Design of Jig for Coordinate Measuring Machine

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ABSTRACT

This project is about the design of jig for Coordinate Measuring Machine (CMM) in metrology laboratory. The CMM is one of precision measuring devices for measuring the physical geometrical characteristics of the product. Measurements are defined by a measuring probe touch the surface of the product. Currently, the box and plasticine are needed as a vice because there is no special vise in CMM to hold, clamp and support the workpiece. The existing vice is not properly in the measurement process but its used for the workpiece with a thickness less than 40mm and measuring probe can touch the workpiece. Because of that, the objective of the design of jig for CMM is to improve the measurement process in order to replace the existing vice. In other words, the design of jig is to ensure the method of measuring process is the correct to obtain the accuracy of measurement. The function of this jig is to hold, support and clamp the workpiece. The conceptual design is used to choose the best design. Based on the feedback obtained from the survey and benchmark, three designs of the jig; design A, B, and C have been evaluated using conceptual selection. The design C is selected as new design since the evaluation result in screening method gave the highest net score. The new design of jig is drawn and analyzed using SolidWorks software. Aluminium and ABS plastics were selected as selection material for the jig. The fabrication of jig has been done with a conventional milling machine and 3D printing. As a result, the jig is suitable and acceptable to apply in engineering measurement because of the accuracy is ±0.01mm.

Keywords: *jig, design, coordinate measuring machine (CMM), measuring probe, conceptual design*

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Introduction

The jig is widely used in the modern manufacturing process such as in machining, finishing, assembly, inspection, and so on. The definition of the jig is a work holding device that holds, support and locates the workpiece for a specific measurement. In other words, the jig is one type of custom-made tool and provide repeatability, accuracy, and interchangeability in the manufacturing products [1]. The inspection in measurement is important to determine the quality of the product in terms of accuracy and precision. In measurement have a few keys in aspect such as to maintain the consistency of quality and prevent or reduce improper techniques, and improve the overall safety of the workpiece, human, and machine, and quality control expenses reduce accident as safety is improved [2].

There are few factors in consideration in designing a jig such as the geometric, tolerances, dimensions, procedures and manufacturing process. Approximately 35% to 40% of rejected parts are due to dimensioning errors [3]. The conceptual design is important to identifying the good product. The design concept must be starting from survey to any reference or benchmark, type of fabrication and computer aided designing software, structural analysis, verified the product and so on. The previous researcher stated that the proper design can reflect production increase, low variability in dimension thereby leading to consistent quality of manufactured products, manufacturing cost reduction, interchangeability and high accuracy of parts, reduces the need for inspection and quality control expenses, reduces accident as safety is improved [2].

This study aims to design a jig for CMM in metrology laboratory in order to replace the existing vice. The existing vice is not practical in engineering measurement. To overcome this situation, the design of jig is required. The purpose of the jig is to hold, clamp and support the multi-geometrical shape such as a cylindrical and square workpiece. Also, to ensure the measuring probe can touch the surface of the workpiece with a thickness less than 40mm. The measurement of CMM is defined by a measuring probe attached to the third moving axis of the machine. The correct relationship and alignment between the tool and the workpiece are maintained [4]. This paper begins with an introduction of jigs, measuring probe in CMM and how to choose the best design. The best design was evaluated by screening method in conceptual design. The jig was designed using SolidWorks Ver.2016 because of reliable software. The conventional milling machine is used to fabricate all the elements in the jig. Generally, the purpose of the advantage of jigs for reducing or eliminating the efforts of measuring and setting of the workpiece on a machine and maintains the accuracy of performance [5].

Coordinate Measuring Machine

The CMM is one of precision measuring tools and widely used in metrology laboratory. In practical, CMMs are most common devices being used for three-dimensional inspection of physical product and multi-geometrical shape in the manufacturing process. The CMM is accurate, highly flexible and capability of measuring in three dimensions and two-dimensional planar or one-dimensional linear evaluations [6].

Basically, CMM consists of three axes and move along three orthogonal axes such as X-, Y- and Z-axis. Application of CMMs in the manufacturing process generally includes the process control, quality assurance of manufactured components, fixture verification, machine alignment [7]. There are several basic CMM configurations such as moving bridge type, fixed bridge type, column type, cantilever type, horizontal arm type and gantry type [8]. In this case study, moving bridge-type CMM is used for measurement of the workpiece. Normally, the CMM has four main components such as main structure, probing system, control or computing system, and measuring software.

The previous researcher suggested that the CMM probe is one of the most important elements of the dimensional measuring instrument and responsible for the coordinate measurement accuracy [9]. The function of measuring probe to determine coordinates of points on workpiece surface [7]. However, measuring probe is one of the physical configurations of CMM and most important elements of the dimensional measuring instrument in contact with the workpiece and responsible for the coordinate measurement accuracy [9-10]. The method of movement of measuring probe depends on the type of CMMs. A typical CMM probe orientation and part orientation is shown in Figure. 1. When an inspection of the workpiece is placed on a CMM table, some parts of the workpiece can be directly contacted by a probe without changing the probe orientation [11].

There are various types of measuring probe are available in the industry such as ball type probe, tapered probe, and cylindrical probe. However, the type of measuring probe is depending on the workpiece material and dimension of measuring. In this study, the type of measuring probe is ball type probe. Normally, the function of measuring probe is to determine the coordinate of points on a workpiece surface. Apparently is the measuring probe in metrology laboratory is not able to touch the surface of the workpiece with a thickness less than 40mm. In order to make a measurement, a vice is a required to hold and clamp the workpiece. Currently, there are no specific devices to hold, clamp and support the workpiece. Figure 2 shows the existing vice of measuring the workpiece with a thickness less than 40mm. The box and plasticine are needed as a vice to hold, clamp and support the workpiece with a thickness less than 40mm. This method is not practical in engineering measurement. In other words, this might lead to the inaccuracy during measurement and take the longest

preparation time. The design of jig is to ensure the proper method in engineering measurement and to maintain the quality of the measurement.

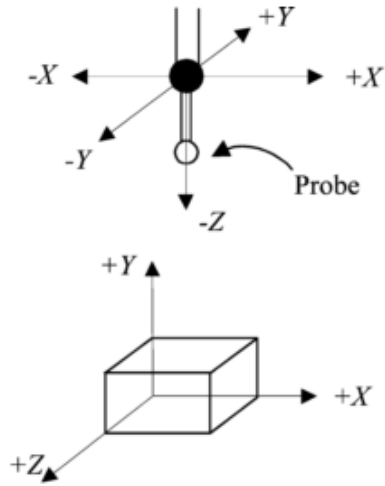

Fig. 1 Probe orientation change and setup change [11]

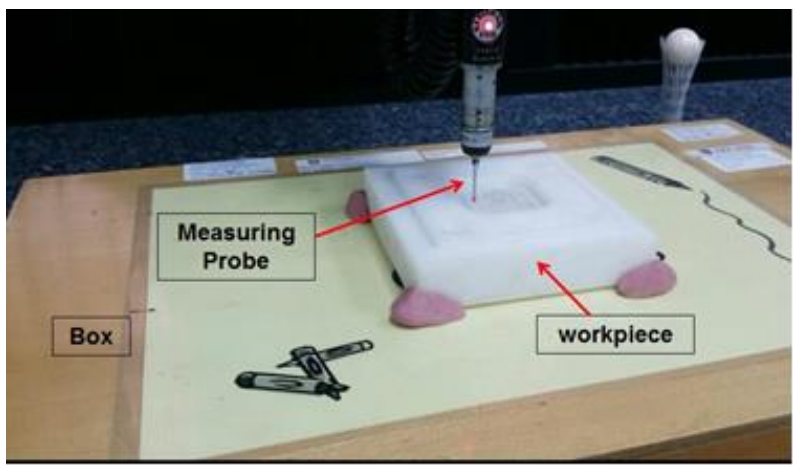

Figure 2: Measuring with existing vice

Design of Jig - Methodology

The purpose of design a jig is to holds, clamps and supports the workpiece with a thickness less than 40mm. A jig should be securely fastened to the CMM during a measurement process. As a designer, all the criteria's need to consider such as product functionality, life-cycle issues, manufacturability, ease of assembly, reliability and maintainability in order to reduce the risk of product launch and to help the effective resource management [12]. There are several characteristics in designing of a new jig such as geometry factor for the specimen, weight of the product, material selection, and safety of the product, durability, portable and replaceable part. Each of characteristics is summarized in Table 1. The conceptual selection is used to define the best design.

Table 1: Design Criteria

Characteristics	Description
Geometry factor	A variety of specimen such as square, cylinder, rod and etc.
Weight	Light and easy to used
Material selection	Strength
Safety	Easy to conduct during measurement
Durability	Can be used in long term
Portable part	Related to hold part and clamping
Replaceable part	Can be replaced depend on workpiece

In order to design the jig, a few ideas are generated to proposed. The best design that can suit the purpose of fabrication jig is selected based on the highest score in concept selection. Table 2 shows the concept selection and variants for each design, design A, design B and design C. The conceptual selection is one of the methods in the initial stage of the product development in the design of jig. The concept selection is a proposing concept to evaluate all related criteria in order to select the best concept in fulfill the objective of the product and developed the best concept. According to the previous researcher, the conceptual selection has been identified as the most crucial for the successful introduction of new products [13].

The concept selection process is based on two methodologies such as concept screening and concept scoring. In this project, the concept screening has been done in Table 2. There are several steps to determine the screening concept such as prepare the selection matrix, rate and rank the concept, and evaluate the concept in order to choose the best concept.

In concept screening, selection matrix is required to represent the idea and criteria's is related to CMM jig. Figure 2 shows design A, design B, and design C respectively for the jig based on the benchmark with others

institution and industry. The drafting for each design is drawn by SolidWorks Ver. 2016 software. The rate concepts are to assign a relative score and the score rates are divided into three symbols such as '+' as better than, '0' as same as and '-' as worse than.

Table 2: Concept Selection

	Concepts variants		
Characteristics	Design A	Design B	Design C
Geometry factor	+	-	+
Weight	0	0	0
Material selection	0	0	0
Safety	-	-	+
Durability	0	0	0
Portable part	0	+	+
Replaceable part	-	+	+
Sum +'s	1	2	4
Sum 0's	4	3	3
Sum –'s	2	2	0
Net score	-1	0	4
Rank	3	2	1
Continue?	No	No	Yes

The evaluation of concept selection is done by using rank concept. The rank concept is the sum of all the 'better than', 'same as' and 'worse than'. The result of net score and rank concept is shown in Table 2. Finally, the rank concept is given in order to evaluate the highest score based on the net score. The previous researcher stated, in order to design a fixture, the best design is selected based on the highest score from Pugh Method evaluation [14]. The fixture and jig are work holding devices and the both functions is to hold and support the workpiece. The Pugh Method or Pugh concept selection is one of the conceptual selection methods.

Result and Discussion

In this project, the design C get the highest net score. Hence it is chosen as the best design among the three design that has been proposed. The design model of the jig is drawn by using SolidWorks Ver. 2016 software. The SolidWorks software is easy to apply total pressure on a region where the clamp plate and work part mate each other [15]. This software is chosen because of the reliability, consistency and accuracy factors compared with manual drafting. Figure 3 shows drawing of a jig for the top view and front view. Mostly, 75% of product life-cycle cost is performed through by

conceptual design [12]. The importance of concept selection in the design of jig is to obtain the accurate design and can be used in metrology laboratory. However, material selection is one of characteristic to evaluate the conceptual design in order to obtain the proper design.

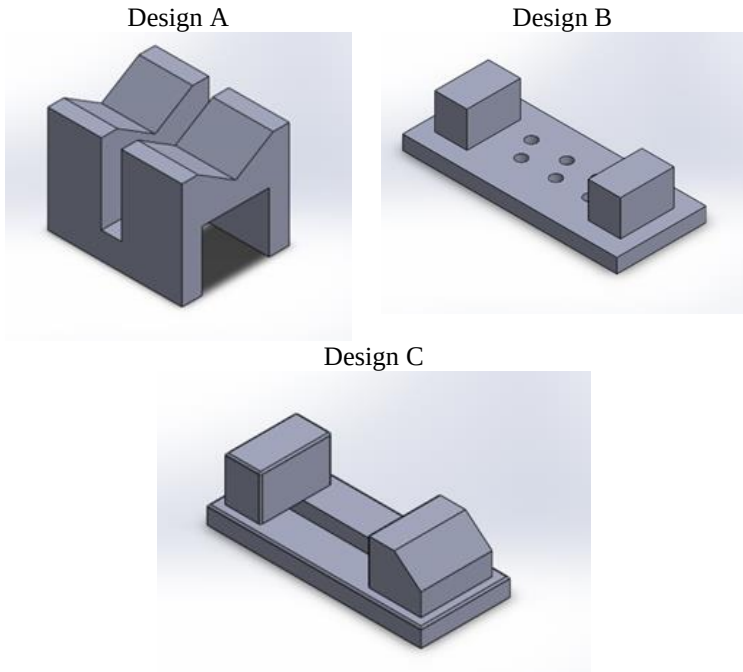

Figure 2: Draft of the Design A, B, and C

Normally, the selection of material is determined by the design. The selection of material cannot depend on process only but the shape and function are needs to be considered. The term of the shape is divided into macro-shape or micro-shape. All the shape is performed by the metal forming process, material removal process, and finishing process. Nonetheless, the fabrication of jig is lightweight material and easy to be machined.The jig is made from a variety of materials, some of which can be hardened or resist. There are few materials are used in the industrial fabrication of jigs such as mild steel, metal, aluminium, cast iron, and others.

There is two type of materials are used in this design such as aluminium 5083 for base plate and feet, and Acrylonitrile Butadiene Styrene, ABS for clamping square and cylinder. The aluminium 5083 is chosen in order to fabricate the jig. The aluminium 5083 square plate is easy of machining and commonly used in industry because of the lightweight

metallic material. The ABS plastic is used because of tough material and widely used in industrial. One of application ABS plastic in the industry is Lego brick. In this fabrication, ABS plastic is used to clamping in order to protect the work piece from stress concentration.

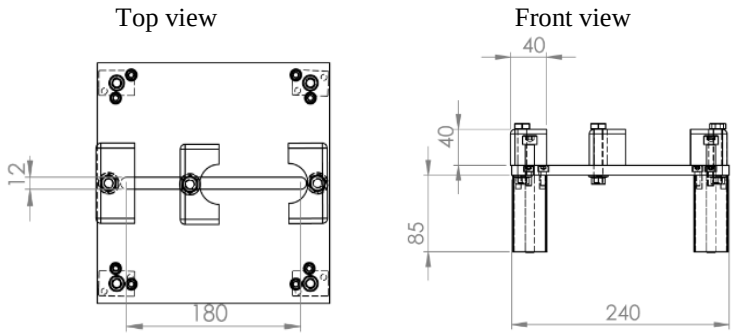

Figure 3: Drawing for top and front view

After finalized the conceptual design model and selection of material, all main parts were fabricated at small dimensional tolerance, ± 0.05mm. Figure 4 shows the exploded view of assembly jig. Table 3 shows each component in the jig with a description of their individual function. The element of design jig consists of the base plate, feet, and clamping for square and cylinder. The main part is the base plate with dimension 230mmx230mm and feet are 90mmx1.5mmx1.0mm. The elements of the base plate and four feet are fabricated by material removal process in a conventional milling machine.

A conventional milling machine is one of the important machining operations in a machine shop. The milling process is a process of producing the flat and complex shape, and to obtain a good surface finish. The function of the base place is to put the specimen and clamped by using the clamping. These designs provide four feet to support and raise the height of the base plate. The four feet should be bolted on the surface table of CMM and to avoid wobble during in measurement. The design and fabrication of jig are to ensure the geometrical shape specimen can be measured by using CMM. These designs have two types of adjustable clamping such as clamping square and clamping cylinder. The both of clamping are fabricated by additive manufacturing as known as 3D printing.

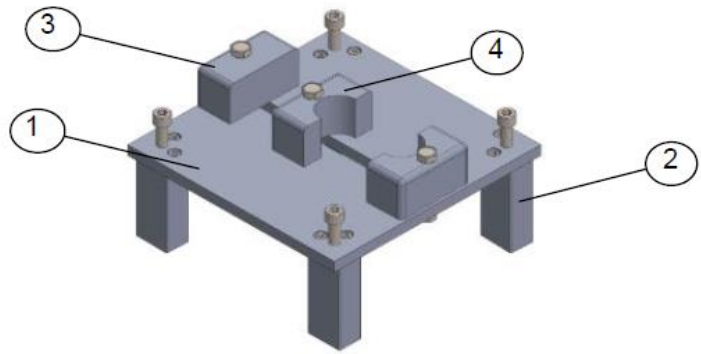

Fig. 4 Exploded view of assembly jig

Table 3: List of Parts and Features

Item	Part name	Description of features
1.	Base plate	Flat surface to put specimen during inspection
2.	Stand	To raise the height of the base plate
3.	Clamping square	Adjust and tighten to hold the square shaped specimen
4.	Clamping cylinder	Adjust and tighten to hold the cylinder shaped specimen

The 3D printing is an evolution of printing technologies, and capable of producing the complex product. The previous researcher mentioned that the printing process is carried out with the initial design is made by a computer aided design system, then the areas are printed through a compilation of two-dimensional slices representing the 3D object to consequently print layer by layer until the object is completed [16]. The functions of both clampings are to clamp the square or cylindrical specimen because the purpose of design is to measure the multi-geometrical shape specimen. The proper design can reflect production increase, low variability in dimension thereby leading to consistent quality of manufactured products, manufacturing cost reduction, interchangeability and high accuracy of parts, reduces the need for inspection and quality control expenses [2].

The final product of jig has been tested and proven to successfully during measurement in CMM. As a result, the accuracy of the jig is ±0.01mm, while the existing vice is ±0.22mm. The differences are both are slightly small, 12%. In the engineering measurement, the proper method is important to obtain the accuracy. The comparison of this jig to the existing

vice has several advantages in some aspects which are the time for the preparation of the vice, the quality of the workpiece, the accuracy of measuring probe and so on. According to the existing vice, the setup of the workpiece is required to identify the suitable size of the box and plasticine. This method can affect the quality of workpiece and movement of measuring probe because of using the plasticine as clamp holder.

Conclusion

This paper illustrates the design of a jig for CMM in metrology laboratory and to replace the existing jig. From the experimental result, the jig is suitable and acceptable to apply in engineering measurement because of the accuracy is ±0.01mm. The benefits of this jig are to hold, clamp and support the square workpiece with the thickness less than 40mm and to avoid measuring probe from any damage in during measurement. Besides that, this design can be measured the multi-geometric shape and easy to use.

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