UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE STUDY ON THE EFFECT OF FAROARM – 3D LASER SCANNER IN DIFFERENT SCANNING DEPTH, SCANNING ANGLE AND TEMPERATURES CONDITION

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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TAJUK: **The Study on the Effect of Faroarm - 3D Laser Scanner in Different Scanning Depth, Scanning Angle and Temperatures Condition**

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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). The member of the supervisory committee is as follow:

………………………………

Supervisor

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ABSTRAK

Tujuan kajian ini adalah untuk mengetahui pengaruh Pengimbas Laser Faroarm - 3D di kedalaman imbasan yang berbeza, sudut imbasan yang berbeza dan keadaan suhu yang belainan. Penyelidikan ini juga akan mencadangkan kaedah imbasan yang sesuai yang mampu menghasilkan dimensi standard yang berhampiran dengan pengukuran. Eksperimen ini akan menggunakan dua bahan kerja yang berbeza iaitu 50 mm bongkah tolok dan 32 mm cincin tolok. Bahan kerja juga disaluti dengan menggunakan semburan aerosol meningkatkan tahap kepantulan semasa pengimbasan. Dengan menggunakan Pengimbas Laser Faroarm-3D, bahan kerja akan diteliti dan maklumat akan dihantar kepada Geomagic Studio and Qualify untuk pengukuran. Kaedah-kaedah pengimbasan adalah kedalaman imbasan, sudut imbasan dan suhu semasa imbasan. Kedalaman imbasan akan dibahagikan kepada dua peringkat iaitu 95mm dan 130 mm. Sudut-sudut untuk imbasan laser ialah 45^{o} dan 90^{o} dan untuk suhu, dua suhu berbeza telah dipilih iaitu 19^{o}C and 25^{o}C. Dengan menggunakan aplikasi MINITAB, data-data dianalisis dan dicadangkan imbasan sesuai yang mampu menghasilkan pengukuran berhampiran dengan dimensi standard adalah pada 130 mm kedalaman imbasan, sudut imbasan iaitu 45^{o} dan pada suhu 19^{o}C. Selain itu, ketidakpastian Pengimbas Laser Faroarm-3D dibandingkan dengan menggunakan Mesin Mengukur Koordinat (CMM). Dari perhitungan ketidakpastian, kaedah pengukuran tidak sentuh kurang tepat jika dibandingkan dengan kaedah pengukuran sentuh. Hal ini kerana beberapa sumber ketidakpastian.

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ABSTRACT

The objectives of this study are to investigate the effect of Faroarm – 3D Laser Scanner in different scanning depth, scanning angle and temperatures condition. This study also proposing the suitable scanning methods that able to produced measurement close to the standard dimension. The experiment will be using two different workpieces, 50 mm gauge block and 32 mm ring gauge. The workpiece also were coated by using aerosol spray to improve the reflectivity during scanning. By using Faroarm-3D laser scanner, the workpiece will be scanned and the information will be send to the Geomagic Studio and Qualify software for measurement. The scanning methods that were applied for this study are scanning depth, scanning angle and different temperatures. The scanning depth was divide into two levels that are 95 mm and 130 mm. The scanning angles are 45^o and 90^o and for the temperatures, two different temperatures were selected that is 19^oC and 25^oC. By using MINITAB software, the data were analyzed and the proposed suitable scanning that able to produce measurement close to the standard dimension are 130 mm of scanning depth, 45^o of scanning angle and 19^oC of temperature conditions. Other than that, the uncertainty of the Faroarm-3D Laser Scanner was compared with Coordinate Measuring Machines (CMM). From the calculation of the uncertainty, the non-contact method measurement is less accurate from contact method measurement. This is because of a few source of uncertainty.

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DEDICATION

For my beloved family:

Mat Yunus Bin Awang

Muji Binti Abas

For my adored friends:

Mohd Kamarul Shaufi Bin Rasidi

Azri Safuan Bin Abdul Halim

Mohd Ikhwan Bin Muhamad

Muhammad Aiman Bin Yusof

Muhammad Rabani Bin Othaman

Muhammad Ammar Bin Hassan

Shukri Zarizi Bin Kamaruzan

BMFP's Students

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LIST OF ABBREVIATIONS

CAD	-	Computer-aided design
AACMM	-	Articulated Arm Coordinate Measuring Machine
CMM	-	Coordinate Measuring Machine
ROI	-	Return of Investment
UK	-	United Kingdom
DOE	-	Design of Experiment
3D	-	3 Dimension

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CHAPTER 1

INTRODUCTION

1.1 Background Study

3D laser scanning is a non-contact inspection method that has the ability of fast 3D modelling. This lead to cloud-to-CAD comparisons, reverse engineering and rapid prototyping capability. The laser scanner attached to the articulated arm coordinate measuring machine (AACMM) represent a complicated measurement tool, whose accuracy and repeatability can be difficult to gauge but better than free movement of scanner in 3D space. AACMMs are widely used in manufacturing industries as an alternative to coordinate measuring machine (CMM). The applications can be found in medical fields, aerospace industries, automotive industries, archaeology and etc. AACMMs take the inspection of conventional floor where can be moved around and also can be used in the field. This will minimize or eliminates down time of parts travelling from production flow to measurement floor. Conventional CMMs carry relative high price tags and complexity. Portables of AACMMs have not only broken the inspection room barrier, but they are comparable inexpensive and relatively to use than their traditional cousins (Paul and Mohammad Kamil, 2010).

Nowadays 3D laser scanner is able to attach on AACMMs which deliver faster return of investment (ROI), a better user experience and improved functionality. This is because the technology enables objects to be digitized and producing 3D images. The 3D image is in the form of cloud of point which can be manipulated for features extraction. These features are very informative which can be used in reverse engineering and inspection applications (Lavelle, 2004).

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One of the effective technique to acquire 3D coordinate data on an object surface is a laser range sensing. Nowadays, commercial laser scanner able to mounted on the computer controlled milling machine, robots or coordinate measuring machines (CMMs) for reverse engineering. Laser digitizing has the advantages over the digitiziting using touch-trigger probe by its high speed, high resolution and non-contact sensing (Feng, 2001).

The most important disadvantages of laser scanners is the accuracy stated by Gestel (2009) are, at this moment, are limited accuracy and the strong influence of surface quality. It is difficult to measure shiny surfaces in example machined steel, aluminium and transparent parts because diffuse reflection is needed in order to capture the projected line by the camera. It is stated that laser line scanner is one magnitude less accurate compare to CMM touch probe. Moreover, with the limitation of camera view, the scanner also will have a limited field of view (Gestel, 2009).

FARO is the market leader in portable computer-aided measurement systems. The FaroArm enables highly precise 3D measurements of both large and small parts in production. It is offering 6 or 7 axes of rotation, the FaroArm is as accurate as large, expensive fixed-bed coordinate measuring machines (CMM), but it is portable and much easier to use. Based on the manufacturer specification, FaroArm has the accuracy of ± 30μm when the laser is used. A laser scanning attachment can be easily added to the FaroArm turning it into a noncontact measurement solution. Large parts can also be measured with the arm in combination with a FARO Laser Tracker, expanding range up to 115ft (35m). The FaroArm's lightweight construction, wireless Bluetooth data transfer capabilities and the integrated battery enable measurements to be taken wherever you need them. Its outstanding ergonomics assisted by internal counterbalance makes daily work much easier. With intuitive hardware and software, extensive training is no more necessary to handle it (Faro SEA, 2010).

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The previous study already been done by using Faroarm Laser Scanner. The researcher is study about error propagation in metrology field. They also suggest the methods that can be use during experiment to minimal the error. For this study, it is approached from previous study but in different field. This study will study the error propagation of Faroarm-3D Laser Scanner in uncontrolled field. Uncontrolled field will have weather and temperatures changing that possibly lead the error.

1.2 Problem Statement

Non-contact device have been proven to be a new way to faster measurements and an effective digitising technique. Manufacturing companies are looking towards faster and more reliable systems that can still comply with high quality in inspection and also reverse engineering (Santolaria et al., 2009). The portable of the AACMMs has favoured their use in inspection and quality control tasks in the industry, where the use of traditional coordinate measurement machines (CMM) is not possible due to operational or cost reasons. The different scanning methods will affect the measurement values. There are a few parameters that already been discussed before this study. There are scan angle, level depth of scan and different temperatures. The accuracy of the machine is one of the factors that will affect the result of the measurement. The different manufacture will produce different machine and also different accuracy. The different accuracy of the machine will affect the result of the measurement. For this study, the uncertainty of Faroarm-3D Laser Scanner will compare with CMM. This study was conduct to propose the suitable scanning methods that produce the measurement close to the standard dimension of the workpieces.

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1.3 Objectives

Objectives of this study are as follows:

i. To investigate the effect of Faroarm – 3D Laser Scanner in different scanning depth, scanning angle and temperatures condition.
ii. To propose suitable set of scanning parameters that able to produce measurement close to the standard dimension.
iii. To compare the uncertainty of Faroarm – 3D Laser Scanner with CMM in order to suggest the accuracy of the machines.

1.4 Scope

For this study, Faroarm-3D Laser Scanner is using to conducting the experiment. Two different workpieces are chosen to for this study. The workpiece is 50 mm gauge block and 32 mm ring gauge. The experiment will conduct in laboratory with different temperature condition. Scan angle is one of the methods that will be use in this experiment. Other than that, the different scanning depth also will be conduct for this experiment. The machine also will have warm-up time before the experiment. For comparison of uncertainty, CMM is used as a reference.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Researcher already studying regarding to this issue but most of it only focusing on scanning paths and data manipulation by the laser scanner. Mekid and Luna (2007) already stated that the accuracy of the laser scanner is affected by the digitizing parameters contribute by the manufacturer and also user. Other than that, Van Gestel (2009) also study about the parameters of angle, scan depth and also thermal stability test. From the study, they can conclude that the parameters will affect the random and systematic errors. Study by Mekid and Luna (2007) already divide the digitizing parameters to two types that are extrinsic parameters and intrinsic parameters.

2.2 Intrinsic Parameters

Intrinsic parameters are the parameters that already embedded in the laser scanner on or on the workpiece that cannot be change by the user.

2.2.1 Speckle Noise

The light waves are travelling in the same phase during the laser light is emitted towards the surface to be measure. When the light hits the target, the lasers rays are reflected towards the photo detector but there will no longer in phase. This happens because when the light strikes the workpiece, the light will strike at different

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positions that will lead the light reflect directly to the speckle while some other part will bounce and arrive later. This is what we call scattered light (Mekid and Luna, 2007).

2.2.2 Digitising Resolution

Mekid and Luna (2007) stated that the sensor camera that with the laser scanner has a limitation on the distance between points acquired from the reflection of the laser stripe. The set distance between points is fixed and it cannot be changed.

2.2.3 Occlusion

Mekid and Luna (2007) mentioned that the occlusion is the obstruction of the highlighted surface from the photo detector. When the laser light strike at the surface of the workpiece, they are expected to reflect towards the photo detector, but because of the physical obstruction (different feature), the reflection will never back to the detector and will lead into missing part of the surface and the cloud of the points will be incomplete. It can be solve by performing different scan angle of the laser scanner.

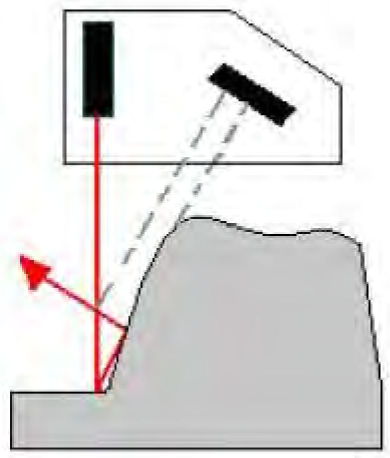

Figure 2.1: Occlusion (Mekid and Luna, 2007)

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2.2.4 Edges

During scanning along the surface of the workpiece, it will arrive to the edge or corner of the feature and will lead to different outcomes. It happens when the orientation of the normal part of the surface is changing that can reflected the light in different direction and the target will not be measured. When laser beam is very close to the edge, it will bounce from the surface that it below of it and lead different wrong points that can be registered while scanning along an edge (Mekid and Luna, 2007).

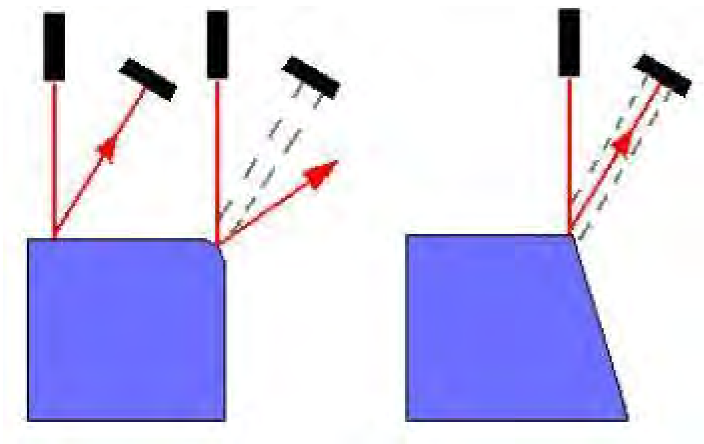

Figure 2.2: Edges that leads to errors (Mekid and Luna,2007)

2.2.5 Deep Features

Different features have different physical shapes. Deep features will be disadvantages against contact methods. As already been described, the principle of laser scanner is based on the reflection of the light to the photodetector when its strikes the surface of the workpiece. But for the deep features, it will hard for the lights to strikes the bottom of the features. But with recent technology, this problem can be avoid by set the scanner to have set of field of view between 0.01-0.05mm below the nominal position. By using this scanning method, more accurate points are taken by including the edges (Mekid and Luna, 2007).

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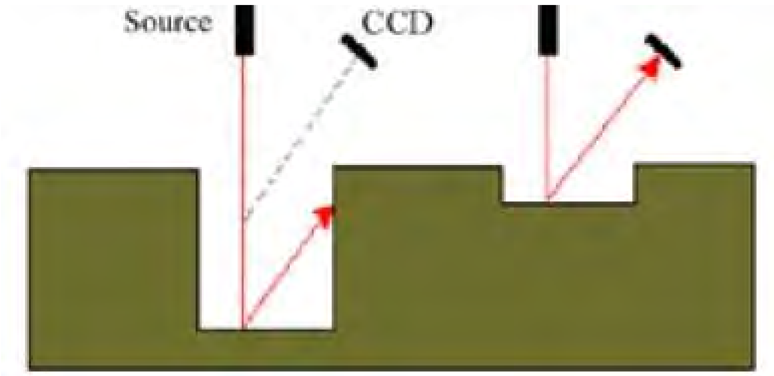

Figure 2.3: The deep of the features (Mekid and Luna, 2007)

2.2.6 Projected Angle

Mekid and Luna (2007) stated that the projected angle already been set by the manufactured and cannot be changed by the users. Metris LC15 laser scanner has the projected angle that was set at 30^o while LC 50 is set at 45^o. Some commercial lasers are available to change its angle of the photodetector in order to increase the accuracy.

2.3 Extrinsic Parameter

Extrinsic parameters are parameters that can be controlled by the user while intrinsic parameters are not accessible by the user. For this study, we focused only on the extrinsic parameters.

2.3.1 Depth of Scan

Van Gestel (2009) already done the scanning depth test and evaluates the influence of the scan depth on the systematic and random error. For that evaluation, the reference plane is scanned at 10 equally spaced scan depth levels and this was done 10 times to get an idea of the repeatability of the results. Level 1 is the position

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where the scanner is closest to the reference plane, level 10 is the level when the scanner is far away from the reference plane, as illustrated in Figure 2.4. The distance between level 1 and 10 almost equals the depth of the field of view of the scanner (50 mm).

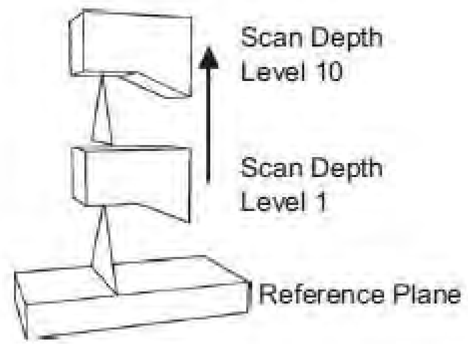

Figure 2.4: Reference plane scanned at several scan depths (Van Gestel, 2009)

The standard deviation for each scanned plane and the distances from each plane to the lowest of the 100 measured planes are visualised in Figure 2.5 and Figure 2.6. The standard deviation is an indication of the digitising noise. The systematic errors in function of scanning depth are indicated by the distances between the planes. When the triangulation angle is becoming smaller with increasing scan depth, the measurement noise should increase with enlarging scan depth (Van Gestel, 2009).

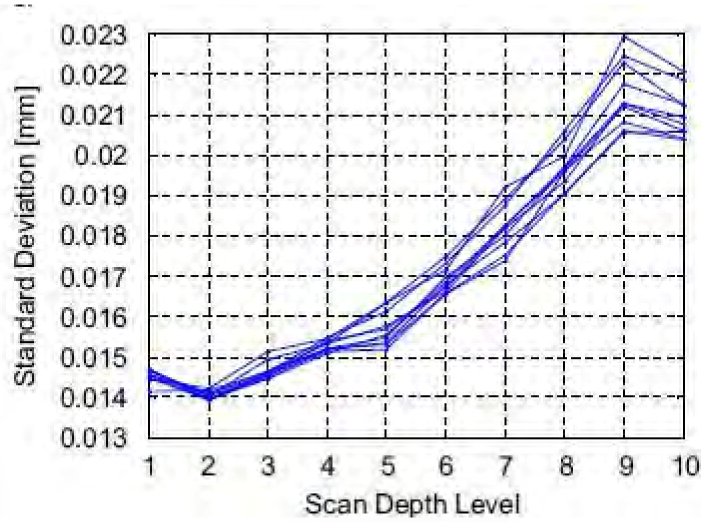

Figure 2.5: Influence of scan depth level on random errors (Van Gestel, 2009)

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