UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PERFORMANCE EVALUATION OF COORDINATE MEASURING MACHINES

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

by

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I hereby, declared this report entitled "PERFORMANCE EVALUATION OF COORDINATE MEASURING MACHINES" is the result of my own research except as cited in references

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Date : 20th Mei 2011

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 (Engineering Process) with Honours. The member of the supervisory committee is as follow:

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ABSTRAK

'Coordinate Measuring Machine' (CMM) dikenali sebagai mesin ukuran yang tepat dan jitu didalam bidang Metrologi. Pemahaman yang tepat tentang sistem akan menyebabkan kesalahan pengukuran boleh dikira. Tujuan projek ini adalah untuk mempelajari penilaian prestasi dua model CMM iaitu Wenzel LH 54 dan Carl Zeiss G2 Contura. Projek ini menumpu pada pengaruh pengukuran pada lokasi yang berbeza di meja granit, panjang 'probe' yang berbeza dan saiz 'probe' yang berbeza untuk pengukuran. Sebelum pengukuran dilakukan, 'probe' akan dikalibrasi. Ia akan dinilai pada lima lokasi yang berbeza dari pengukuran di meja granit. Untuk saiz 'probe', ia akan berubah-ubah dari 2mm kepada 6mm. Setiap pengukuran akan diambil tiga kali pada setiap titik. Kesalahan akan dikira dan hasilnya akan diterbitkan sebagai teknik pengukuran optimum yang akan menghasilkan kesalahan minimum.

ABSTRACT

Coordinate Measuring Machine (CMM) is known as an accurate and precise measuring machine. The aim of this project is to study the performance evaluation of two models of CMM which are Wenzel LH 54 and Carl Zeiss Contura G2. This project concentrates on the effect of measurement at different location on the granite table, different probe length and different probe size to the measurement. In addition, this project also done to see the effect of using automatic mode and manual mode. Before measurements are taken, the probe will be calibrated. This is compulsory in order to make sure the measurements are precise all the time. There will be five different locations of measurement on the granite table. For the probe size, it will be varies from 2mm to 6mm. Errors are calculated in chapter 4 and the result will be published as the optimum measurement techniques that produce minimum errors.

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DEDICATION

Dedicated, in deepest appreciation for support, encouragement and understanding to my beloved family.

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LIST OF ABBREVIATIONS

CMM	-	Coordinate Measuring Machine
mm	-	Millimeter
CAD	-	Computer Aided Design
3D	-	3-Dimension
DOE	-	Design of Experiment
ANOVA	-	Analysis of variance
U	-	Uncertainty
U_c	-	Cumulative Uncertainty
S_x	-	Standard Deviation

CHAPTER 1

INTRODUCTION

1.1 Background Study

Coordinate Measuring Machines (CMM) are mechanical systems designed to move a measuring probe to determine coordinates of points on a work piece surface. CMMs provide the tools to precisely inspect critical dimensions, thus dramatically increasing the number of acceptable parts for our clients and decreasing the occurrence of errors.

CMMs are useful in nearly every industry due to their capabilities in dimensional measurement, profile measurement, angularity or orientation measurement, depth mapping, digitizing or imaging and shaft measurement. Consequently, CMMs reduce the incidence of nonconforming parts by providing exceptional inspection abilities. Furthermore, their ability to accurately reverse engineer existing parts is extremely helpful when prints are no longer available.

CMM move a measuring probe to obtain the coordinates of points on an objects surface. Often these parts have tolerances as small as 0.0001. The machine uses an X, Y, Z grid to determine its position on a worktable. The probe is used to touch different spots on the part being measured. The machine then uses the X, Y, Z coordinates of each of these points to determine size and position. The probes drag along the surface of the part taking points at specified intervals. This method of

CMM inspection is more accurate than the conventional touch-probe method and often faster as well. Many thousands of points can then be taken and used to not only check size and position but to create a 3D image of the part as well. This "point-cloud data" can then be transferred to Computer Aided Design (CAD) software to create a working 3-dimension (3D) model of the part. This procedure is often used to facilitate the "reverse engineering" process. This is the practice of taking an existing part, measuring it to determine its size, and creating engineering drawings from these measurements. This is most often necessary in cases where engineering drawings may no longer exist or are unavailable for the particular part that needs replacement.

Reductions in product life-cycle durations are driving companies to develop and produce products at an ever-increasing rate. Industry experts are predicting the arrival of rapid manufacturing through the use of flexible manufacturing systems. Even a brief examination of industry periodicals such as manufacturing engineering, Technimetrics, production and quality or supply chain systems would reveal discussions about highly integrated systems that are flexible, agile and lean. One result of these trends is the incorporation of CMM, which allow companies to perform data collection and process verification within the manufacturing cell. Research on various coordinate metrology issues have paralleled the increased usage of CMM in industry as inadequacies are uncovered and new needs develop. Research topics have covered such areas as the development of new probe compensation algorithms, sampling strategies, part orientation optimization, and computer generated inspection paths. As is often the case in research, assumptions have to be made in the interest of ensuring study feasibility. One such assumption is that the part orientation will not affect the measurements made by the CMM. This is one of the assumptions that this study challenged.

1.2 Objectives

The objectives of this study are:

1.2.1 To suggest which location is the best to do measurement for both machine, to suggest which probe is the best to use when doing measurement and which mode is more precise to use when doing measurement (manual / auto).

1.2.2 To compare the measurement results between the Wenzel CMM and the Carl Zeiss CMM to see which is more precise.

1.2.3 To evaluate the measurement errors at different location.

1.2.4 To evaluate the measurement errors of CMM for different size of touch probe.

1.3 Problem Statement

Measurement accuracy can be obtained if the users understand the behavior of the measuring machine. This issue always be ignored by the industrial user which usually focusing more on the result of the measurement. Operators always operate CMM according to understanding on the available current setup and base on the user's own knowledge instead of the correct way to use it. This is not suitable especially in metrology area. The approach on using CMM with different approach will affect the level of accuracy. The approach of this study will be based on the touch probe and location of the workpiece on the table.

1.4 Scope

The scope of this study is to evaluate the measurement results produce by two CMM model manufactured by Carl Zeiss and Wenzel. In addition, this project will focus on the best probe to choose for a particular measurement that needs to be made and the effect of different location on the measurement platform. This project will also try to find errors that effect measurement. Finally, this project will propose the best condition during measurement so that the best result can be obtain. Different size and length of touch probe will be used. The measurement will be done at different locations on the granite table. In understanding the behavior of the result, errors will be calculated and all results will be compared. Lastly, the results will show the performance of both machines

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Engineering precision in manufacturing is very important. But how engineers determine that the product is precise in measurement? There are seldom techniques to use. One of it is by using Coordinate Measuring Machine (CMM). According to Ogura, Okazaki (2006); they said that a CMM is generally used to measure product profiles. Although it can make various product measurements, such as the diameter of holes or complicated profiles, the measurement scale of a CMM is usually several tens of millimeters or more, and it is not suitable for measuring small parts of submillimeter order. In addition, T. Oiwa(2008); said in recent years, CMM has been widely used for precision measurement in various fields. Such the conventional CMM employs an X, Y, Z mechanism consisting of three mutually orthogonal slide mechanisms. Ali et al "A Proposed Diagnostic Tool Based on Evolved Deviations in Geometrical Measurements" Accurate dimensional and geometrical measurements using precision devices are crucial during the manufacturing processes of parts to insure their compliance with the design requirements. In addition, these measurements may also be employed with reference to their benchmark values to monitor the extent and severity of functional deterioration of the parts, especially those working with their surfaces during service.

2.2 Probing in CMM

In CMM, knowing to know the correct probe to use for a measurement is very important because it will affect the output result from the measurement. According to Towery (2000), there are several types of probes which are:

- Touch Trigger Probe

  This type of probe is made to deflect when it comes into contact with the surface. It is very similar in principle to an electrical switch. When the switch is activated the scales of all three axes are read. The touch trigger probe is probably the most widely used probe on the market making it very cost effective.

- Nulling Probe

  The nulling probe is somewhat a CMM by itself. It consists of three super-imposed spring parallelograms and an inductive linear measuring system is provided in each axis for the position measurement. This probe uses a electronic positioning control until the inductive sensor has come to a zero point. After the zero point is reached the machine reads the scales of the CMM.

- Non-contact Probe

  The newest, most advanced, and most costly probes are probes that do not contact the surface of the workpiece. Non-contact probes use optical principles like triangulation, focusing, reflecting, image processing, or a combination of these principles. This type of probe has benefits like rapid point collection (at rates of 40-80 per second), the ability to measure parts with complicated features that a contact probe cannot reach, and the ability to measure parts that are sensitive to surface contact.

According to Liu, *et al.* the first task in the reconstruction of a freeform surface is to obtain the measurement data. Among the various sensing techniques available, mechanical contact probes such as CMM's (Coordinate Measuring Machine) touch probe, and 3D vision systems using structure-light are widely used in practical applications. CMM with touch-triggered probes can provide high measurement accuracy at sub-micron level. However, the measurement speed is much lower than using a 3D vision system. A vision system can acquire thousands of data points over a large spatial range in a snapshot. However, the achievable resolution is relatively lower, at around 200-100 µm. Therefore, in practical applications, using one of the techniques means that the user has to suffer from its limitations, e.g. the low speed with CMM. In addition, Xiong, Li (2003) added that the touch trigger probe, which is also called a switching probe or touch probe, provides an economical method of on-machine metrology on tool machines as well as on CMM. The touch trigger probe has become one of the basic building blocks for supporting untended machining in manufacturing systems. In spite of the high precision of the touch trigger probe, there are errors associated with touch probing applications. Two sources of errors specifically, pretravel or lobing variations and errors due to probe radius. In further research, an article had by Sheffield Measurement, page 18 (2006), by using effective probe techniques when inspecting a workpiece, a worker can eliminate many common causes of measurement error. For example, probe measurement should be taken perpendicular to the work surface whenever possible (figure 2.2.1). Touch trigger probes used on CMM are designed to give optimal results when the probe tip touches the workpiece perpendicular to the probe body. Ideally, an operator should take this with plus minus 20 degree of perpendicular to avoid skidding the probe tip. Skidding produces inconsistent and non repeatable result. Figure 2.2.2 shows the approach vectors are perpendicular to the surface of the sphere.

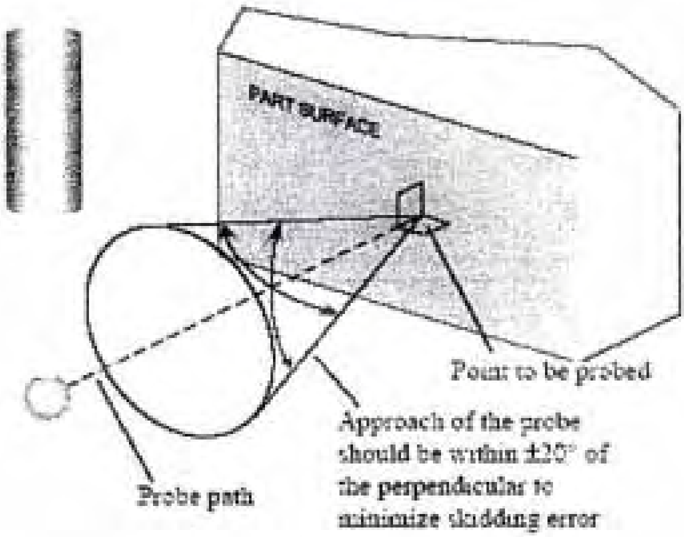

Figure 2.2.1: Perpendicular touch

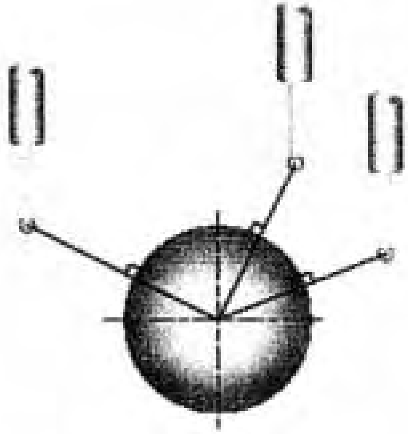

Figure 2.2.2: Approach vector

Probe hits taken parallel to the probe body that is along the axis of the stylus are not repeatable as those taken perpendicular to the axis like example in figure 2.2.3.

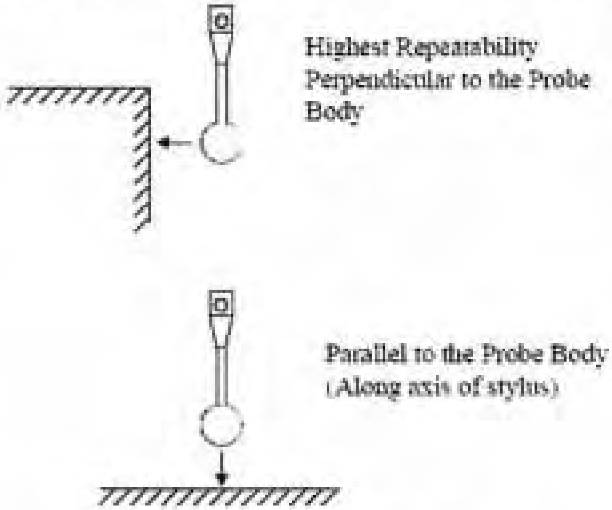

Figure 2.2.3: Probe hits

Using effective techniques is a techniques where a probe hits neither perpendicular nor parallel to the probe body and produce result that are even less repeatable than those taken parallel to the probe body. An operator should avoid taking probe hits parallel to the stylus and at angle to the probe body since they will produce large error.

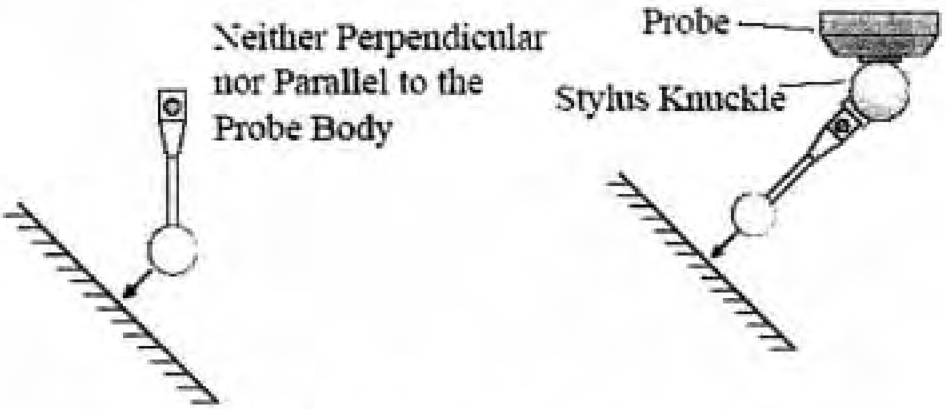

Figure 2.2.4: Non-perpendicular touch

Shanking is another cause of measurement error. When probe contact the workpiece with the shank of the stylus and not the tip, the measuring system assumes the hit was taken in a normal manner and large error will occur.

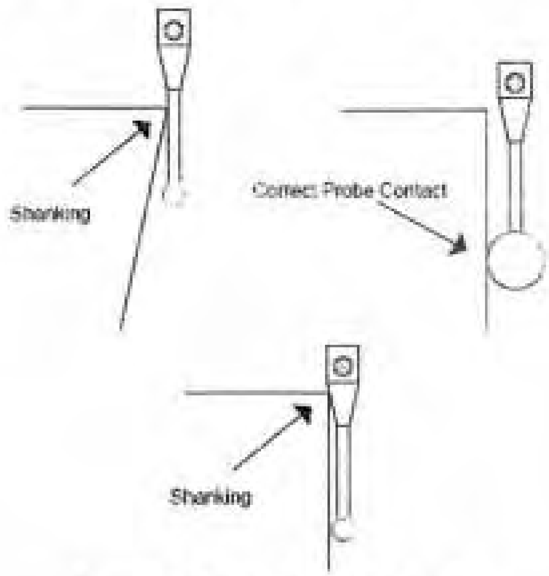

Figure 2.2.5: Effect of shanking

An operator can reduce the likelihood of shanking by using a larger diameter tip to increase the clearance between the ball/stem and the workpiece surface. Generally, the larger the tip diameter, the deeper the stylus can go before it touches the workpiece feature. This is called the effective working length of the probe. Also, the larger the tip, the less effect it has on the surface finish of the workpiece since the contact point is spread over a larger area of the feature being measured. However, the largest tip that can be used is limited by the size of the smallest hole to be measured.

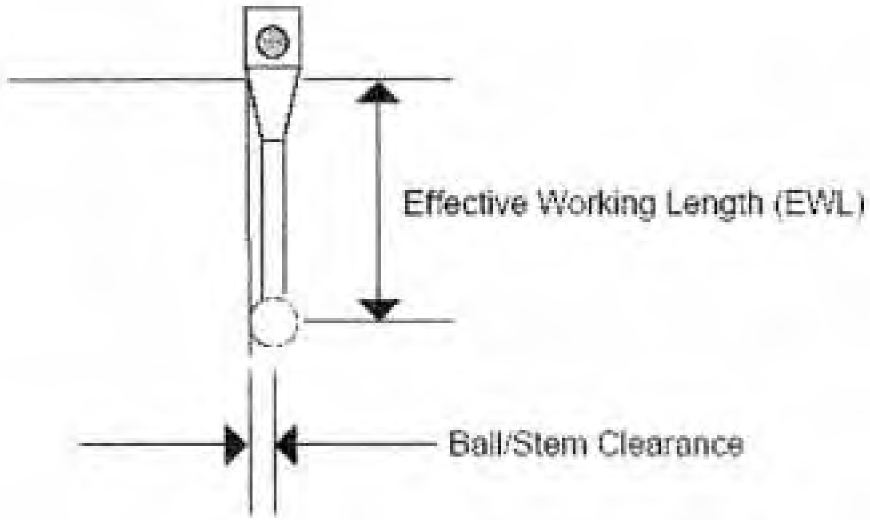

Figure 2.2.6: Probe length

Measurements taken with an electronic probe are recorded when the stylus is deflected enough to either break mechanical contacts or generate enough force to trigger pressure sensitive circuitry. The physical arrangement of the contacts causes slight errors in accuracy although these are reduced during probe qualification. However, the longer the probe tip extension, the larger the pre-travel error and more residual error is left after probe qualification. Longer probes are not as stiff as shorter ones. The more the stylus bends or deflects, the lower the accuracy. An operator should avoid using probe with very long stylus or with long extension combination. In doing measurement using CMM, there are always problems occurred on how many points should be taken so that the optimum result can be evaluated. Now there is a solution because according to Romano, Vicario (2002) in industrial usage of CMM, seldom more than eight points are measured on any surface. This makes estimation of uncertainty an even more critical issue. With a few points only, the pattern of the experimental design becomes a governing factor concerning the uncertainty of the coming outcome. Berisso and Ollison (2010) stated that the available literature implies that there is no single answer for the determination of the proper sampling strategy (how many data points to collect). While all authors agree that more points will provide better representations (Choi, W., Kurfess, T. R. & Cagan, J., 1998; Marsh, 1996; Hocken et al., 1993; Ramaswami, Kanagaraj & Anand, 2009; Weckenmann, A., Eitzert, H., Garmer, M. & Webert, H., 1995), the