
JCGM	-	Joint Committee for Guides in Metrology
MPK	-	Mesin Pengukur Kordinat
NIST	-	National Institute of Standards and Technology
PSM	-	Project Sarjana Muda
RSS	-	Root Sum of the Square
SPC	-	Statistical Process Control
TP	-	Touch Probe
UTeM	-	Universiti Teknikal Malaysia Melaka
VIM	-	International Vocabulary of basic and general terms in Metrology

CHAPTER 1
INTRODUCTION

This chapter presents the general introduction of the project. The problem statement, objectives and scope of the study are identified in this chapter. Briefly to say, this project is carried out to create an evaluation tool by using Excel for the evaluation of uncertainty in Coordinate Measuring Machine (CMM) measurement. The Guide to the expression of Uncertainty in Measurement (GUM) is used in this study. The factors that contribute to the uncertainty of measurement are studied in this project as well. Last but not least, the overview of this study is summarized in the end of chapter.

1.1 Background

Measurement is one of the procedures that essential in wide range of areas such as the fields on nuclear, space, electronics, manufacturing industries and so on. Measurement is known as a process that performed to determine the value of a physical quantity with assist of measuring instrument. However, it is impossible to obtain the ideal value of measurement because of the presence of uncertainties.

By referring to the International Vocabulary of Basic and General Terms in Metrology (VIM) (GUM,1993), uncertainty of measurement is defined as the parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributes to the measured objects.

Uncertainty of measurement is to be anticipated in the result of a measurement. It can be taken part in the calibration, test or tolerance of any products. Careful measurement with properly identified and quantified uncertainties could lead to a high quality of product and improve the safety margins in such system. Therefore, the better way is set an interval to the final outcome when the measurement is made. Interval here meant that the range inside the desired value lies.

According to Fornaisini (2008), physical quantity of measurement is generally quoted as

$$X = X_0 \pm \delta X \qquad (1.1)$$

Where X_0 is the true value of measurement

δX is the uncertainty due to the display resolution.

Since there no measurement is exact, thus, the measurement taken by using CMM is also no exception. CMM is the machine that created to measure the dimension of the part with three dimensional spaces. According to the CMM's manufacturers, this machine is playing the important role in nearly all of the industry because it can be used for dimensional measurement, profile measurement, angularity or orientation measurement, depth mapping, digitizing or imaging and shaft measurement. CMM uses a probe to measure points on a part. Each point on the workpiece is unique to the machine's coordinate system. With the supporting of software and hardware of CMM system, the product dimension can be easily measured but it is not including the error and uncertainty of measurement made. Since Fornaisini (2008) told that uncertainty can be caused by many different factors which cannot be reduced by the instrument characteristics, it is better to understand the measurement process and determine the factors that may influence the measurement.

The uncertainty of measurement is evaluated according to the GUM which provides the step by step procedure to construct the analysis of measurement uncertainty. In accordance with Joint Committee for Guides in Metrology (JCGM) (2008), the ideal method for construct the evaluation of the uncertainty should be universal, internally

consistent, transferable, and readily provide the level of confidence that corresponds in a realistic way with that required.

This project is focused on the making use of Excel to evaluate the uncertainty of measurement by determining the values of mean, standard deviation, degree of freedom and uncertainties in CMM measurement. Excel is known as the spreadsheet that can be used for storing, organizing and manipulating data. Microsoft Office Corporation (2011) stated that Excel Calculation Services is one of the basic components of Excel Service which can load the workbook, calculate and revive the data. Excel is not only can be used to store the data, but it also provides the built-in functions to perform the same calculations multiple times by using different input values, reuse the calculations in another program without retype it and allocate a simple task to make the complex program to be easily understood (Larsen, 2009).

1.2 Problem Statement

In general, the uncertainty measurement can be evaluated by manual or software programs. However, evaluating uncertainty of measurement by manual is not an easy task. The equations for uncertainty of measurement are complex to be memorized and complicated to be calculated as well. Yet, in this modern world, there is a number of software programs have been implemented to provide the needs of evaluation on measurement uncertainty. "Uncertainty Calculator" by Chris Grachanen is one of the software programs that may download from the website (Agilent Technologies, 2004). However, most of these software programs are uncommon to all users. The users are sometimes required to purchase for the software. Apart from that, users need spend more time to learn and understand the program as well. Also, the programs sometimes need support by other software with the specific programming language.

In order to overcome the difficulties for evaluation of uncertainty in CMM measurement, this project is carried out to study and introduce the method of computing the uncertainty measurement by using Microsoft Excel as the evaluation tool. This evaluation tool can be used by the entire Excel users in any areas with the

basic knowledge in Excel. The evaluation tool created is to make sure users friendly and allow users to evaluate the CMM's uncertainty with a systematically method which is standardized. Besides that, invention of this evaluation tool with Excel application is easy to use as it has shorten the learning time of user. As a result, the uncertainty in measurement can be evaluated with low cost, short time and accurate result.

To accomplish the project, CMM is used as the measuring instrument to carry out the measurement of artefact (ceramic sphere). The measurement of artefact is carried out by using different variables. Then, the data is collected and the uncertainty of measurement is evaluated in accordance with GUM by using Excel.

1.3 Objectives

The objectives of this project are:

- To study and understand the method of evaluation for CMM's uncertainty.
- To identify the factors those cause uncertainty in CMM measurements.
- To set up an evaluation tool for the purpose of evaluate the uncertainty in CMM measurement.

1.4 Scope

This study is focused on the creation of an evaluation tool to evaluate the uncertainty in CMM measurement. The project involved the GUM to investigate the measurement uncertainty. It also involved the application of Microsoft Excel for the purpose of evaluates the uncertainty in CMM measurement. In order to get data for the evaluation, CMM is used to measure the artefact in this project with a number of variables.

1.5 Organization

This report begins with a description of the project. Chapter 1 contains a general introduction of the report. This chapter includes the background, problem statement, objectives and scope of the project. The organization of the report is provided as well. In chapter 2, the literature reviews related to the project are presented. Through the understanding and reviewing of the project in Chapter 2, the methodology to accomplish this project is then described in Chapter 3. After carried out the studies, the results and discussion are discussed in Chapter 4. Last but not least, Chapter 5 encloses with the conclusion and suggestion for the project as well. In the end of the report, the documents related with the study are attached in Appendix such as Gantt charts of the Project Sarjana Muda (PSM) I and PSM II and the graphs of analyses.

CHAPTER 2
LITERATURE REVIEW

This chapter basically presents the literature reviews of topics related to the project title. First of all, the general introduction of coordinate measuring machine (CMM) is presented which including the types of CMM, CMM probing system and CMM software. Next, the errors and uncertainties which always influenced the measurement accuracy are explained as well. Sources of errors and uncertainties of CMM are then further described in this chapter. Apart from that, the general introduction of the tool that used to evaluate CMM uncertainty which is Excel is presented. Finally, a brief summary of the literature reviewed is provided in this chapter as well.

2.1 Coordinate Measuring Machine (CMM)

CMM is one of the important tools for post-process inspection of products and check the dimension in a variety of process tooling in the manufacturing industry. CMMs are widely used in order to ensure dimensional quality of products exactly meet the customers' requirements. Benbow *et al.* (2003) stated that CMMs are widely used because the flexibility and speed of CMMs to measure the dimensional characteristics of many products. Comparing with CMM, the conventional equipment may take longer time and more procedures for the similar measurement.

Leach (2010) described that the CMMs as the machine which can be used to determine the spatial coordinates of surface part being measured by the movement of probing system. In general, CMMs are functioning with the three linear axes and

Cartesian coordinates. Besides that, CMMs are used to measure the part by single point probing or scanning. The data are collected continuously when the stylus tip is in contact with the single points of surface or dragged across the surface.

CMMs can be either function with manual or automatic mode. In manual mode, the machine is operated by user. However, in automatic mode, the CMM is actuated by electric devices and driven by a CNC controller (Zhao *et al*., 2011). CMMs are typically able to readout and analyse the distances of the part being measured with the interface between the CMM three linear axes guide ways (*x, y*, and *z* axes), CMM probing system and CMM software. As an example, Figure 2.1 is about the basic design of a CMM.

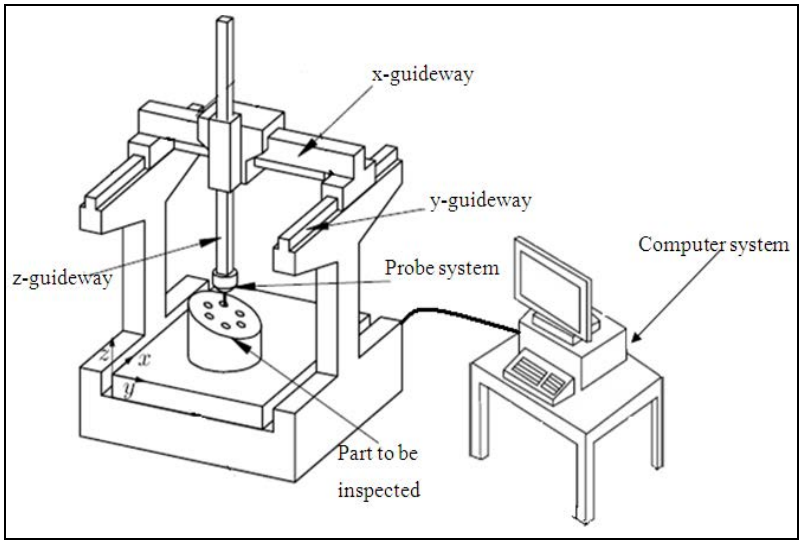
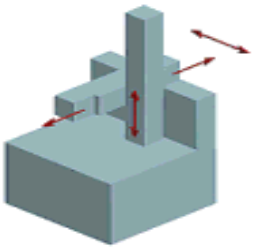
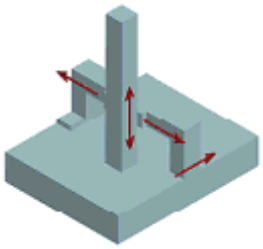
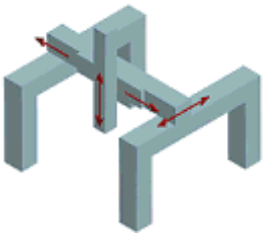
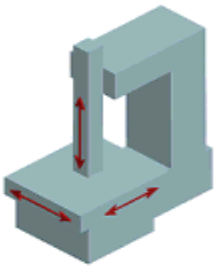
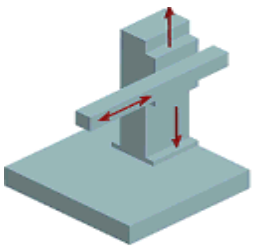


Figure 2.1: The basic structure of CMM.

2.1.1 Types of CMM

As Colosimo (2011) mentioned that, the different characteristics of CMMs are usually performing the different tasks based on their advantages and disadvantages. Even though there are several configurations and sizes of CMMs are used for the geometrical part measurement, they can be reduced to five basic configurations which are described by ISO 10360-1 (2000). The basic types of CMMs are showed and described in Table 2.1.

Table 2.1: Classification of CMMs (Leach, 2009 and Tooling University LLC, 2011).

Types	Description	Figures
Cantilever	Cantilever CMM is the CMM with a single, moveable vertical support that suspends a horizontal arm that holds the probe.	
Bridge	With a horizontal beam holding the probe and high accuracy, bridge CMM are commonly used in the manufacturing industry. This type of CMM can help to measure small and medium-size parts accurately.	
Gantry	The ram moves vertically on cross side which moves side to side on third carriage. The third carriage moves on two large fixed beams on either side of part.	
Column	Ram of column CMM moves vertically with a fixed column. The part to be measured placed on the working table which moving in x and y direction.	
Horizontal arm	CMM with a horizontal arm supporting the probe. The horizontal CMM makes it easy to load large, heavy parts. It is usually ideal for inspecting the parts in automotive, ships, aerospace industries.