NEW DEVELOP SMALL SCALE MACHINE OF NON-DESTRUCTIVE TEST (NDT) FOR COMPOSITE INSPECTION

by

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ENDORSEMENT

I, Mohamad Akmal Ridzuan Bin Radzi hereby declare that all corrections and comments made by the supervisor and examiner have been taken consideration and rectified accordingly.

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(Signature of Examiner)

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Date:

DECLARATION

This thesis is the result of my own investigation, except where otherwise stated and has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any other degree.

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MOHAMAD AKMAL RIDZUAN BIN RADZI

Date: 21/6/2019

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NEW DEVELOP SMALL SCALE MACHINE OF NON-DESTRUCTIVE TEST (NDT) FOR COMPOSITE INPSECTION

ABSTRACT

There are many types of the non-destructive test (NDT) method and ultrasonic testing is the most common method used in composite inspection. The main purpose of the inspection is to detect the defect that occurs in the composite such as cracks, delamination, void and others. The common Ultrasonic NDT equipment is quite larger, expensive and the system is also complex. This research is conducted to develop a small scale of NDT machine with a simple system and able to operate immersion ultrasonic testing of the composite and obtain the same result as the current product. The water is used as a coupling medium for the sound beam to travel between the transducer and specimen. The new design of water tank also has been developed to make this product become more ergonomic. This small scale machine will operate in two axis which is x and y axis and there are 2 NEMA-17 stepper motor used on the axis and controlled by using Arduino Genuino Mega 2560 and Adafruit Motor Shield v2 as a microcontroller and a motor driver respectively. In the inspection process, a tranducer of Harisonic Ultrasonic from Olympus corporation with a frequency of 2.25 MHz is used and a pulser-receiver is from US Ultratex. The process of inspection will be considered done after the performance of the machine has been optimized by undergoes some analysis. The result of the specimen such as the location and size of a crack can be gained from the signal. The sample of the specimen that being tested fibre glass composite laminates (FGCL) with holes as an artificial defect. The suitable stepping mode of the stepper motor with the least vibration produced during operation is analyzed. The structural analysis also is done by using simulation in Solidwork

software. Motion study is used to analyze the basic hand, arm and body movements of users as they use this machine.

PERKEMBANGAN MESIN BERSKALA KECIL BARU UJIAN TANPA MUSNAH UNTUK PEMERIKSAAN KOMPOSIT

ABSTRAK

Terdapat banyak jenis kaedah ujian tanpa musnah (NDT) dan ujian ultrasonik adalah satu kaedah yang paling konvensional digunakan dalam pemeriksaan komposit. Tujuan utama pemeriksaan adalah untuk mengesan kecacatan yang berlaku dalam komposit seperti retak, terubah lapisan dan sebagainya. Secara kebiasaanya, peralatan ultrasonik NDT adalah agak besar, mahal dan sistem yang digunakan agak kompleks. Kajian ini dijalankan untuk menghasilkan satu mesin NDT yang berskala kecil dengan sistem yang mudah serta dapat beroperasi rendaman ujian ultrasonik komposit dan mendapatkan hasil yang sama seperti produk semasa. Air digunakan sebagai medium gandingan untuk perjalanan sinaran di antara transduser dan spesimen. Reka bentuk baru tangki air juga telah direka untuk membuat produk ini menjadi lebih ergonomik. Mesin skala kecil ini akan beroperasi dalam dua paksi iaitu paksi x dan paksi y. Terdapat dua motor stepper bersaiz NEMA-17 yang digunakan pada setiap paksi dan dikawal dengan menggunakan Arduino Genuino Mega 2560 dan Adafruit Motor Shield v2 sebagai pemacu motor. Dalam proses pemeriksaan, transduser daripada Harisonic ultrasonik dari Olympus dengan frekuensi 2.25 MHz digunakan dan pulser-penerima adalah dari US Ultratex. Proses pemeriksaan akan dianggap selesai selepas prestasi mesin telah dioptimumkan dengan menjalani beberapa analisis. Keputusan daripada pemeriksaan terhadap spesimen seperti lokasi dan saiz retak akan disiarkan dalam bentuk signal. Sampel spesimen yang diuji adalah laminates gentian kaca komposit (FGCL) dengan lubang sebagai kecacatan tiruan. Pengunaan mod yang sesuai terhadap motor stepper dengan nilai getaran yang dihasilkan adalah kurang

semasa operasi dianalisis. Analisis struktur juga boleh dilakukan dengan menggunakan simulasi dalam perisian Solidwork. Kajian gerakan dijalankan untuk menganalisis pergerakan tangan, lengan dan badan dari pengguna apabila mereka menggunakan mesin ini.

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LIST OF ABBREVIATIONS

NDT	Non-Destructive Test
IUT	Immersion Ultrasonic Testing
MRO	Maintenance, Repair and Overhaul
MOST	Maynard Operation Sequence Technique
DC	Direct Current
CNC	Computer Numerical Control
FFT	Fast Fourier Transform
PWM	Pulse Width Modulation

CHAPTER 1

INTRODUCTION

1.1 Brief Introduction

Non-Destructive Test (NDT) play important role to assure safety and ability of the equipment and assets used by the people in their daily life. NDT has been utilized for the inspection of the equipment that works in the high-pressure environment. This type of testing is widely used because it does not give any impact to the specimen being tested. In the aerospace industry, NDT is used for the inspection of the material, especially composite material. Inspection process needs to be precise to avoid any structural failure due to a small defect occur in the composite material such as voids and delamination. There are various type of method of NDT and ultrasonic testing is widely applicable in the aerospace industry especially for the inspection of composite material. The results from the testing are shown as the signal profiles. The signal profile will have a different pattern that represent different information on each.

1.2 Problem Statement

The common of the non-destructive test equipment is quite larger, expensive and the system is also complex. This research is conducted to develop a small scale of non-destructive test (NDT) machine with a simple system and able to operate immersion ultrasonic testing of the composite and obtain the same result as the current product. There are some modifications from the previous product which is Multilayer Scanning Array Unit in order to improve the performance of the newly developed machine and become more ergonomic. Some analysis is needed to optimize the performance of the machine.

1.3 Objective

The objective of this research are:

1. To design and fabricate a small scale machine of Non-Destructive Testing (NDT) for composite inspection.
2. To increase the performance of the new developed small scale machine with using suitable part of mechanical and reduce vibration of the system.
3. To make the new developed small scale machine become more ergonomic with new features.

1.4 Scope of Work

The scope of work in this project divided into 4 parts which are designing, fabrication, system development and analysis. The new design of the machine has been made via using Solidwork with added some new features. The fabrication process will involve some type of processes such as machining and others. To control the mechanism for the inspection process the stepper motor is programmed and the data acquisition system is developed in the system development. Some analysis needs to be done to optimize the performance of the machine.

CHAPTER 2

LITERATURE REVIEW

2.1 Non-Destructive Testing (NDT)

NDT refers to the evaluation and inspection method of materials or additives for characterization or locating defects and flaws in evaluation with some standards without altering the original attributes or harming the specimen being tested. Structural integrity is a formalized process that uses advanced non-destructive testing (NDT) methods to detect, locate and identify damage size. There are other terms to describe non-destructive testing (NDT) which are Non-destructive evaluation (NDE) or Non-destructive inspection (NDI). There are various technique in the non-destructive testing (NDT) such as Visual Testing (VT or VI), Ultrasonic Testing (UT), Thermography, Radiographic Testing (RT), Electromagnetic Testing (ET), Acoustic Emission (AE), and Shearography. All of the technique are divided into two categories which are contact and non-contact methods. Contact method requires contact between the sensor and the surface of the specimen to obtain good data. Non-contact is developed in order to accelerate the process of data collection. Each type of techniques have their own advantages and disadvantages (Gholizadeh, 2016) .

2.1.1 Immersion Ultrasonic Testing

In this project, the small scale of NDT machine will be develop able to operate the Immersion Ultrasonic Testing (IUT). This type of testing uses high frequency sound energy to conduct examinations and make measurements. Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material and characterization. A common ultrasonic testing (UT) inspection system consists of several functional units, such as the pulser /receiver, transducer, and display devices

(Zhang & Richardson, 2011) . There are several techniques used in this testing such as pulse-echo, through-transmission, back-scattering, acousto-ultrasonics and ultrasonic spectroscopy. UIT is chosen due to its can maintain a continuous column of coupling fluid between the transducer and specimen which is preserved when the specimen probe distance change significantly (“Introduction to Ultrasonic Testing,” n.d.) .

2.1.2 Working Principle of Ultrasonic Testing

A pulser / receiver is an electronic device that generates high voltage electrical pulses. The transducer generates high frequency ultrasonic energy driven by the pulser. Sound energy is introduced and propagated in the form of waves through the materials. Part of the energy is reflected back from the defective surface such as a crack when a discontinuity is present in the wave path. The transducer transforms the reflected wave signal into an electrical signal and is displayed on a screen. The reflected signal strength is displayed versus the time from the signal generated when an echo was received. The meaning time of signal travel is the same as the distance that the signal traveled. Information about the specimen such as the location and size of a crack can be gained from the signal (Zhang & Richardson, 2011) . The result of the ultrasonic testing can be shown some type of data presentation. There are three most common ways to interpret the data which are A-scan, B-scan, and C-scan (“Introduction to Ultrasonic Testing,” n.d.). All of the type of data presentation have different ways and informations. The capability to gather all of type of data presentation is depend on the modern computerised ultrasonic system.

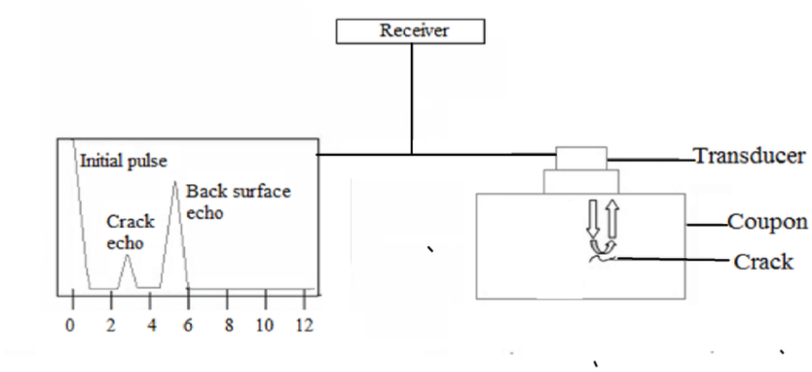


Figure 2-1: Working princple of ultasonic testing (Pelivanov, Buma, Xia, Wei, & O'Donnell, 2014)

A-scan is shown the relative amount of received energy or amplitude is plotted along the vertical axis and the time traveled is displayed along the horizontal axis. By comparing the signal amplitude obtained from an unknown reflector to that from a known reflector a size of defect can be estimated. Position of the signal on the horizontal sweep can represent the reflector depth.

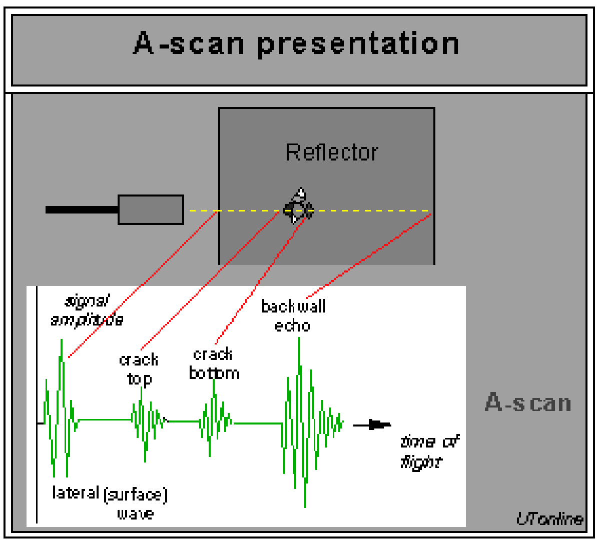


Figure 2-2: Example of A-scan data presentation ("Weblet Importer," n.d.)

The cross-sectional view of the specimen can be presented in the B-scan. While in B-scan, the vertical axis is represent travel time of the sound energy and the horizontal axis is represent the linear position of the transducer is displayed along. The

B-scan can be generated by establishing a trigger gate on the A-scan with a great enough of signal intensity.

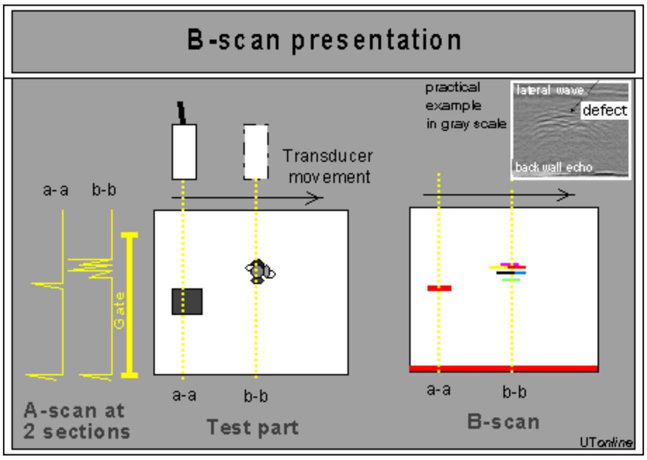


Figure 2-3: Example of B-scan data presentation (“Weblet Importer,” n.d.)

Then, C-scan is shown from the top view where the location and size of test specimen can be seen. C-scan is generated with an automated data acquisition system such as a computer controlled immersion scanning system (Zhang & Richardson, 2011).

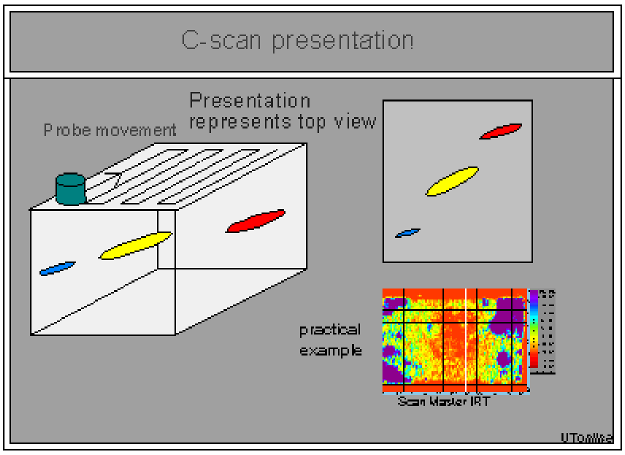


Figure 2-4:Example of C-scan data presentation (“Weblet Importer,” n.d.)

2.2 Current Products

Current product of fully automated Immersion Ultrasonic Testing Systems by TecScan is shown in Figure 2-5. This company provides machine with systems range from small tanks for laboratory immersion ultrasonic testing to large multi-axis industrial ultrasonic immersion systems. TecScan also offers specialized non-destructive immersion ultrasonic testing systems for MRO (Maintenance, Repair, and Overhaul) of aerospace components and structures, as well as for the testing of power generation and industrial applications component. All of the equiment by TecScan can arhive C-scan and tomography using these automated ultrasonic testing systems ("Immersion Ultrasonic Testing Systems - TecScan," n.d.) .

Figure 2-5:Current product from TecScan

Another current product is GE's MUCT-1000 series shown in Figure 2-6 . It also is an automatic ultrasonic C-Scan inspection platform. It use unique modular design approach in order to provide various scanning operation for different type of specimens. ("MUCT-1000 Modular Ultrasonic C-scan Immersion Tanks - JWJ NDT," n.d.).

Figure 2-6:MUCT-1000

2.3 Defects

Composites are made from a polymer matrix that is reinforced with the fiber or other reinforcing material . Therefore there will be some defect in the composite. Most of the defects are occur during the manufacturing process. A small defect of composite could lead to a major structural failure of a part during its service (Smith, n.d.) . There are two source of defect which are:

2.3.1 Manufacturing Defect

2.3.1(a) Porosity

Porosity is defined as the volume fraction of small voids in a material. In a composite, a void is occur when that space is not occupied with resin or fibre. It is too dificult to avoid any void occur during the manufacturing of composite material (Fernlund, Wells, Fahrang, Kay, & Poursartip, 2016) .

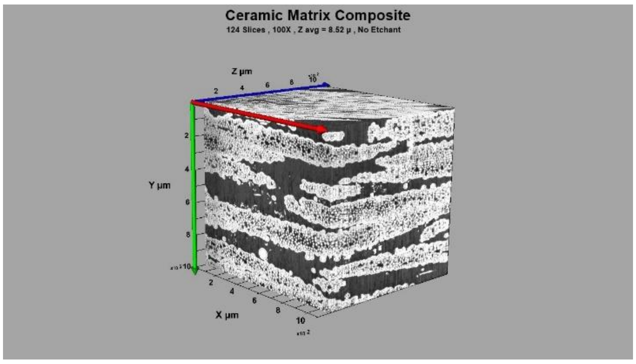


Figure 2-7:Porosity in 3D view (Fernlund et al., 2016)

2.3.1(b) Ply Misalignment

Ply misalignment is defined as the fiber is not align according to its fix angle. Mistakes made in lay-up of the component plies could lead to ply misalignment. This defect will effect the overall stiffness and strength of the laminate and may cause bending during cure (Smith, n.d.).

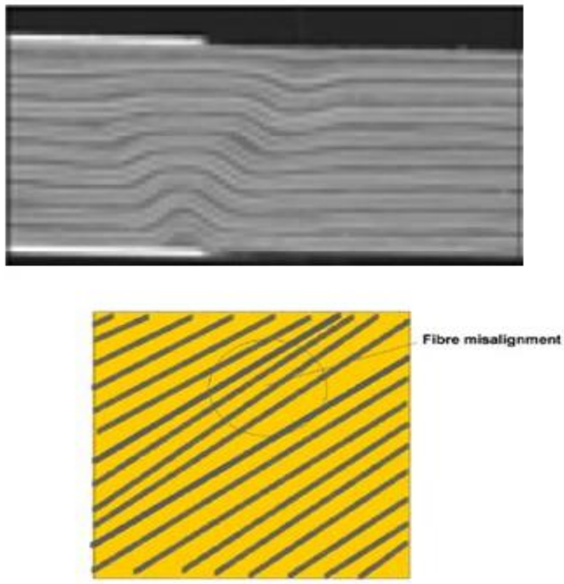


Figure 2-8:Ply misalignment in composite (Smith, n.d.)

2.3.2 In-service Defects

2.3.2(a) Cracks

Crack is form in the composite material cause of tensile loading, fatigue loading, changing in temperature and thermal cycling. Crack also can occur due to defect occur in the manufacturing process such as void and inclusions. The small crack could lead to the bigger failure if the crack is not modified. These crack occur along the fiber and matrix (“A review on study of composite materials in presence of cracks,” n.d.).

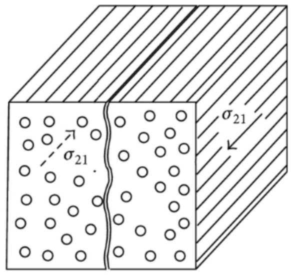


Figure 2-9:Crack along the fiber and matrix (Smith, n.d.)

2.3.2(b) Delamination

Delamination is one of the most common failure modes of composite materials. It also may occur during the production process. Delamination is a separation between two layer due to weaking of interface between them. This defect can reduce the strength and stiffness of the composite ("Delamination in composites," n.d.).

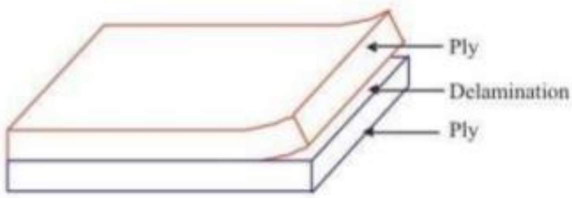


Figure 2-10:Delamination between ply ("Delamination in composites," n.d.)

2.4 Motion Study

Motion study is an analysis of the basic hand, arm, and body movements of workers as they perform work. Motion study analysis is done in this project in order to determine the machine is user-friendly. Work elements consist of basic motion elements which are actuations of the limbs and other body parts. Example of motion is reaching for an object, grasping the object, moving the object, walking and eye movement. Work element is a series of work activities that are logically grouped together because they have a unified function in the task. For example, assembling a component to a base part using several nuts and bolts. The required time is only six seconds or longer.

Work consists of tasks. The task is an amount of work that is assigned to a worker or for which a worker is responsible. There are two types of task which are a repetitive task and non-repetitive task (Pablos, 2010). The analysis of the motion study on the current product is compared with the machine developed in this project.

Basic Most Data Card					
ABG Get ABP Put A Return	General Move				
Index × 10	A Action Distance	B Body Motion	G Gain Control	P Placement	Index × 10
0	≤ 2 in. (5 cm.)	No Body Motion	No Gain Control Hold	No placement Hold Toss	0
1	Within Reach		Grasp Light Object Grasp Light Objects Simo	Lay Aside Loose Fit	1
3	1 - 2 Steps	Sit without Adjustments Stand without Adjustments Bend and Arise 50% occ.	Get Non-simo Get Heavy/Bulky Get Blind Get Obstructed Free Interlocked Disengage Collect	Loose Fit Blind Place with Adjustments Place with Light Pressure Place with Double Placement	3
6	3 - 4 Steps	Bend and Arise		Position with Care Position with Precision Position Blind Position Obstructed Position with Heavy Pressure Position with Intermediate Moves	6
10	5 - 7 Steps	Sit Stand			10
16	8 - 10 Steps	Bend and Sit Climb on Climb off Stand and Bend Through Door			16

Figure 2-11:General motions in MOST standards

2.5 Vibration Test

Vibration is defined as an oscillating motion of an object about a reference position. In this project, the body frame of the machine will undergo a vibration test in order to examine the amount of vibration produced by the stepper motor. An accelerometer is mounted on the structural that need to being tested. There are two types of accelerometer which are high impedance charge output accelerometer and low impedance output accelerometer. The result of the vibration test can be formed in the signal graph, which is the vertical axis can be displacement and the horizontal axis is frequency. There are some environmental that could influence the result of the test such as transverse vibrations, acoustic noise, and corrosive substances. Therefore all of what factors need to be reduced in order to get the good result (Bruel and Kjaer, n.d.).

Figure 2-12:Accelerometer

2.6 Components and Materials Selection

In the inspection process, precise and accurate is very important to get a good result during the process. For example, the threaded rod will be used because it has good accuracy for the inspection process compared to beltIn the inspection process, precise and accurate is very important to get the good result during the process. For example, the threaded rod will be used because it has good accuracy for the inspection process compared to belt (*Topic 5 Power Transmission Elements I*, 2008) . The Table 2-1 shows another the comparisons between threaded rod and belt :

Table 2-1: Threaded rod against belting system

Parameter	Threaded Rod	Belt
Length of stroke	Short to medium	Long
Linear velocity	Low to medium	High
Axial force (thrust)	High	Medium
Unidirectional repeatability	Good	Medium
Backdriving	Will occur with some of the nut leads	Will always occur
Resistance to shock loads	Good	Medium
Operation at high duty cycle	Medium to good	Excellent
Expected service life	More predictable	Based on testing
Maintenance	Low to medium	Low
Drive efficiency	Medium to high	High

The material selection needs to be considered in this project, especially for the body frame. The body frame of the machine need to be lighter and have high durability.

Therefore the most suitable material is aluminum due to its characteristics are suitable for the body frame.

Based on the study about the stepper motor, it is suitable equipment to make this machine functionally works. A stepper motor, also known as a step motor or stepping motor which is a Brushless Direct Current (DC). It is a special electric motor that divides a full rotation into a number of equal steps. Stepper motors are widely used in industrialized fields as CNC machines, printers, and flexible welding arm cause a very precise positioning and speed control can be gain with a computer-controlled stepping (“Stepper Motors,” n.d.). Then there are some advantages of stepper motor such as high torque at low speed, low cost, and low maintenance. There also various type of stepper motors such as variable reluctance stepper motor, permanent magnet stepper motor, and hybrid stepper motor. The difference between these three types is according to the rotor construction.

The stepper motor rotor is a permanent magnet, the stator winding will produce a vector magnetic field when the current is flowing through it. The rotor will rotate driven by the magnetic field with an angle so that the pair of magnetic fields of the rotor and the magnetic field direction of the stator are consistent. When the stator's vector magnetic field is rotated by an angle, the rotor also rotates with the magnetic field at an angle. The motor rotates one degree further when each time an electrical pulse is input. The output of the angular displacement is proportional to the number of pulses input and the speed is proportional to the pulse frequency. The motor will move backward if the order of wind power is change. Therefore, by controlling the number of pulses, the frequency and the electrical sequence of each phase winding of the motor can control the rotation of the stepping motor (“Stepper Motor Basics & Working Principle | ATO.com,” n.d.).

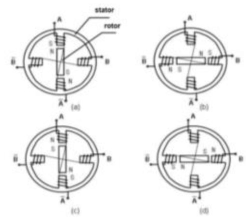


Figure 2-13: Inside the stepper motor

Figure 2-13 show the configuration of the stepper motor. There are three modes of operation in the stepper motor which are a full step, half step, and microstep. The mode of the operation can be programmed by using the microcontroller and motor driver.

The full step mode has two types of phase which are one and two phases. One phase in means only a single phase is activated in each time. This phase will make the motor provide low torque and the least amount of power is required compared to other modes. Then two phase is attained by energizing both of the motor's windings while alternately reversing the current. This mode will provide higher torque and a high amount of power is required to power the motor.

A half step is a mode where one winding is energizing after the other which makes the motor rotate halfway. For example, normally stepper motor with 200 rotor teeth will rotate rotates at 400 steps every revolution. This mode will produce smoother rotation than full-step and it also provides approximately 30% less torque.

Microstep mode divides each step into 256 discrete micro steps which allow 51200 steps for each revolution. Therefore microstepping mode is usually used in operation where highly accurate positioning is required. The motor operation becomes more smooth especially in low speed hence it will reduce the vibration produced ("Stepper Motors," n.d.).

CHAPTER 3

METHODOLOGY

3.1 Introduction

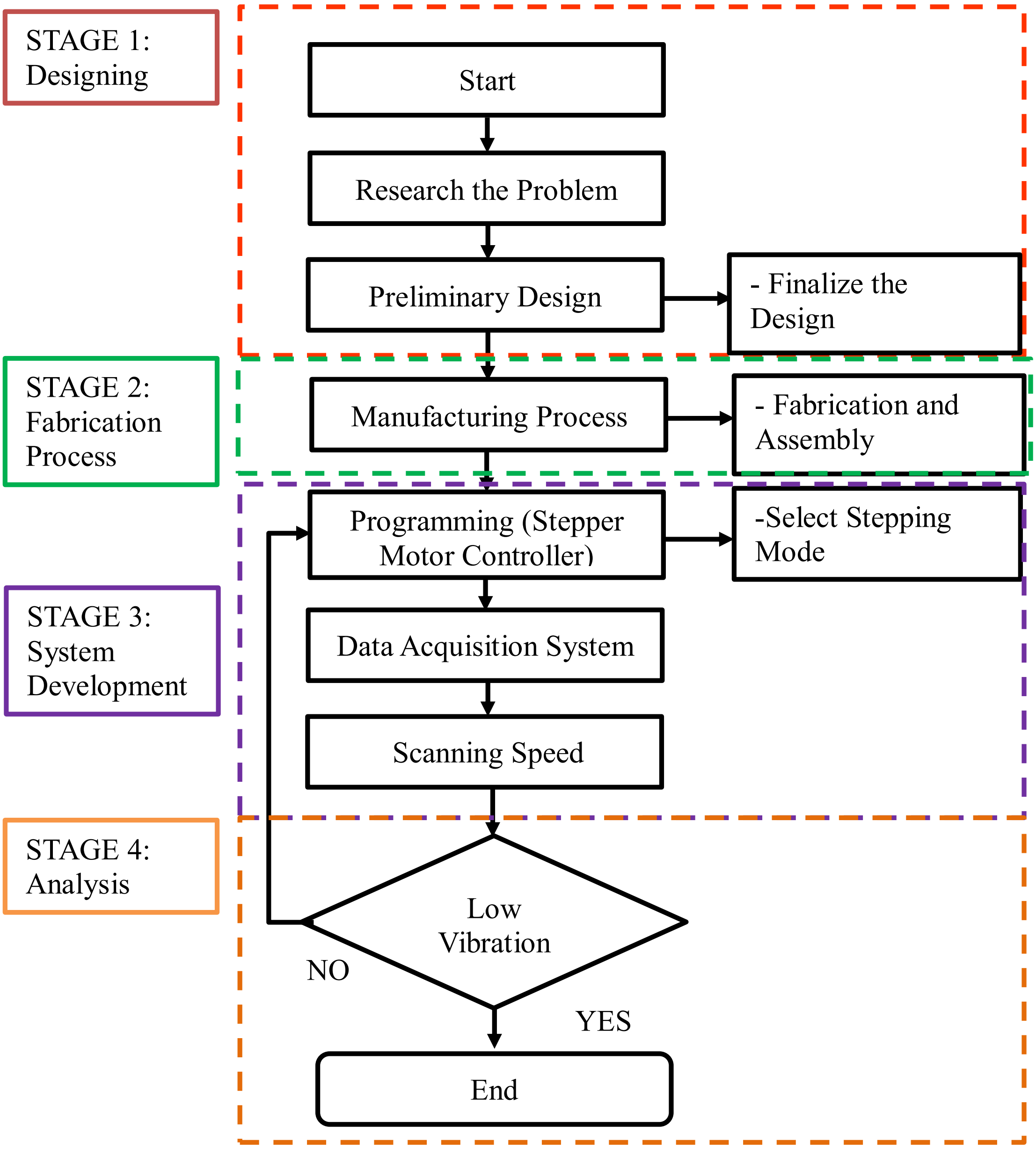


Figure 3-1:Flow chart of methodology

Flow chart in Figure 3-1 is the overall process in this project. There are some stages in the methodology of this project. The first stage is designing, the project starts with the research on the problem that has on the current product in term of its mechanism and design. After the problems are identified, the preliminary design of the new product is done by using Solidworks and the design is finalized according to the requirement. The second stage is started with the fabrication process which involves machining the housing of the stepper motor and linear shaft holder, purchasing the electronic part and assembly. Assembly and finishing process is done after all of the parts are ready and this is the final step in this stage. The third stage is system development, it is important because it will determine the performance of the inspection process. This stage begins with the programming of the stepper motor controller that involve in this process. The data acquisition system also is developed in this stage that makes the transducer able to collect the data. Then the final stage which analyzation is performed, the analyzation of the performance of the product is conducted. The suitable stepping mode of the stepper motor with the least vibration produced during operation is analyzed. The structural analysis also is done by using Solidwork. Motion study is used to analyze the basic hand, arm and body movements of users as they use this machine.

3.2 Designing

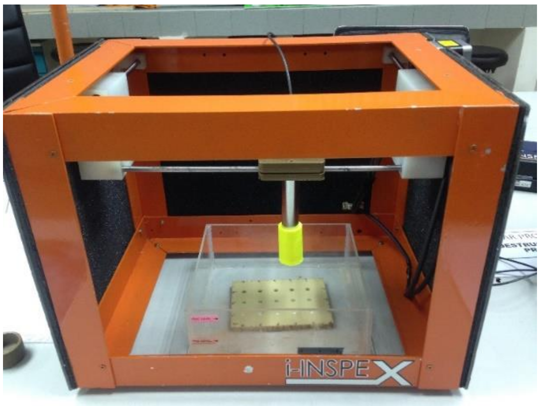


Figure 3-2:Multilayer Scanning Array Unit

The design of this machine is a redesign of the previous scanning unit which is Multilayer Scanning Array Unit as shown in Figure 3-2. The new design of the machine is done in order to become more ergonomic than the previous product. The conceptual design of the new machine is done by using Solidworks. The new design of the new developed machine as shown in the Figure 3-3. The mechanism of the scanning unit is about the same with the new design machine as it used the same amount of stepper motor and transducer. The size of the scanning unit is also the same with a smaller dimension of 360 x 280 x 280 mm. As mentioned before, the new design is redesign from the previous product by changing some design of the parts, add new features and used a more suitable component according to its operation.

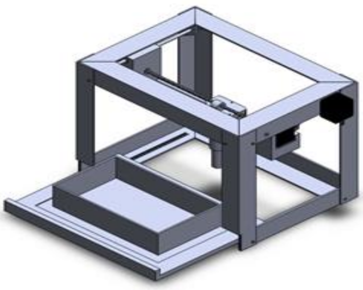


Figure 3-3:New design in Solidwork

Table 3-1:Improvement from Scanning Unit

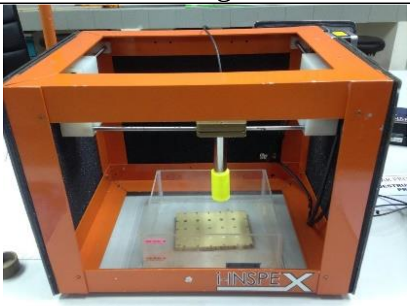
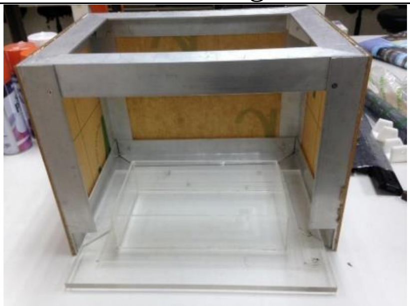
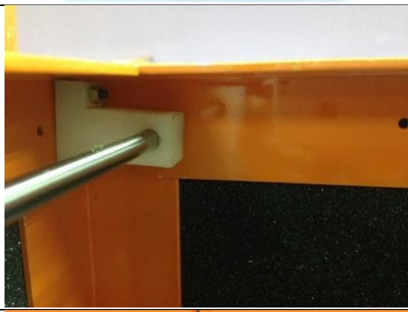
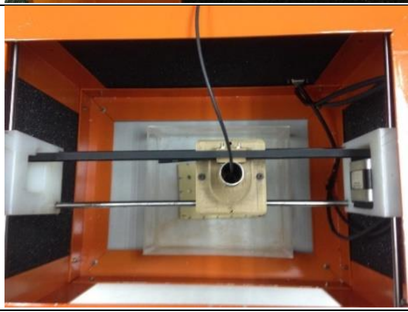
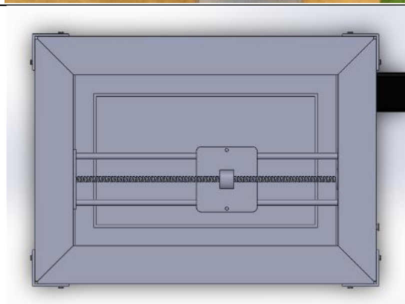
Item	Scanning Unit	New design
Water Tank		
Shaft Holder		
Material		

Table 2-1 shows the improvement that has been made from the scanning unit and applied to the new developed machine. The parts that have been redesign from the scanning unit are linear shaft holder, transducer holder, and stepper motor holder. All of the parts are redesign in order to make it easy for installation and the structure become more stable. The new features that have been added to the new machine is a water tank. The user of the scanning unit had much trouble in handling the water tank. Therefore the new design of water tank for this machine is created in order to make it more ergonomic. There also some change in a component used because it is not suitable for the inspection process. Threaded rod is used in the new machine compare to the belting system used in scanning unit because it has many advantages such as it is more precise and the maintenance also can be reduce.

Table 3-2: Design score

Design Criteria	New machine	Scanning Unit
Installation	4	3
Handling	5	2
Aesthetic Value	4	4
Maintenance	5	3
Total Score	18	12

Table 3-2 shown, the new machine score highest marks with 18 point compare with 12 points of scannning unit. The score is rated based on the survey that has been done. Therefore the new machine is relevant to be continue as the new project because it can give more advantages.

3.3 Fabrication

The fabrication process is started after the design is finalized and meet the requirement. Before the fabrication process is started, a good plan and schedule also need to be done in order to reduce the cost and optimized equipment usage.

3.3.1 Frame Development

The fabrication is started with the frame development. The edges of the frame are joined by using the fastener and formed a strong frame of the machine. The holes for the fasteners at each edge of the frame is made by a drilling process. The linear shaft holder also has been fastened at each edge of the body frame.

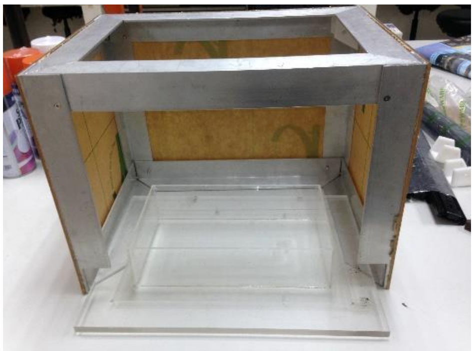


Figure 3-4:Frame of the machine

3.3.2 Axis and Holder Installation

Linear shaft is used as the motion path to move the transducer and helped by the stepper motor. There two types of holder have been made in this project which is stepper motor holder and transducer holder. Stepper motor holder is made from a block of Teflon and machining process is required to get the shape needed by using computer numerical control (CNC) milling machine. The transducer holder is designed and made by using the 3D printer.

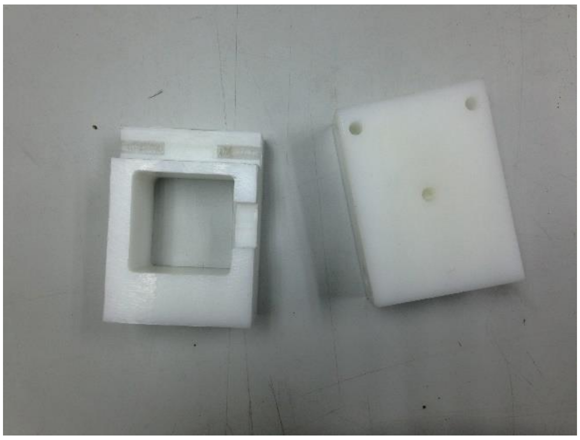


Figure 3-5:Teflon after the machining process

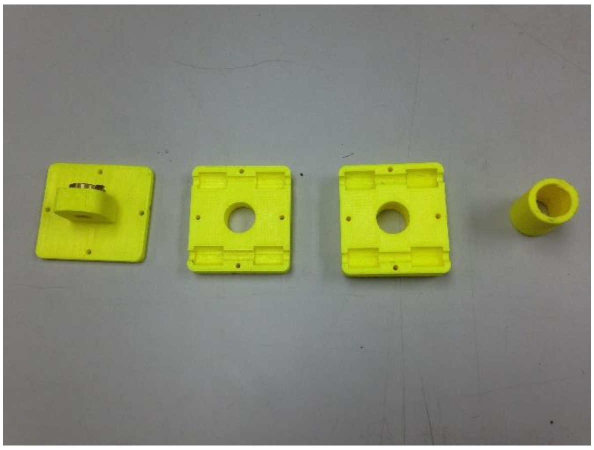


Figure 3-6:Transducer holder printed by 3D printer

The installation linear shaft needs to be precise in a straight line to ensure the inspection process is smoothly operated. Linear shaft is installed on each axis which is x and y-axis. The fabrication of x and y-axis have the same function in holding and moving the transducer during the inspection process. On the x-axis, the linear shaft is attached with stepper motor holder and transducer holder which will travel along with it. On the y-axis, the linear shaft is attached to its holder at each edge of the body frame with the stepper motor holder that will travel along with its.

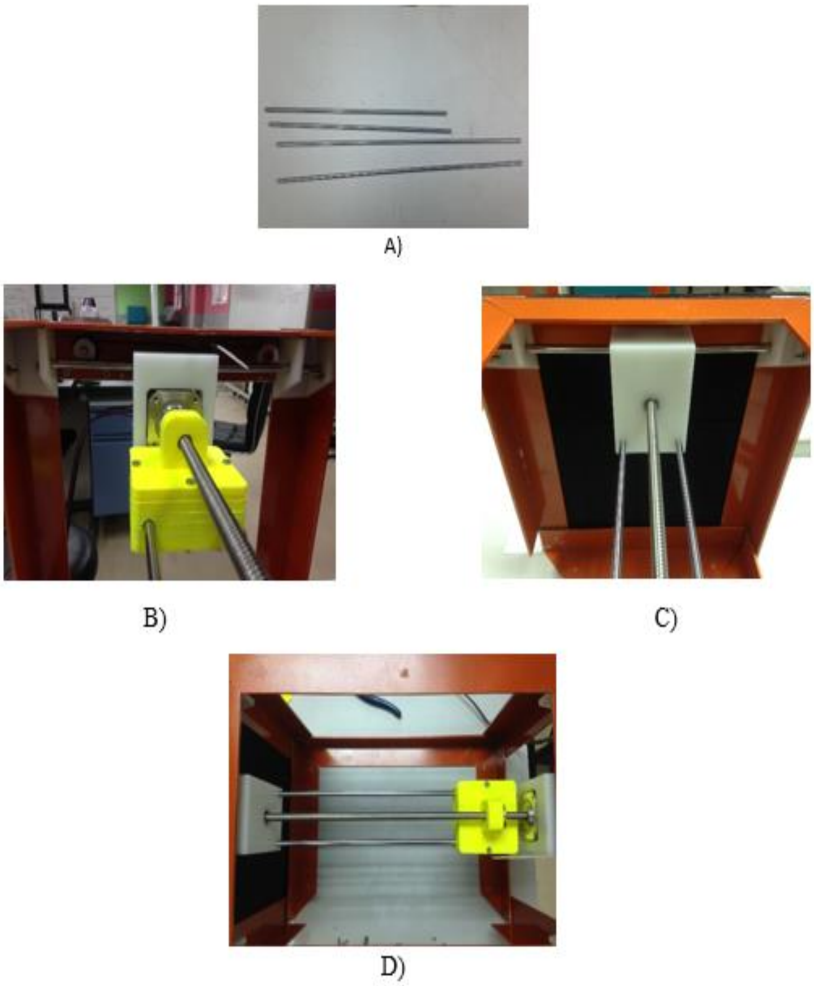


Figure 3-7:A)Linear shaft B)Linear shaft on y-axis C)Linear shaft on y-axis D)Linear shaft on x-axis

A stepper motor is screwed on the upper right side of the body frame to control the motion of transducer on y-axis support with the belting system. A stepper motor with a threaded rod is placed on the stepper motor holder to control the motion of transducer on the x-axis. A thin sponge is added to the holder in order to reduce the vibration produced and make it fit with the stepper motor.

Figure 3-8:Belt with pulley

3.3.3 Water Tank

The new design of water tank is setup after all of the others part is assembly. The water tank is made up of Perspex and glued together to get a container shape. The water tank is also has been tested to avoid any leakage occur during the inspection process. The drawer rail is installed on the below of the body frame and tide with bolt and nut. The platform of the water tank is screwed together with the drawer rail. To make the drawer rail operate smoothly some grease oil is applied to its ball bearing.

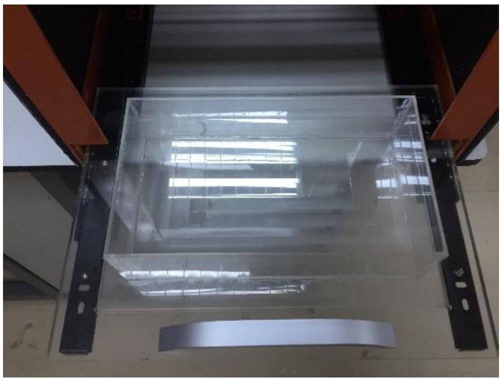


Figure 3-9:Drawer rail with the water tank installed on the platform