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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: Design and Analysis of Hand and Wrist Support Device

SESI PENGAJIAN: **2013/14 Semester 2**

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I hereby, declared this report entitled "Design and Analysis of Hand and Wrist Support Device" is the results of my own research except as cited in references.

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Date : 20 JUNE 2014

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 Design) (Hons.). The member of the supervisory is as follow:

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(Project Supervisor)

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ABSTRAK

Tujuan projek ini adalah untuk mereka bentuk alat sokongan tangan dan pergelangan tangan dengan menggunakan Kejuruteraan Songsang (RE) kaedah dan Additive Pembuatan (AM) proses. Matlamat projek ini adalah untuk menghasilkan alat sokongan tangan dan pergelangan tangan dengan meningkatkan ergonomik dan selesa kepada pesakit. Projek ini memberi tumpuan kepada reka bentuk prototaip alat sokongan tangan dan pergelangan tangan berdasarkan geometri tangan dan pergelangan tangan pesakit dan jenis kecederaan yang dialami. Kebanyakannya, alat-alat sokongan yang sedia ada untuk tangan dan pergelangan tangan terutama bagi pesakit yang mengalami kecederaan yang teruk seperti patah tulang atau retak mempunyai saiz standard mengikut umur mereka. Tetapi apabila mengalami kecederaan yang teruk seperti patah tangan masih lagi menggunakan "plaster of paris" yang mana menyukarkan pergerakan dalam membuat sesuatu perkara. Walau bagaimanapun, pengguna akan berasa tidak selesa. Satu tinjauan awal telah dijalankan melalui soal selidik untuk tindak balas awal sokongan peranti pada tangan dan pergelangan tangan. Perisian boleh memudahkan data dan merekabentuk semula tangan dan pergelangan tangan perlu digunakan dan sebahagian daripada perisian adalah Geomagic Studio 10 dan Solidwork 2013. Untuk proses imbasan, Faro Arm digunakan untuk mendapatkan bentuk tangan menggunakan patung palsu dan bentuk tangan yang diperbuat daripada lilin. Kemudian peranti sokongan tangan dan pergelangan tangan yang telah dihasilkan oleh Solidwork akan dihantar kepada Pemodelan Endapan Terlakur (FDM) mesin untuk menghasilkan prototaip. Proses seterusnya adalah melukis keperluan untuk dianalisis menggunakan simulasi

Solidwork, keputusan analisis menunjukkan bahawa tekanan rekabentuk tangan dan pergelangan tangan sokongan yang dihasilkan oleh FDM adalah selamat untuk digunakan berdasarkan faktor keselamatan adalah lebih tinggi daripada 1.

ABSTRACT

The purpose of this project is to design a hand and wrist support device by using Reverse Engineering (RE) methods and Additive Manufacturing (AM) process . The goal of this project is to produce hand and wrist support device to improve ergonomics and comfort to patients. This project focuses on the design of a prototype tool based on the geometry of the hand and wrist support for patients and types of injuries sustained. Mostly, the tools available to support the hand and wrist , especially for patients suffering from severe injuries such as fractures or cracks have standard size according to their age but when suffering severe injuries such as fracture hand and wrist still using plaster of paris which makes it difficult for the movement to make a thing . However, users will feel uncomfortable. An initial survey was conducted through a questionnaire for early response on hand and wrist support device. Software with can facilitate data and redesign the hand and wrist support device need to used and some of them are Geomagic Studio 10 software and Solidwork 2013. For the scanning process, Faro Arm is used to get hand shapes using fake statue and hand shape made of hand wax. Then the hand and wrist support device that has been produced by Solidwork will be sent to the Fused Deposition Modeling (FDM) machine to produce a prototype. The next process is drawing need to analyzed using Solidwork simulation, the results of the analysis indicate that the design pressure of the hand and wrist support FDM produced parts are safe to use based on the safety factor is higher than 1.

DEDICATION

I dedicate this project to my family, friends and lecturers. I am able to accomplish the goals and objectives of this project is all thanks to everyone for the time and knowledge they have given me throughout the project.

ACKNOWLEDGEMENT

I would like to thank my supervisor Dr. Shajahan Bin Maidin, for guiding me along the way from the beginning of this project. I also would like to say thank you to my fellow classmates and friends for helping me in perform various work day and night. Lastly I want to give my deepest gratitude to the university for giving me the opportunity to undergo this subject which has helped me greatly in gaining better insight on the vast world of design and development. This project has helped to grow into a better person with better experience.

CHAPTER 1

INTRODUCTION

1.1 Background of research

Additive manufacturing is defined and refer ability to produce a layer by layer fabrication of three-dimensional physical model protottype or whether the actual product by directly or indirectly from computer-aided design (CAD). This help and engineers and designers to print up their ideas in three dimensions (Kenneth ,2002,p1). Additive manufacturing is one of the rapidly increasing use of alternative because of their capacity to produce alternative faster and cheaper to produce prototypes and working models compared to the conventional route that requires a lot of process to produce the output. (Kenneth, 2002,p1).

Haughton et al (2012) described fracture is caused by soft tissue injury involving bone-related injuries. According to Haughton et al.(2012), hand fracture is a very common fractures encountered in either accident and emergency department and in orthopedic clinics. Statistic based on emedicinehealth.com, hand injuries account for nearly 10% of hospital emergency department. Out of 1000 consecutive hand injuries showed the following distribution: It shows that 42% of lesions (lesions), 27% contusions (bruises), fractures of 17% (broken bone), and 5% of infections. Hand injuries account for about 17% of all lost workday injuries. The most common causes of hand injuries involve blunt trauma resulting from a 50% followed by injuries from sharp objects. Another statistic at below showed the hand fracture in Southern Asia.

Type of fracture	Number	*Percentage*
Fingertip fractures	92	*20.3*
Epiphysial fractures	130	*28.7*
Shaft fractures	109	*24*
Joint fractures	84	*18.5*
Comminuted fractures	39	*8.6*
Total	454	*100*

Figure 1.1: Classification of fractures of the phalanges (Barton, 1984)

Based on Figure 1.1, it shows that the classification phalanges fracture. Although this statistic just cover fractures of the phalanges but for this statistical it show that it need to design a new splint to change previous treatment for hand and wrist fracture from using cast to another product that easy to install.

Design for fracture hand and wrist need to present additive manufacturing as reference to get a good result for heal support for frature hand or wrist. This is due to the additive manufacturing can produce or develop products to start producing very thin cross sections or simply called layer by layer, one above another, until solid physical part completed. (Kenneth, 2002,p1). Other advantages that can be with additive manufacturing, because it can be used in the manufacture of products based medicine, it is also able to create form complex shapes that are nearly impossible to make using the machine, and can build an internal structure, and even its ability to produce features a very thin wall (Kenneth, 2002,p1).

Important thing that need to consider is an ergonomic and make a product is ease to use and fitting. Based on Silverstein and Clark (2004), Ergonomic will help a patient or human in two ways: by design an appropriate task and equipment, it can avoid strainful body exertions and by using suitable body structure. So, it is important to design a good splint to reduce stress for hand and wrist and help patient to heal as soon as possible.

1.2 Introduction

According to Matthews (2012), the most common ailments that facing athletes is injuries to the hand and wrist. This is an example of pain that happend such as hand fracture. Hand have made up of bones called phalanges and metacarpals. Bones of the fingers is called phalanges and bones that make up your knuckles and connect to your wrist. Figure 1.2 show the example of hand and wrist bones.

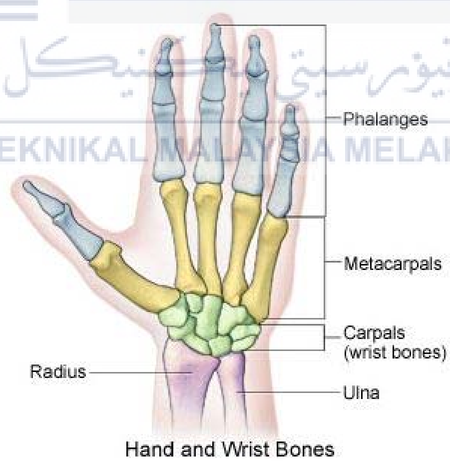


Figure 1.2: Example of hand wrist bones

(Source :< http://www.drugs.com/cg/hand-fracture-discharge-care.html> 01/10/13)

Hand are common injuries that affect specialist athletes and common people when get involved with an accident. It can also be classified into two main categories: traumatic (acute) and overuse (chronic) (Matthews,2012). Traumatic usually occur for athletes that participate in footbll, hockey or wrestling and for overuse usually occur for athletes that participate in baseball, tennis or golf (Matthews ,2012).

The are two types of supporting device available in market to support hand or wrist fracture cast and splint. Because of different ages and body sizes, surface of the device not completely close to hand or wrist. When using cast, cast need to cover with plastic back to prevent cast for an infection. Among the important factors and should be considered is the material and ergonomic. It is use in the production of the device because it is sufficient to give effect to the hand and wrist as a supoort for the hand and as a device for healing.

So, to make supporting device, research must be focused on ergonomic with an analysis using SolidWork to make Finite Element Analysis. With questionaire, all customer requirement and needs will be identified to facilitate the manufacture of the device.Additive manufacturing is one of technology that used in all manufacturing process. It is easy for engineers to produce a good prototype as well as to reduce the lead time of a product.

1.3 Problem statment

Currently, most of the supporting device for hand or wrist fracture made from cast or splint. According to Bernett (2007) patient usually need to wear cast or splint for a number of week. To reduce pain in hand and wrist, usually it used cast or splint as one of the healing device. Material for cast are plaster of paris or fiber class. When using a casts, it is too big because it used with two layers of stiff bandages. The inside layer, which rests against the skin, is made by soft cotton. The outer layer is hard to protect a broken bone from moving to reduce injuries. Figure 1.3 shown layer of cast and it's usually made from one of two materials such as :

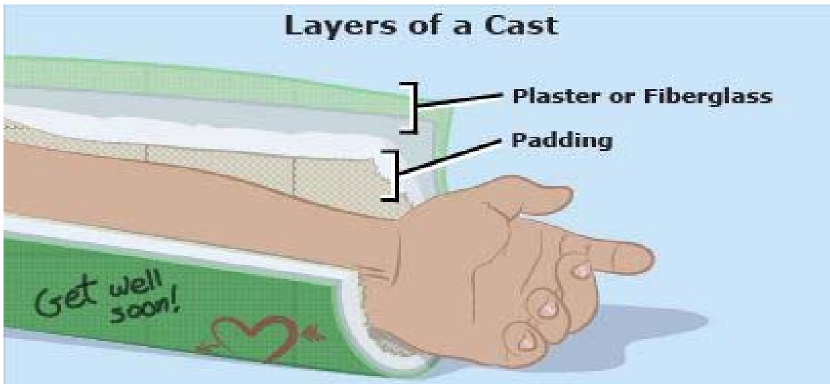


Figure 1.3: Layer of cast

(Source :< http://kidshealth.org/teen/safety/first_aid/casts.html> 29/09/13)

Plaster of Paris usually used for school art projects but in medical it used to heal properly when patient keep broken or injured bones from moving. A heavy white powder is mixed with water to form a thick paste that hardens quickly. Plaster casts are heavier than fiberglass casts and can start to dissolve if they get wet. It is difficult to patient to cure a plaster cast when take bath. If the plaster get wet, the surface of plaster cast will delicate. The picture below in Figure 1.4 shows an example of cast for hand broken using plaster of paris.

Figure 1.4: Example cast for broken hand using plastic of paris

(Source :< http://kidshealth.org/teen/safety/first_aid/casts.html> 29/09/13

Fiberglass is a type of moldable plastic available in many different colors. Fiberglass casts are lighter and cooler than plaster casts. The outer layer of a fiberglass cast is water resistant, but the inner layer is not, although it's possible to get a waterproof liner for a fiberglass cast. Fiber glass is ease to install and light however , it does not help when a patient have to take a bath.

There are a lot of device to support healing of fracture hand or wrist hand but it is not convince because they are not water proof and difficult to make a movement. when got fracture or injuries with hand or wrist, it not just hand or wrist because the soft tissue around it is often injured as well. When a cast or splint removed, hand or wrist need to get heal support for continues resting before tissue fully recover.

1.4 Objective

The main objective of this project is to produce hand and wrist support device. The overall objective of research are listed below:

1. To redesign the splint device to improve the comfort and ergonomic aspects.
2. To analysis the design with Finite Element Analysis (FEA).
3. To produce the prototype via Fused Deposition Modeling (FDM) machine.
4. To test and validate the prototype.

1.5 Scope of project

This project focused on disable individual who has problem with hand such as hand fracture. Hand and wrist fracture are the most common fractures presenting at both accident and emergeny and within orthopedic clinic. This project will propose a prototype of splint for hand using the Fused Deposition Modeling (FDM) machine.

Faro Arm will be used to scan the hand statue to get geometry and CAD data of patient's hand and wrist. The project intends to produce hand and wrist support device that will be more comfort and easy to use by patients with and emphasis in some aspects of safety, ergonomics and fit shape to reduce the burden of pain suffered by the patient. The scope of the project if finally to implement the factor of safety on the prototype.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Hand and wrist injuries often happen not only to athletes but also among the public. It is also not just occur to young people, but also happens to old ages. They can suffer hand and wrist injuries caused of effect of higher levels contact in sport such as baseball, tennis, and wrestling and so on (Dan Matthews, 2008). The hand and wrist support is designed to provide general stability and protection to allow an injured hand and wrist to heal properly. Beside that hand and wrist support is flexible device which offers the advantage of compression around the hand and wrist and must easy to move.

2.2 Human hand and wrist

The hand consists of a main body known as the palm and five digits a thumb and four fingers. Each hand is attached to the forearm at the wrist joint. There are twenty-seven bones within the hand, arranged into three distinct group carpals, metacarpals and phalanges (Haughton et al, 2012). The hand has a volar surface that includes the palm, and a dorsal surface that commonly referred to as the “back” of the hand. The two lateral borders of the hand are commonly referred to according to their relation with bones of the forearm, with the thumb forming the radial border and the little finger relating to the ulnar border. These terms are important when describing fractures and how they are displaced, subluxed or angulated (Haughton et al, 2012).

According to Tarr (2013), the hand consists of 27 bones including the eight bones of the wrist. When the other associated structures nerves, arteries, vein, muscles, tendons, ligaments, joint cartilage, and fingernail are considered, the potential for a variety of injuries exists when trauma involves the hand. Hand injuries account for nearly 10% of hospital emergency department visits. A series of 1,000 consecutive hand injuries showed the following distribution: 42% lacerations (cuts), 27 % contusuions (bruises), 17% fractures (broken bones), and 5% infections. Hand injuries account for about 17% all workday loss injuries and the most common cause of the injuries 25% from a sharp object. Figure 2.1 show an example hand anatomy which is described hand structure.

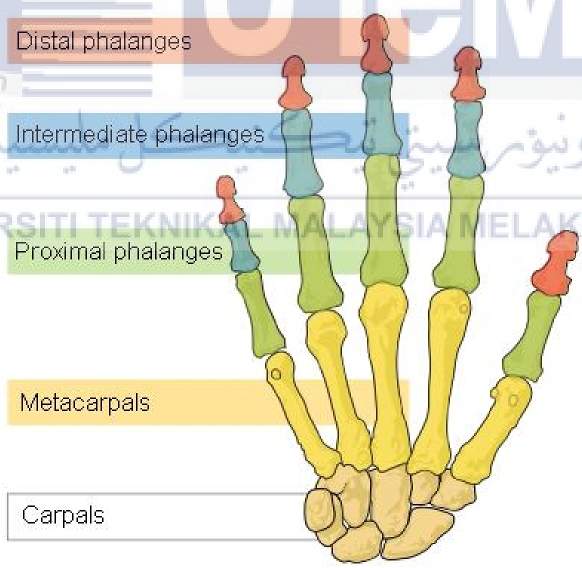


Figure 2.1: Hand Anotomy
(Source :<
http://pages.uoregon.edu/esorens1/hphy362.pbwiki.com/Wrist+and+Hand+Anatomy.html> 22/11/13)

Metacarpals	These bones are numbered from the thumb to the little finger and run the length of the hand. The distal ends are convex to accept to the concave surface of the phalanges while the proximal ends are concave to accept the convex surface of the carpals.
Phalanges	Each finger of the hand is made up of a proximal, middle and distal phalanx except for the thumb which only has a proximal and distal phalanx) named for their location in the finger. The base of the distal phalange articulates with the head of the corresponding metacarpal for the digit.

According to Mike Rossister (2009) wrist joint is one of the most complex joints in the body. It is the articulation between the distal radius and ulnar head with the scaphoid, lunate and triquetral bones. It is a synovial ellipsoid joint surrounded by a capsule, which is attached to the lower ends of the radius and ulna and the proximal row of the carpal bones. The capsule is strengthened by a complex system of anterior and posterior ligaments, which stabilise the wrist in all positions. The triangular fibrocartilage complex sits between the ulna head, lunate and triquetrum, stabilising the distal radioulnar joint in rotation and providing a cushion to the ulnar side of the wrist. A synovial membrane lines the capsule and attaches to the margins of the articular surfaces (Mike Rossister, 2009). Figure 2.2 shows the anatomy of wrist with describe wrist structure.

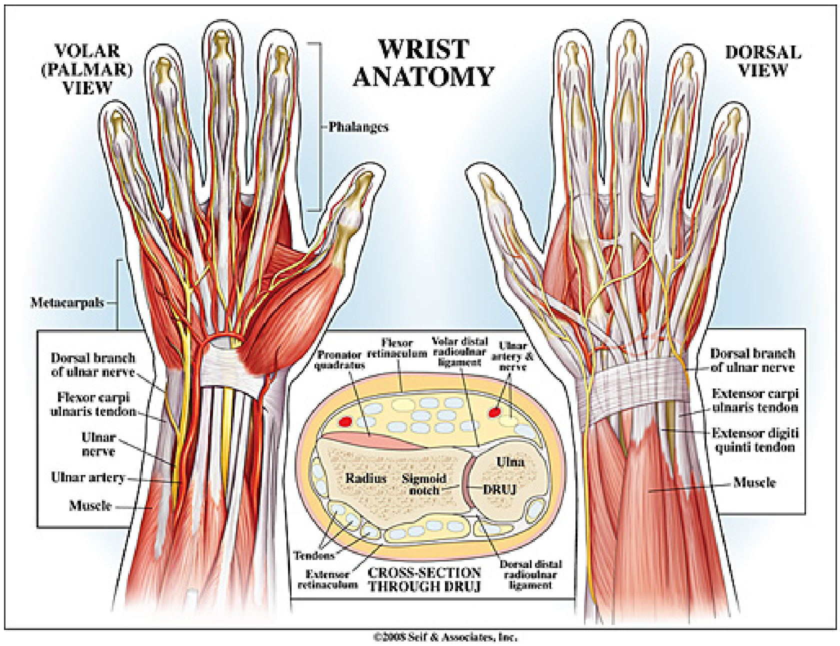


Figure 2.2: Anatomy of the wrist.

(Source :< http://handsport.us/patient-education/wrist-anatomy/> 12/11/13)

2.3 Common injuries

According to Sidney et al, (2012) hand injuries range in sport-related and work-related from seemingly minor problems to those more serious, such as a fracture or dislocation to the wrist or finger joint. This is some of the most common injuries:

1. **Carpal Tunnel Syndrome**

   Occur when one of the main nerves to your wrist and hand becomes pinched and causes numbness, tingling and even night pain that prevents sound sleep in some individuals.

2. **Trigger Finger**

   Inflammation of the tendons can give a result that moves our fingers. This condition can result from repetitive activities such as typing, texting, etc. the fingers may actually "click" and become stuck with attempted clenching or straightening.

3. **Skier’s thumb**

   This is a high energy injury in which the ligament at the base of the thumb is torn resulting in pain, swelling, laxity at the thumb joint, and may progress to painful arthritis.

4. **Wrist fracture**

   It can occur from many athletic activities or from a simple fall on an outstretched arm. It is one of the most frequently seen injuries in individuals of all ages from young children to grandparents.

5. **Finger sprain**

   It can occur during any athletic activities where the hand comes in contact with a ball or sporting equipment, and ranges in severity from a sprain to a dislocated finger joint or even a bony fracture.

2.4 Problems with previous bracing system.

According to Ingel (2012), there are significantly more medical treatment episodes for upper extremity fractures than for those of lower extremity. The vast majority of forearm, hand and wrist fractures occur in paediatrics and young adults as they to be more active and involved in sporting activities. Fractures are typically stabilized via surgical procedures and or with a traditional fiberglass or plaster cast depends on the severity or displacement.

For a long time fiberglass and plaster casts have been around for decades. Fiberglass and plaster casts are effective and have been the standard of care for a long time. Casts are static devices that cannot adjust to changes in limb volume due to swelling or disuse atrophy and a big issue for patients is difficulty they cause in maintaining hygiene (Ingel, 2012). Comfort, skin issues and being unable to view the patient’s skin and injury site are also of concern (Ingel, 2012).

Cast are often replaced during the course of treatment, which takes patient and clinician time and requires a cast saw for removal. While the cast saw can be unnerving for adults, it can be more traumatic for children (Ingel, 2012). The important thing is the vibration of the oscillating saw blades will generate heat during a process of elimination cast. If the cast saw blade held in a similar position, the heat generated by it can be dangerous to the patient and trauma to the patient. (Colditz et al, 2002). Figure 2.3 shows example of cast saw to cut plaster of Paris and fiberglass.

Figure 2.3: Example of cast saw.

(Source :< http://www.childrenshospital.org/orthopedic-center/your-orthopedic-visit/cast-care-and-maintenance> 22/11/13)

In the application of plaster of Paris to the patient, the important thing is that care should be taken to avoid improper positioning and stabilization to ensure proper pressure. The pressure and circulation constraints are much more common when plaster of Paris is used to acute hand injuries, it should also help in the recovery. Patients with sentient area most vulnerable to complications from the appropriate pressure (Rowley, 1996).

On other hand, according to AAOS (2011) swelling can create a lot of pressure under cast. This can lead to problems. Caused by swelling can increase pain and the feeling that the splint or cast is too tight. When have to more pressure on the nerves can numbness and tingling in your hand or foot. Too much pressure on the skin can caused burning and stinging. Furthermore, the cast can slow your blood circulation when excessive swelling below the cast. Other problem with previous cast wills loss of active movement of toes or fingers.

Plaster disease is syndrome can be reduced to a minimum in the early use of functional braces, isometric exercise and early weight-bearing. These in turn promote a rapid retrieval of function. When a limb is put into plaster of Paris and the joints immobilized, joint stiffness, muscle wasting and osteoporosis are unavoidable Rowley, (1996).

Another factor than can gives problem compartment syndrome when using plaster of Paris according to Rowley (1996) is an ischaemia of individual muscle compartments of a limb can be produced by the principal injury with incorrectly applied tourniquet or a POP cast that is too tight. Symptoms and signs of compartment syndrome include: pain out of proportion to the injury; increased pain on passive stretching of muscles; complaints of paraesthesia. The peripheral pulse may be present if only one muscle compartment is affected.

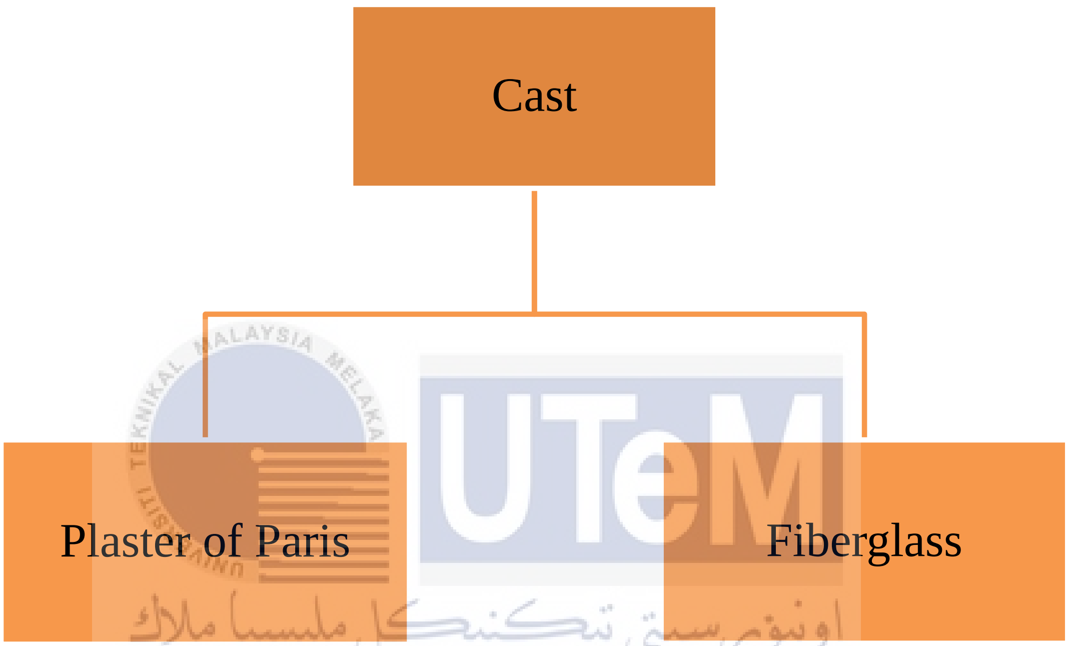
2.5 Types of casts and splint

Casts and splints may seem like a nuisance, but they’re part of the healing process. It is used to support and help to avoid a longer healing time. All casts and splints serve essentially the same purpose:

1. To keep broken or injured bones from moving so it can heal properly.
2. To reduce pain and swelling and support the muscles of injured limbs.

Splints are used to treat the small fracture and for new bone broken if the swelling around the injury. Splints is a better choice to help restore from the site of injury is too tight and affects a person's blood circulation. Broken bones are usually replaced with a splint to cast after the swelling has gone down. Cast enclosed will give more protection during the time it takes for broken bones to knit back together (Colditz, 1996).

Casts are sort of like big, stiff bandages with two layers. The inside layer, which rests against the skin, is made of soft cotton. The hard outer layer prevents a broken bone from moving. It’s usually made from one of two materials:



1. Plaster of Paris

Based on Rowley, (1996) plaster of Paris slabs function by providing a well-fitting support which is bandaged onto the limb over the wound dressing with minimal risk to the circulation through constriction. The bandages can be slackened or tightened easily. A heavy white powder is mixed with water to form a thick paste that hardens quickly. Plaster cast is heavier than fiber glass casts and can start to dissolve if they get wet (Colditz, 1996).

A Plaster of Paris cylinder or functional brace works in two ways. First, it is moulded to the limb so that there are three applied forces, one on one side and two on the other side,providing counter-forces which splint the injured limb in three-point fixation (Rowley,1996). The single point is positioned at the fracture site on the side most deformed by the injury. This method of three-point holding is particularly suitable for low-energy injuries when there is soft-tissue continuity the so-called ‘‘soft-tissue hinge’’. Second, it gives general support to soft tissues by providing a rigid exoskeleton of strong material to compensate for the loss of bony continuity. This in turn supports the fracture through a hydraulic effect permitting positional control and weight-bearing. Figure 2.4 and 2.5 show diagram about three point force applied through a moulded cast.

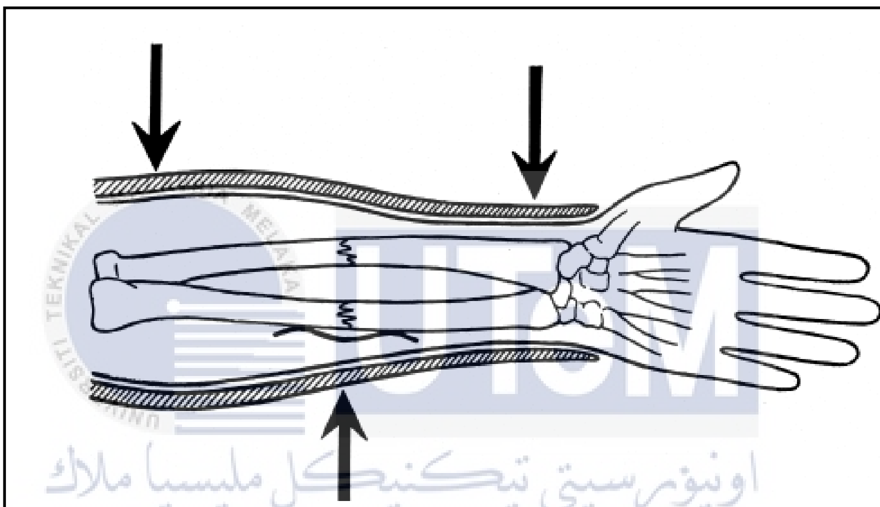


Figure 2.4: Diagram showing how a fracture is subjected to a three point force applied through a moulded cast. (Rowley, 1996)

Figure 2.5: Moulding also helps to prevent rotation and the rigid form of the cast will exert an even hydraulic support around the fracture site. (Rowley, 1996)

Usually Plaster of Paris used:

a) As the initial holding method of open fractures
b) As a later holding method after soft tissue healing
c) In the management of nerve palsies
d) As primary treatment of closed, low-energy injuries.

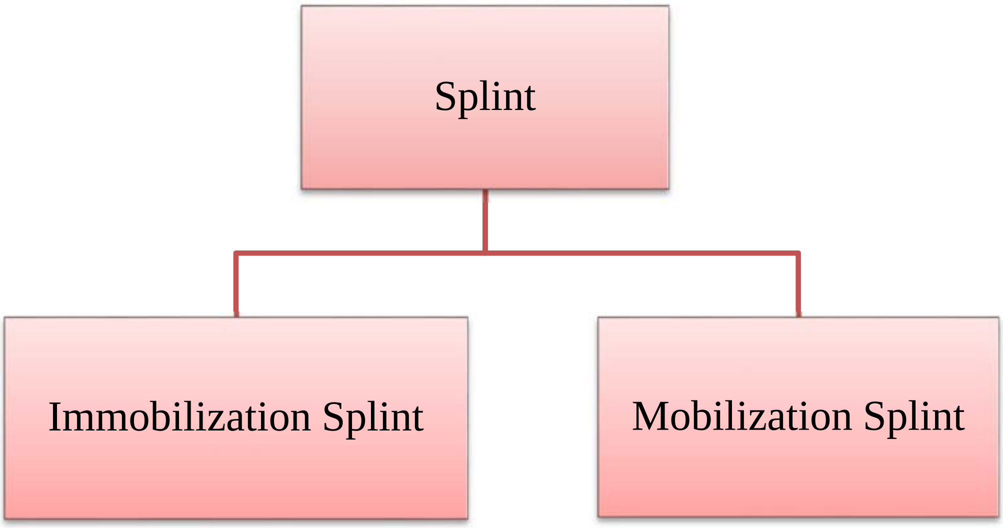
2. Fiberglass

This type of moldable plastic is available in many different colours. Fiberglass casts are lighter and cooler than plaster casts. The outer layer of a fiberglass cast is water resistant, but the inner layer is not, although it's possible to get a waterproof liner for a fiberglass cast. Figure 2.6 shows examples of commonly used fiberglass cast on the hand injury.

Figure 2.6: Example fiberglass cast.
(Source :< http://www.tradekorea.com/e-catalogue/woosammed/product-detail/P00234409/Polyester___Fiberglass_orthopedic_casting_tape_Hygia_Cast_Plus_.html#.UqEYo9IW2So> 22/11/13)

2.6 Principle and goal of splinting

It can have one or two purpose of hand splinting: immobilization or mobilization. It has useful functions for both splinting in helping gain maximum function following trauma or surgery. The challenge for therapist and surgeons is to decide when each type of splint is most useful Colditz, (1996).



2.6.1 Immobilization splints

Usually, the most commonly splints are used to immobilize and rest healing tissue.

a) Reduction of Inflammation from Trauma.

Resting hand tissue reduces inflammation to encourage orderly healing without disruptive external influences and is the initial choice for the acutely injured part. The normal inflammatory response to trauma, infection, and pain will respond positively to rest. It was emphatic that such splinting should cease when possible because of the atrophy and stiffening which rapidly occurs in the immobilized hand. Immobilization periods have become shorter to minimize the negative effects of prolonged stiffness.

b) Reduction of inflammation from arthritis

Inflammatory arthritis responds to rest, but this rest may be short-lived, providing daily symptomatic relief. Splinting to provide rest, used with other treatments, has long been recognized as a standard protocol in this patient population.

c) Control pain

Without infection, rest of the acutely injured hand can decrease pain. In the healing hand, a delicate balance between rest to reduce painful inflammation and exercise to maintain tissue glide can be accomplished by a removable splint.

d) Provision of external support

Splints may be used during any stage of healing to provide external support to internal structures. Unstable joints resulting from trauma or arthritis can benefit from such splinting for symptom relief and functional assistance.

e) Substitute for absent, weak , or imbalanced muscles

Splints may also be useful when a major nerve injury deprives the hand of its normal muscle balance. Although a splint cannot simulate the dynamic balance of muscles, it can provide a blocking or stabilizing force to prevent overstretching of enervated muscles and joint contractures.

f) Evaluation of the potential for surgery

Finally, in selected cases, the temporary use of splints may help in surgical fusion can assist the patient and surgeon in deciding the best position for arthrodesis.

2.6.2 Mobilizing splints

The second purpose of hand splinting is to mobilize tissues using force applied by a splint to aid the way tissue heals. The appropriate use of mobilizing splints may eliminate the need for a surgical procedure. Many mobilization splints have a movable component, which applies force to the joint or joint of the hand and increase joint motion.

a) **Protection of Healing Structures**

Splints can provide defined limits to tissue glide or stress. It controlled motion has been shown to produce superior clinical results following flexor tendom repair and is an effective technique for unstable dorsal proximal interphalangeal dislocation.

b) **Influence on skin scar formation**

All scar contracts as it heals. In the hand this is of particular functional concern if skin crossing joint becomes too short to allow normal motion. Prolonged positioning of the scar at maximum length combined with positive pressure to minimize scar hypertrophy can often prevent the need for surgical release.

2.7 Categories of splint which immobilize and mobilize

There are four types of splints such as static splints immobilize and dynamic mobilization. Serial static and static progressive splint hold tissue at maximum length and are changed frequently to encourage tissue to lengthen. These two types combine positive characteristics of both immobilization and mobilization splints.

a) **Static**

A static splint is a device molded or applied directly to the hand that maintains the hand or joint in one position example in Figure 2.7, example static splint. It may be worn continuously to support healing tissues or removed periodically to allow periods of specific protected exercise. Static splints are used most often rest tissues, provide external support, and intermittently gain or maintain motion which has little resistance.

Figure 2.7: Example static splint
(Source :< http://www.assistireland.ie/eng/Products_Directory/Orthoses/Hand_Wrist_Splints_and_Braces/Hand_and_Wrist_Positioning_Splints/Radial_Bar_Wrist_Cock-up_Splint.html> 22/11/13)

b) Dynamic

Dynamic splint provide a constant force to the joint. A dynamic splint has a base, usually made of molded plastic material, held securely to the hand or forearm. The force is generated either by stretched rubber band or a wire spring coil via an outringger attached to the base. The outringger assures that the force is directed at or close to a 90 degree to the long axis of the bone like example at Figure. While the splint is worn by the patient, there is a constant force applied and even as motion improves, the splint force continues. Dynamic splints are removable and the force is intermittent because the splint is removed periodically. Figure 2.8 shows the example dynamic splint. Dynamic splint used to securely to the hand or forearm.

Figure 2.8 Example dynamic splints.
(Source :< http://old.mysplint.com/hand-therapy/splints> 22/11/13)

c) Serial static

Serial static are molded in a stationary position with the tissue at maximum length. They are changed frequently to accommodate the decreased resistance in the tissues. Such a splint may be a plaster cast worn continuously until removed by the therapist or a molded plastic splint applied and removed by the patient. The splint is worn for long periods so that the tissue adapts to this new position. Ideally the serial cast is changed every other day, or at least twice weekly with brief periods of supervised exercise when out of the splint.

Plaster of Paris has long been recognized as an effective means of applying effective serial static splinting because of its conformity and the belief that inelastic splint are more effective. Many believe serial casting is indicating where use of dynamic splints has failed. Figure 2.9 shows the static serial used to maintain the position of the injured hand.

Figure 2.9: Example plaster of paris

(Source :< http://www.britannica.com/EBchecked/media/128076/> 12/11/13)

d) Static Progressive

Static progressive splints may be identical with dynamic splints in construction of the splint base and outringger, but the application of force is not dynamic. The force may be applied via the same outringger and finger loop system or by another means. Instead of a rubber band or spring, tension is maintained once fitted or mechanical components which can be adjusted in small increment. Figure 2:10 shows the static progressive used depending on the type of injury. This means that the form of static progressive group based on the type of injury suffered by the patient.

Figure 2.10: Example Static progressive

(Source :< http://www.platinum-mobility.com/orthopaedics/splinting/finger-splints-1/finger-splint-rolyan-static-prog-finger-ext-splint-xxs/9446l > 12/11/13)

2.8 Existing Product

There are variuos types of hand and wrist support devices available with provide cushioning and promote quick recovery using healing support. Many treatments depend on the location, type, duration, and severity of the injury. Some injuries needed for surgery such as ligament tears, medication, taping the injured finger to a neighbouring one for support, splint, braces, casts, or physical therapy may be used as a treatment option (Dan Matthews, 2008).

2.8.1 Wrist Splint

Figure 2.11 shows one of the hand and wrist splint. This invention is a rigid splint to get an injured wrist joint where the ulna and radius bones fused with the bones of the hand and arm consisting of mixed or socket around the sleeves and open at the bottom to hug her palm. It is held in place by straps for uniting the open sockets and which passes under the thumb and secured the buckle in the back. he is one of the advantages of not having to open splint for x rays(W.J.Jones, 1940).

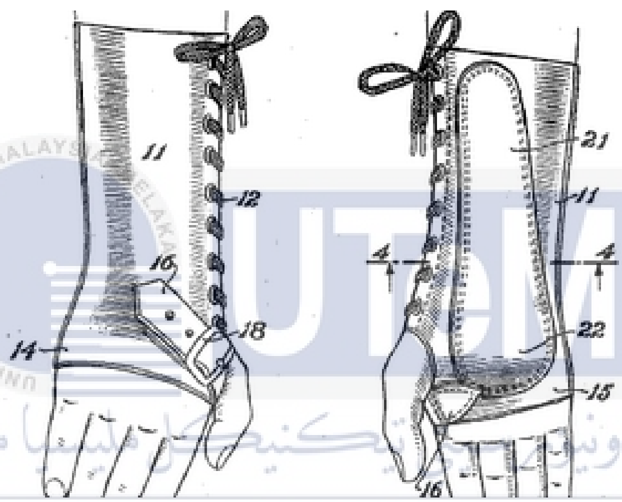


Figure 2.11: Wrist Splint (W.J.Jones, 1940).

2.8.2 Flexible wrist splint

Figure 2.12 and 2.13 shows that a flexible splint to be used in the treatment of carpal tunnel syndrome includes an elongated proximal portion. This design is palmar that have sickle or hook a curved shape and define the thumb notch. Part of the palmar angle with respect to the proximal part to lay hands on cocked or near normal anatomical position. Flexible member conFigured to avoid contact with the volar surface of the wrist that is located above the tunnel. Splint has elastic straps, including a hook and loop fastener, attach a splint for the wrist and the palm of the user (Lemmen, 1993).

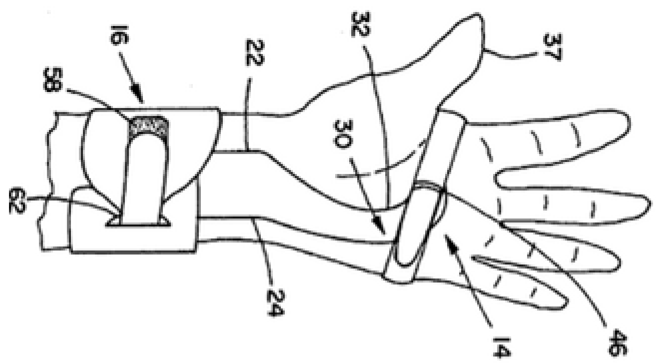


Figure 2.12: Flexible Wrist Splint (Lemmen, 1993)

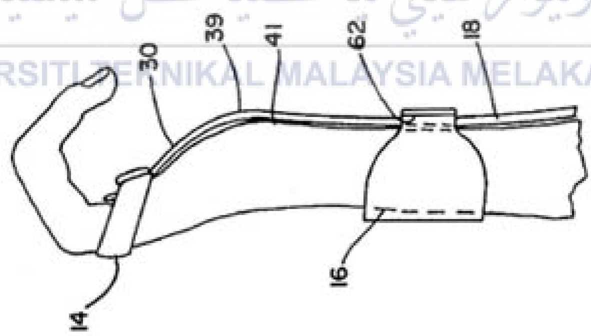


Figure 2.13: Flexible Wrist Splint (Lemmen, 1993)

2.8.3 Other patents design

Figure 2.14 until Figure 2.15 show the other design of existing hand and wrist support used for hand and wrist injuries treatment. Each design has their advantages and disadvantages based on properties in term of material, shape, and function. They have the finger supporter for maintaining bone structure in the finger.

Figure 2.14: Example of hand and wrist splint

(Source :< http://www.platinum-mobility.com/orthopaedics/splinting/finger-splints-1/finger-splint-rolyan-static-prog-finger-ext-splint-xxs/9446l > 23/11/13)

Figure 2.15: Example hand and wrist splint

(Source :< http://www.mediroyal.se/en/product/pre-formed-functional-splint-perforated > 23/11/13)

2.9 Summary for hand and wrist.

This portion briefly describes the tool support for the hand and wrist, including information about the human hand and wrist. Hand and wrist injuries usually happend among people of all ages whether athletes or ordinary people. Hand and wrist support is designed to provide general stability and protection to allow the hand and wrist hurt can heal and give comfort in doing the movement. The hand and wrist support is a flexible tool that offers the advantages of controlled compression around the hand and wrist and rigid lateral support. It would not only help heal when broken even help if sustained minor injuries. There are different kinds of tools supporting hand and wrists are available to provide cushioning and promote faster recovery. Many of the hand and wrist braces, wraps, and straps designed specifically for certain types of hand and wrist problems.

2.10 Introduction prototypes

In recent years, opening up local markets for worldwide competition in manufacturing field, it has led a new product development in order to stand line with other competitors. The manufacture should be able to attain and sustain them as "World Class Manufacture". This is the time where manufacture should be able in produce a product that meet and fulfil customer requirement, products in higher quality, reduce lead time in produce a product with reasonable cost and fulfil safety requirement.

In manufacturing field, sometimes when produce a new designs often have unexpected problems. So it need designer and engineer to produce a prototype because the ability to explore design alternative, make an analysis about the product and to confirm performance prior to starting production of new product. Prototype is the best way as a benchmark for the approval of a product.

Definition prototype by dictionary.com is the original or model on which something is based or formed. It also same like Merriam-Webster that give a definition prototype is an original or first model of something from which other forms are copied or developed. By Hartmann, (2009) prototyping is to create concrete models and approximations based on those ideas.

Prototype modeling in the sense that there is a traditional method from time immemorial. The prototype is made to enable the realization of the design concept. The prototype is usually made before, to identify problems that occur before the start of full production product. Chua, (2003).

2.11 Types of prototypes

The general definition of the prototype contains three aspects of interests:

1. The implementation of the prototype; from the entire product or system itself to its sub-assemblies and component.
2. The form of the prototype; from a virtual prototype to a physical prototype.
3. The degree of the approximation of the prototype; from a very rough representation to an exact replication of the product.

Among the aspects of producing prototypes must cover the full range of prototype products either in terms of a prototype system for a part of, or sub-assemblies or components of the product. Usually it is carried out by using a full-scale and fully functional.. Figure 2.16 shows an example of product prototype. Prototypes can be built into a replica is in a full-scale and accurate product. every aspect of the product model, a pre-production prototype used not only made to meet customer needs assessment but also deal with manufacturing issues and concerns about the execution of the manufacturing process. Prototype is crucial to the final stage of the product development process.

Figure 2.16: Example product prototypes

(Source :< http://www.javelin-tech.com/3d-printer/stratasys-printers/idea-series-printers/uprint-se/ > 12/11/13)

2.12 Additive manufacturing

Additive manufacturing (AM) is a process or method that starts from a 3D CAD model to help create physical prototypes automatically within a short period of time Lenning, (1997). According to Iliescu, (2009) with AM, geometric complexity or intricacy without the need for elaborate machine setup or final assembly of objects can be formed either by using additive manufacturing. It can be made from various materials and one of material is composites, and materials can be varied in a controlled manner in any part of the object. So, the construction of the complex can be reduced to a manageable process, frankly, and quite quickly. It is the best way for engineer to transfer directly an idea to form a product. From Figure 2.17 shows that product that can be produce by AM.

Figure 2.17: Example of additive manufacturing product.

(Source:<http://business.utsa.edu/cite/files/spring13/Live%20Oak%20Logic%20Presentation%20for%20CITE%20Boot%20Camp%20Feb%209,%202013.pdf > 21/10/13)

2.12.1 Advantage of Additive Manufacturing

According to Liou et al, (2012) it have a lot of advantage when used AM to build complex three dimensional parts from their CAD models rapidly in a layer by layer manner. Rapid manufacturing exhibit significant advantages over conventional manufacturing process including:

a) Reduced lead times
b) Zero tooling costs
c) Design and redesign flexibility
d) Material flexibility
e) Part complexity

W. Jun, (2013) also gives the same advantage of AM with Isanaka and Liou, (2012) but there is yet another addition of advantage using AM:

a) Minimal material waste.
b) Enables personalized manufacturing
c) Energy efficient
d) Green manufacturing
e) Excellent for mass customization.

2.12.2 Fundamental of Additive Manufacturing

The basic approach they adopted the same to all the different techniques AM and it can be described as follows:

1. Computer Aided Design / Manufacturing (CAD / CAM) Computer Aided system can be modeled either in the form of models or components. Physical parts to be built to represent the model must be represented by a closed surface that clearly define an enclosed volume. This means that the data inside, outside and boundary model to be specified.

2. Stereolitography format (STL) file format is derived from the 3D system can be changed when completed solid or surface model. When using the STL file format that is curved parts can be very large and the file format approximates the surface with a polygonal surface model.

3. STL files can also analyze a computer program can define the model dwellings to be designed and cut to the cross-sectional model. To create a 3D model cross sections is systematically reinvented and incorporated by solidification of either liquid or powder.

Figure 2.18 shows that rapid prototyping wheel. Fundamentally, the development of AM can be seen in four primary areas. They are input, method, material and applications.

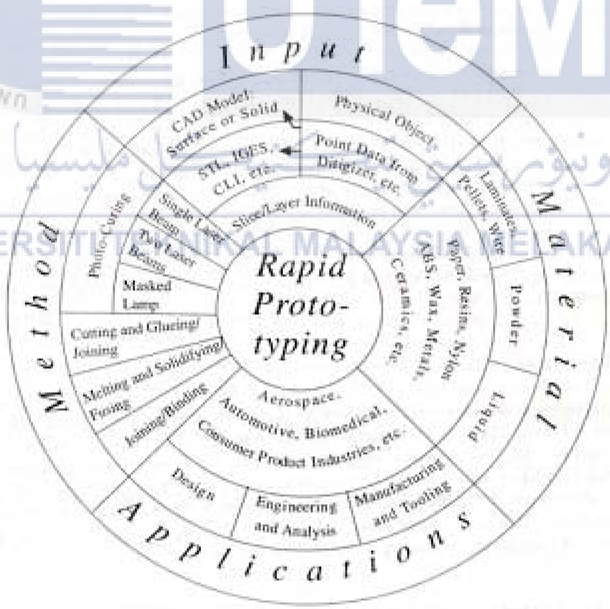


Figure 2.18: Example of rapid prototyping wheel (Chua, 2003)

a) Input

Input refers to the electronic information required to describe the physical object with 3D data. There are two possible starting points a computer model or a physical model. The computer model created by a CAD system can be either a surface model or a solid model. The physical model for 3D data is not at all straightforward. It requires data acquisition through a method known as reverse engineering.

b) Method

They are currently more than 20 system or method in AM. It has several categories such as photo curing, cutting and gluing, melting and solidifying and joining.

c) Material

Additive manufacturing is material where it can come in many forms whether solid, liquid or powder state. As in the solid state, various forms such as pellets, wires, or laminates produced for use in additive manufacturing. Various materials such as paper, nylon, wax, resin, metal and ceramics used in additive manufacturing.

d) Application

A wide range of industries can benefit from AM. Most AM before it is used for the next application of the finished parts or touch. Applications can be grouped into three as

1. Design.
2. Engineering, analysis, and planning.
3. Tooling and manufacturing.

2.12.3 Additive Manufacturing System

There are three main AM systems, depending on initial the form of materials involved:

1. **Liquid-based AM systems –** early form of the material is in a liquid state and, through the curing process, the liquid is converted into a solid state; system include: Stereolithography 3D Systems' (SLA), Light Sculpting, Rapid Freeze and Two Laser Beam;
2. **Solid-based AM systems –** early form of solid substance is, except powder (wire, roll, laminates, pellets); This system includes: Stratasys 'Fused Deposition Modeling (FDM), 3D Systems', Systems Multi-Jet Modeling (MJM) and pares coating technology (PLT);
3. **Powder-based AM systems –** powder is an early form of the material; system include: 3D Systems' Selective Laser Sintering (SLA), Optical Precision Metal Manufacturing is directly Deposition (DMD) and Z Corporation Three Dimensional Printing (3DP).

2.12.4 Additive Manufacturing Technique

According to Kulkarni P, (2000) AM is emerging as new manufacturing technology that can enhance the scope of manufacturing. AM system can generate both models and parts with different functions. Most prototyping and production tool using this method. Rosochowki A, (2000).

a) Stereolitography

{hoto-polymerization monomer liquid resin is a method used in Stereolitography (SLA). It is the bidder selected by coating the surface of the laser beam follows the path defined in the model slicing. After this layer has been created, the movable platform is lowered into the vat, a new thin layer of liquid monomer floods and the process is repeated.

b) Selective laser sintering

Selective laser sintering (SLS) is a method a thin layer of finely ground plastic powder is spread onto a working platform. The laser energy is directed onto the powder with a scanning system where it causes the powder to sinter to become a solid. Then the working platform is lowered, a new covering of powder layer is spread and the scanning is repeated.

c) 3D Printing

It similar process with the SLS, which is a binder phase is sprayed selectively onto the powder by means of ink jet type printing heads.

d) Fused depositon modelling

The fused deposition modelling (FDM) machine is an XY plotter device that carries an extrusion head. The build material is heated to just above its melting point and extruded in the areas within the bounds of the part. After extrusion the material solidifies immediately and welds to previous layer.

e) Solid ground curing

It is similar method which uses ultra-violet radiation as the energy source has been named solid ground curing (SGC). In this method data from the CAD model are used to produce a mask, through which the liquid is illuminated and cured.

f) Microcasting

Microcasting is a droplet-based shaped deposition manufacturing (SDM) process which consists of four processing stations such as thermal deposition, shot peening, cnc milling and cleaning. A plasma arc robot produces discrete droplets of super-heated metal which fall to the surface and bond. Shot peening is used for stress relief and then CNC milling to obtain the final form of the layer.

g) Ballistic particle manufacturing

In a similar process called ballistic particle manufacturing (BPM), a stream of molten material is ejected from a nozzle: the material separates into droplets which it hit the substrate and immediately cold weld to form the part.

h) Laminated object manufacturing

In this laminated object manufacturing (LOM) method the build material takes the form of a sheet of paper, metal, plastic or composite. Each layer of the model is profiled from the sheet using a laser. This section is then laid on and bonded to the previous layer using a hot roller which activates a heat sensitive adhesive.

i) Secondary operation

Prototype model often require further processing depending on the AM technique used. In many systems support structures have to be detached from the model. This is done manually and requires some skill to get good surface finish. A powder support is easier to deal with some method that provides only limited structural, so that, the models are subjected to further curing and sintering, depending on the material used and its structure.

2.13 Fused Deposition Modeling (FDM)

Method of AM is most commonly used for rapid production of new part intended for presentation purposes. It can use different tests and analyses to manufacture models Kuric I (2012). FDM previously was developed by Stratasys in Eden Praire. FDM machine is the process, extruded through a nozzle by using materials such as plastic or wax to give the effect of the cross-sectional geometry layer by layer of plastic or wax. It builds the material is usually supplied in the form of filaments, but some setup using plastic pellets fed from a hopper Kuric I (2012).

According to Gebhardt, (2003) FDM prototype melts bulk or wired-shaped plastic material in a heated nozzle and applies the pastry, melted matter on the model. The layer generation results from solidification due to heat conduction. The layers in FDM machine are determined usually 0.50 to 0.25mm by the extruder-die-diameter. This thickness represents the best achievable tolerance in the vertical direction. In the (x-y plane), dimensional accuracy can be as fine as 0.025 mm-as long as a filament can be extruded into the feature. A wide variety of polymers and waxes are available for different applications Chua, (2003). Figure 2.19 shows the FDM machine that is normally used to produce the product.

Figure 2.19: FDM Machine

(Source :< http://www.solidconcepts.com/content/pdfs/brochures/fused-deposition-modeling-fdm-brochure.pdf> 22/11/13)

2.14 FDM process

There are several AM technique exist, all employ the same basic five step process. The steps are:

1. Process begins with drawing 3D model using 3D CAD software to get a data and convert into STL file format.
2. STL data can “sliced” with and CAD software.
3. Dual heated nozzles trace each cross section, depositing thermoplastic material.
4. When a cross-section is complete, the build is slightly lowered and the process continues.
5. Completed parts are removed and support material is cleaned off.

2.14.1 Process begins with 3D CAD data in STL file format.

The first step is the object to build is 3D modelled using software Computer Aided Design (CAD). It have several software can be used such as SolidWork, Catia, Autocad and other CAD software. Figure 2.20 shows that example of cad model that can be made by using CAD software. This process is identical for all the AM build technique. After that convert from 3D model to STL format. This format represents a three dimensional surface as an assembly of planar triangles like the facet of a jewel.

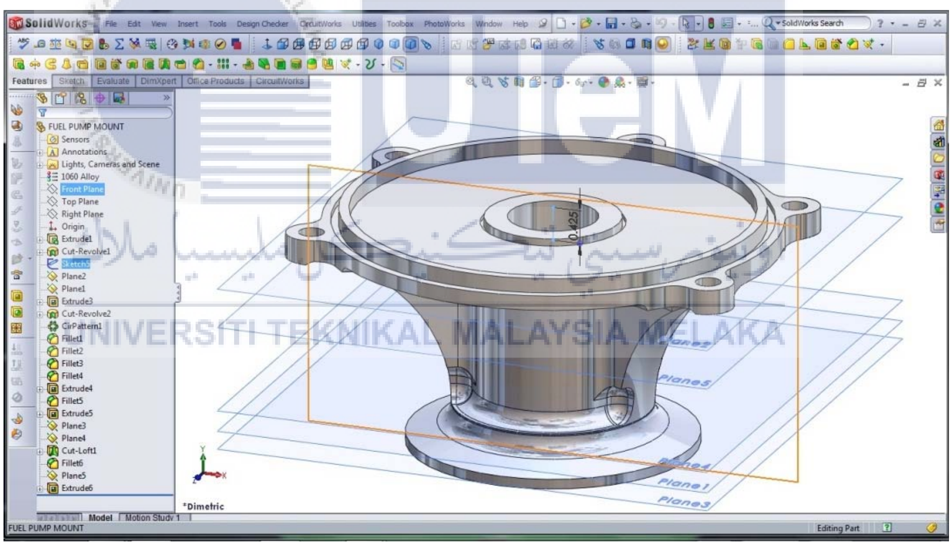


Figure 2.20: Example CAD Model

(Source :< http://krisbunda.com/blog/2011/09/19/3d-cad-modeling-a-high-performance-engine-part-how-to/> 22/11/13)

2.14.2 STL data is "sliced" with software.

STL file is slicing process where operating software that creates a thin, horizontal cross-sections which are then used to create a security code for the machine. In a quick slice, slice normal is composed of 0.005 inch to 0.015 inch and the thickness of the pieces can be altered before slicing. Thin slices can be used to model high-definition, but this increases the time required where the higher the time, the more perfect a build. Cooper K.G (2001). Figure 2.21 shown example of sliced data process before transfer in FDM machine.

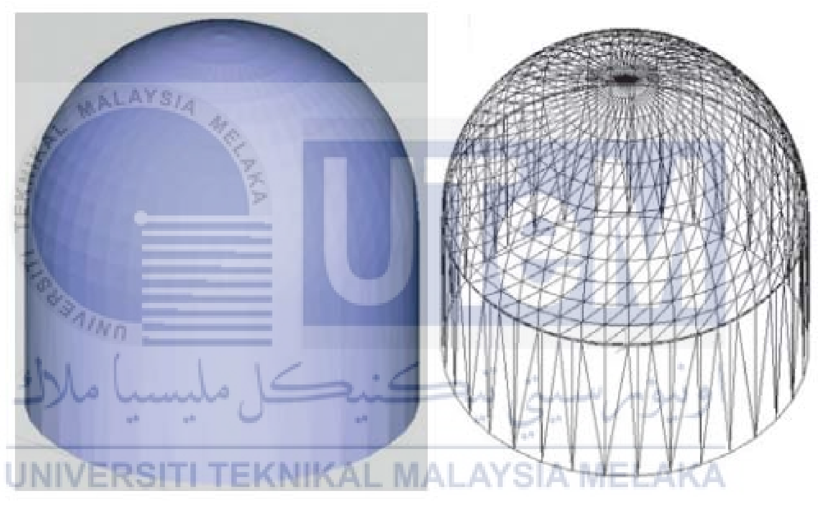


Figure 2.21: Example Sliced data.

(Source :< http://area51machinedesign.com/3d-printing/stl-export-tips/> 22/11/13)

2.14.3 Layer by layer construction.

The next step thickness and material need set as default to build parameters for the slice chooses. To decease build time, model weight, and the amount of material some of the parameter can be tweaked that required for the build Cooper K.G (2001). AM technique has many techniques, one of which is a machine that can build one layer at a time from polymers, paper, or metal powders. Most machines still need little human intervention. Figure 2.22 show the construction process of model using the AM machine.

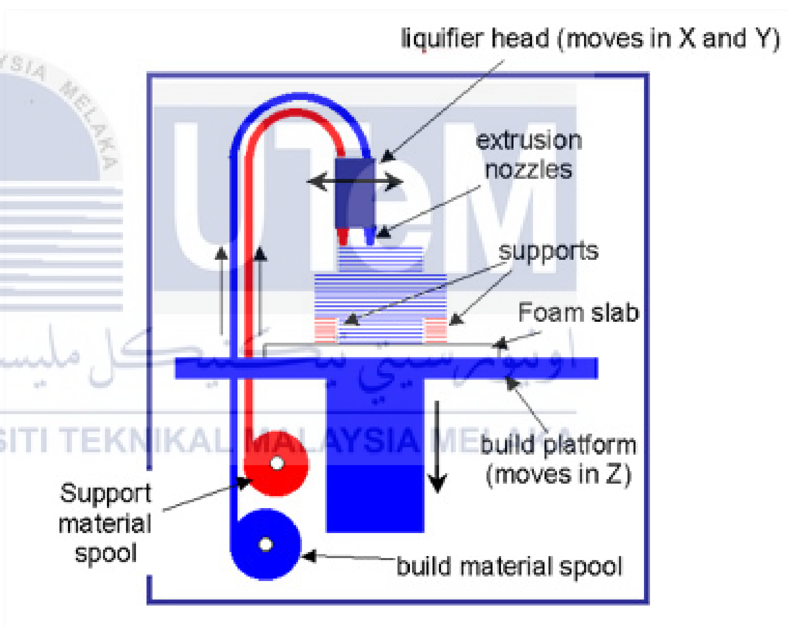


Figure 2.22: Layer by layer construction

(Source :< http://www.hs-heilbronn.de/2857605/34_rapidprototyping> 12/11/13)

2.14.4 Cleaned off completed parts are removed and support material.

The final step is FDM part is remove the prototype from the machine and detaching any support. Product need to clean and got good surface finish. The support material that needs to peel away is easily can make by hand with a knife or pliers. ABS plastic can be made very smooth by wiping them down with a cloth moistened with acetone or similar solvent light. By using materials that are easy to solve by sanding time to complete easier. Cooper K.G (2001). Figure 2.23 shown that product finish need to cleaned off before used or for next process.

Figure 2.23: Cleaned off complete part.

(Source :< http://www.tridimake.com/2013/04/rollerstruder-filament-feeder-driver.html> 22/11/13)

2.15 Applications FDM

According to Chua (2003), FDM models can be used in the following general applications areas:

1) Models for conceptualization and presentation.
   Models can be marked, sanded, painted and drilled and thus can be finished to be almost like the actual product.

2) Prototypes for design, analysis and functional testing.
   The ABS system can produce fully functional prototype. ABS parts resulting in a 85% of the actual strength of the mold. Thus the product user can run the actual test.

3) Patters and master for tooling.
   Patterns for investment casting, sand casting and molding usually used as models.

2.16 Advantages of FDM

According to Chua, (2003) the main advantages of using FDM technology are as follow:

1) **Fabrication of functional parts.**

FDM process is able to fabricate a prototype with materials similar to the actual mold products. With ABS it has 85% of the actual strength of the mold, the components can be made fully functional. This is very useful in developing products that require rapid prototyping to test the function.

2) Minimal wastage.

The FDM process builds parts directly by extruding semi-liquid melt onto the model. Thus only those materials needed to build the part and its support are needed, and material wastages are kept to a minimum. There is also little need for cleaning up the model after it has been built.

3) Ease of support removal

With the use of Break Away Support System (BASS) and Water Works Soluble Support System, support structures generated during the FDM building process can be easily broken off or simply washed away. This makes it very convenient for users to get to their prototypes very quickly and there is very little or no post-processing necessary.

4) Ease of material change

Building materials, supplied in spool form when substances in the weakening system is easy to operate and can be changed easily and allows easy operation and maintenance of the machine is quite simple.

2.17 Disadvantages of FDM

According to Chua (2003), there are several disadvantages for FDM technology. The disadvantages such as:

1) Restricted accuracy

Parts built with the FDM process usually have restricted accuracy due to the shape of the material used. Typically, the filaments are used tend to set limits on how accurately can the built and has a diameter of 1:27 mm.

2) **Slow process**

The process of product development for FDM machine is slow because the entire cross section will be filled with building materials until the entire finished product. Speed of construction products is limited and depends on the rate of extrusion or build a flow rate of material from the extrusion head. As the materials used are plastic and have a relatively high viscosity, so it is not easy building process can be accelerated.

3) **Unpredictable shrinkage**

As the FDM process that extrudes the material depends on the shape of the extrusion head and the process quickly cool the deposition, because the pressure exerted due to the rapid cooling as is often included in the model. Therefore, shrinkage and distortions are difficult to predict because the resulting state of the built model is a normal process, even with experience, users may be able to compensate for this by adjusting the parameters of the machine.

2.18 Introduction Reverse Engineering

Reverse engineering is the process of building and developing a 3D CAD model of the same, from the existing physical object that can be used for manufacturing or other applications (Schodek et al, 2005). Generate the surface model using the technique of three-dimensional (3D) scanning some of the product development process reverse engineering allows this method can help to produce different parts such as car,household appliances and tools such as molds, dies, press tool in a short period of development (Sokovic et al, 2006).

By using the reverse engineering to the development of a product turn out to be shorter and can help pushing all the production chain with a great in time consuming (Sokovic et al, 2006). Reverse engineering methodology and rapid prototyping and rapid tooling technologies, this allows reducing manufacturing lead time parts cast, increasing the quality of the part, and ensure better partnership with its customers. It can solve the congestion making patterns/tools, through the interfacing of information technology in producing a product (Ferreira et al, 2003).

According to Sokovic et al, (2006) reverse engineering is a very important tool,it helps in this process in scanning system in the short time dimension of the digital concept description is accurate, useful for direct control of machine tools in advance. Figure 2.24 show the process sequence of RE from the scanning process until to final product. 3D scanning is used in many different fields.

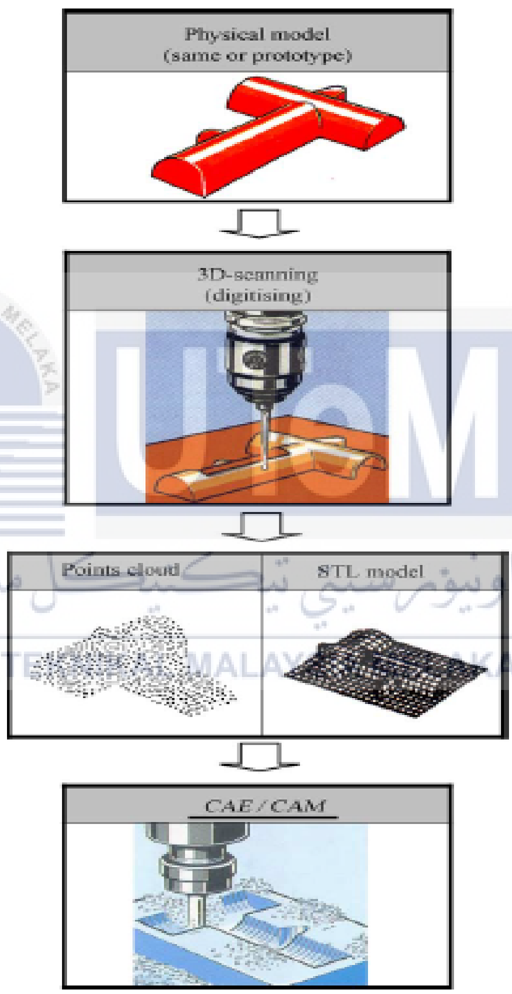


Figure 2.24: Example of the sequences of the reverse engineering,(Sokovic et al, 2006)

2.19 3D Digitizing process

Reverse engineering can helps in solving the congestion making patterns/tools, through the interfacing of information technology, the reverse engineering methodology and the rapid prototyping and rapid tooling technologies, allow and assist in reducing manufacturing lead time parts cast, increasing the quality of the parts, and keep sharing better with customers (Ferreira et al, 2003). Research and development of reverse engineering methodology integrated with CAD/CAE to produce optimized equipment rapid tooling was schematised in Figure 2.25.

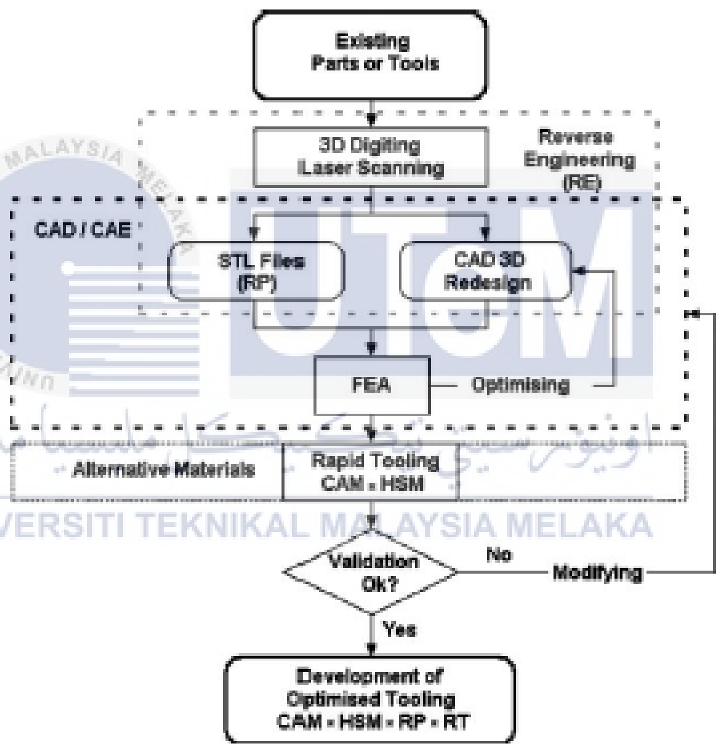


Figure 2.25: Developed RE methodology integrated with CAD/CAE and FEA for optimised RT (Ferreira et al, 2003).

With using 3D Laser scanning digitisers bring more automation for data collection such as product whether large or small part or product. These device without contact by scanning a laser beam profile striped physical model and CCD camera captures the images profile that the triangulation algorithm to generate digital data that show in Figure 2.26. by exploiting the laser stripe triangulation of a ‘reverse’ sensor, guided by the “REPLICA” NC machine, measuring hundreds of surface points per second for a product, take a few minutes to digitize a common object, no matter how complex the geometry of the flat surface or not (Ferreira et al, 2003).

3D scanning system in LMP-IST can strip coordinate data points on the scanning speed standard 6000 points/min with accuracy at ± (Z) = 25 µM. some real limitation concerns the preparation of the surface scan RP prototype should be sprayed with matt white paint and for this reason the scan accuracy is reduced for about ± 20 µ M in the X -Y- Z axis (Ferreira et al, 2003).

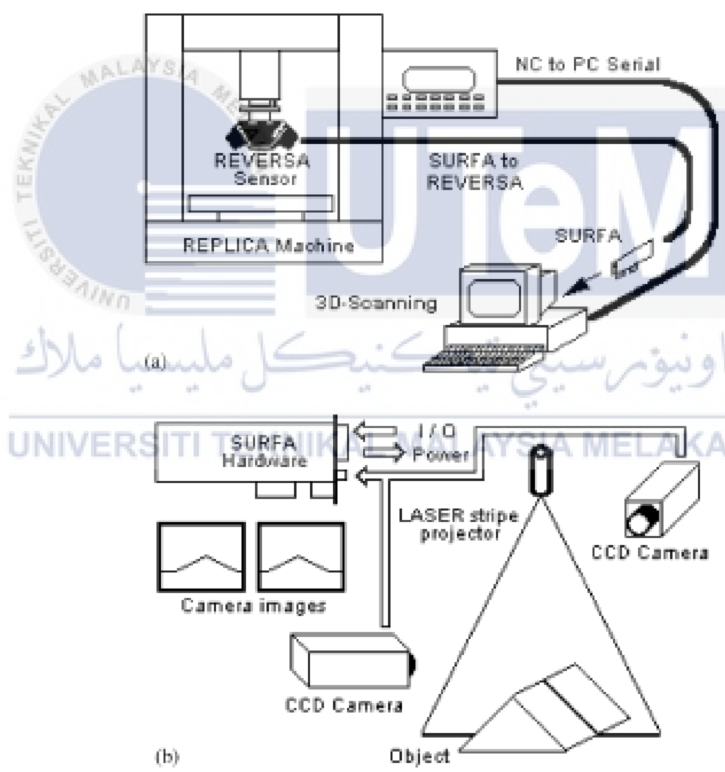


Figure 2.26: (a) Scanning machine configuration (“Replica”), (b) 3D-scanning laser digitiser principle (Ferreira et al, 2003).

2.30 Summary

This portion briefly describes the subject of Additive Manufacturing. Additive manufacturing has emerged as one of the key technologies that enable the ability to shorten the product design and developing the product.. There are several methods used in the process of producing a prototype additive manufacturing for manufacturing a product using Selective Laser Sintering process like (SLS), Fused Deposition Modeling (FDM), Stereolithography (SLA), 3D printers, and more. The additive manufacturing is better than other manufacturing processes, particularly in the run production and costs because it can produce a product without requiring a lot of processes and requires little space to produce. Reverse Engineering is used to develop a product without complete data or from existing products.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology is a method used to record the course of a project to plant that is comprehensive. In addition, each of the setup process will be described in greater detail. The purpose of the methodology is to ensure that all processes involved can be understood more clearly. Several original concepts sure described briefly before the concept will be modified to run the project.

Methodology is a method for recording data for the overall planning for development projects from beginning to end. In addition, selection of highly focused to produce automated hydroponic water tank so that it does not cause any problems when using the product.

Methodology is essential in order to carry out a project for us to know the status of projects as well as to detect any deficiencies in the implementation of the project. Thus, we can ensure and overcome the weaknesses and deficiencies to ensure that projects meet the requirements and the resulting criteria specified.

This chapter shows how the process to design a “hand and wrist healing support” applied according to the equipments and methods used. The processes begin with perfect planning made on the sequence process involved in this project from the beginning until the real product is produced. Methodology is a document process for management of project that include procedures, definitions and explains of techniques used to collect, store, analyze and present information about project flow process.

In this project the methodolgy used to get information and to give an explaination about "hand and wrist healing support" for hand and wrist fracture.The project planning of the design and analysis can be easily implemented when the flow chart is drawn. The flow chart of the project is stated in this chapter. Flowchart is used to explain the achievement and procedure needed to make sure the final design will meet the objective of this project and also meet the specific requirement which obtained from the data collection. The flow chart is showing out the process flow accordingly to the sequence. In addition, it becomes the guidelines to the project and each step in the process is state clearly in the flow chart. By preparing flow charts in Figure 4.1 this project can be reviewed more comprehensibly.

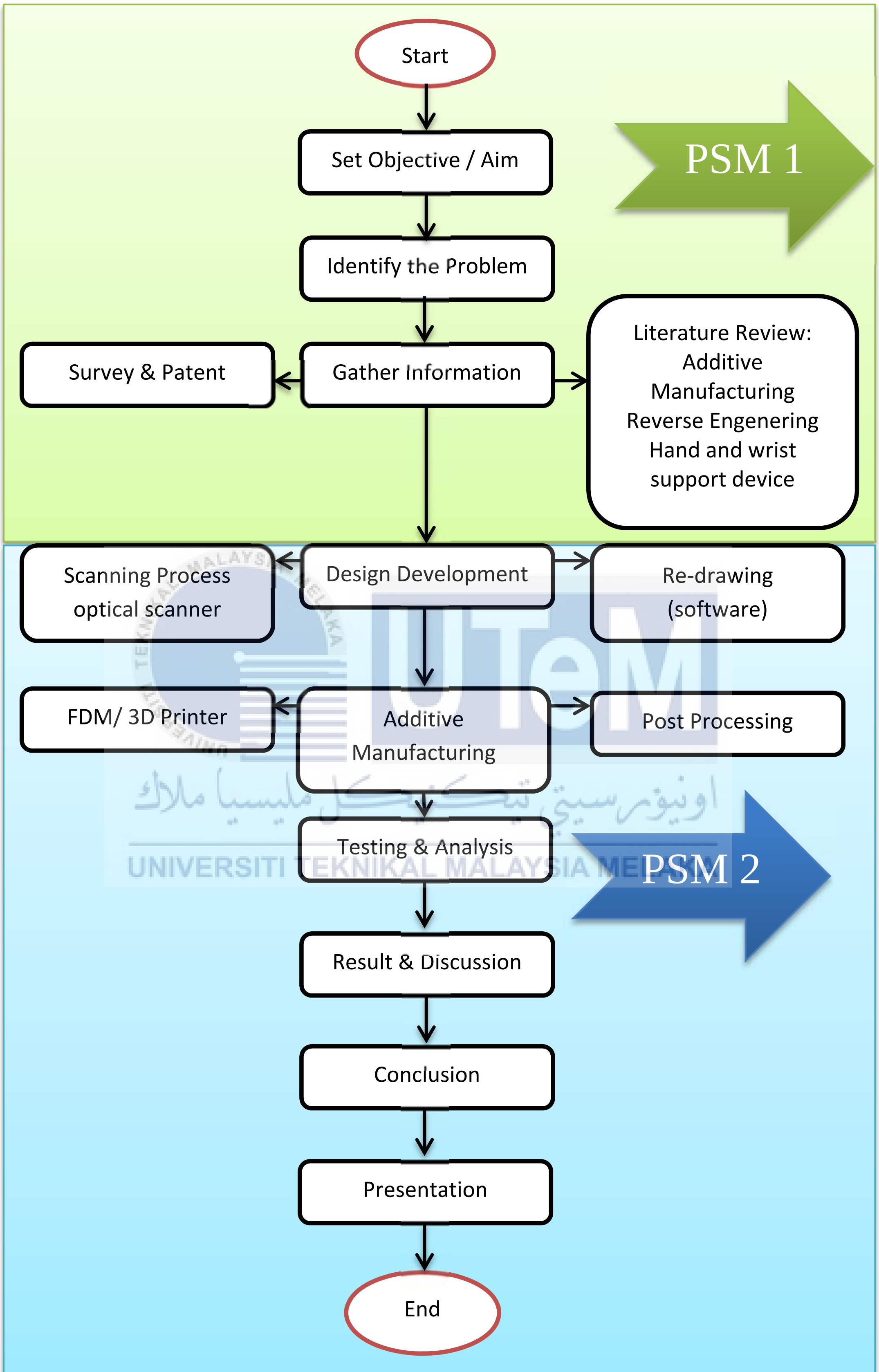


Figure 3.1: Methodology Chart

3.2 Identify problem statement

Identify problem statement is an integral part of the concept development phase of the product development process. The result from previous are used to guide in establishing new product specifications, generating product concepts, a selecting a product concept for further development and material selection. The process of identifying what is the problem with previous product needs includes five steps which are:

a) Gather raw data from patients.
b) Interpret the raw data from patients.
c) Organize the needs into a hierarchy.
d) Establish the relative importance of the needs.
e) Reflect on the results and the process.

The goal of this activity is to understand what is patients needs and to effectively communicate them to the development “hand and wrist healing support”. The output of this step is a set of carefully constructed product needs statements, organized in a hierarchical list, with importance weightings for many all of the needs. All listed below is the method use to identifying the “hand and wrist healing support” needs and requirements.

3.3 Collecting Data

The following objectives have been identified, the process started on product collecting the data related to the title. All of the information that has been collected will be used to produce for make backgrounds and also literature review. In order to get the suitable methods of the “hand and wrist healing support”, the data were collected from books, journals, internet and etc. This is very important to make sure that only valid data are collected to do the project.

3.3.1 Questionnaire

Questionnaires typically entail several equations that have structured response categories; some open-ended questions may also be included. The questions are examined for bias, sequence, clarity, and face-validity. Questionnaires are usually tested on small groups to determine their usefulness and perhaps relability. In sample surveys, data are collected in a standardized format, usually from a probability sample of the population. The survey is the preferred method to obtain a small amount of information from a large number of subjects. This is several objectives that need to achived in questionaire:

i. To identify the "hand and wrist healing support" needs and user suggestion about the existing design itself.
ii. To get information on "hand and wrist healing support" and problems experienced by the patient.
iii. To serve input for the design improvement.

3.3.2 Survey

Survey is the appropriate mode of inquiry for making inferences about a large group of people based on data drawn from a relatively small number of individuals in that group. Its basic aim is to describe and explain statistically the variability of certain features in a population. The general logic of survey research gives a distinctive styleto the research process; the type of survey instrument is determined by the information needed.

Surveys are conducted in three ways: by mail, telephone, and personal interview. But for this product just used personal interview to gather information. Survey have definite advantages when the goal of research require obtaining quantitative data on a certain problem of population. Between the survey conducted to identify whether the patient is comfortable with the sling they wore. The strengths of surveys include their accuracy, generalizability,and convenience. Accurancy in measurement is enhanced by quantification, replicability, and control over observer effects. Result can be generalized to a larger population within known limits of error. Surveys are amenable to rapid stastical analysis and are comparatively easy to administer an manage.

3.4 Concept Generation

Concept generation is the part of the project when the team finally gets to use its creativity to develop innovative solutions to meet the customer's or pateint needs. Once the critical sub problems were identified, the group developed and examined various ideas to address each of the sub problems. Next, the group combined the solutions to the critical sub problems to generate some potential full device solutions.

The concept generation process begins with a set of customer and patient needs and target specifications and results in a set of product concepts will make a final selection. The intent of this project is not necessarily to design any new technologies, but rather to combine existing technologies and solutions in a novel way to accomplish a specific task.

3.5 Concept Selection

3.5.1 Stuart Pugh Selection Method

The Pugh method is a quantitative technique used to rank the multi-dimensional options of an option set. It is frequently used in engineering for making design decisions. A basic decision matrix consists of establishing a set of weighted criteria upon which the potential options can be decomposed, scored, and summed to gain a total score which can then be ranked. The advantage of this approach to decision making is that subjective opinions about one alternative versus another can be made more objective. Another advantage of this method is that sensitivity studies can be performed.

A two-stage concept selection methodology is described is a concept screening and concept scoring. Each concept is supported by a decision matrix, which is used to rate, rank, and selects the best concept(s). Concept selection is often performed in two stages as a way to manage the complexity of evaluating dozens of product concepts. The concept sketch was generated by various types before the selection process.

During concept screening, rough initial concepts are evaluated relative to a common reference concept using the screening matrix. At this preliminary state, detailed quantitative comparisons are difficult to obtain and may be misleading, so a coarse comparative rating system is used. After some alternatives are eliminated, the team may choose to move on to concept scoring and conduct more detailed analysis and finer quantitative evaluation of the remaining concepts using the scoring matrix as a guide.

Concept scoring is used when increased resolution will better differentiate among competing concepts. In this stage, the team weights the relative importance of the selection criteria and focuses on more refined comparisons with respect to each criterion. The concept scores are determined by the weighted sum of the ratings. Throughout the screening and scoring process, several iterations may be performed, with new alternatives arising from the combination of the features of several concepts.

3.5.2 Concept Screening

Concept screening is a formal or structured methodology for identifying and evaluating new product ideas or product concepts. The first step in evaluating and identifying viable product concepts is to conduct a “category due diligence”. The due diligence process gathers information on the industry dynamics and competitive environment of the target product category. This information is then evaluated as part of the concept screen model.

Concept screening method can be as simple as a checklist of criteria in the form, of questions that fall into two categories: “must-meet” and “should-meet” criteria. Must-meet criteria are questions used to determine the viability of the opportunity. These criteria should be structured as closed-ended questions and are designed to provide go/no-go decision points.

3.5.3 Concept Scoring

The weighted scoring system is often used to evaluate and quantify a wide range of product concept criteria. Individual ‘evaluation criteria’ are scored and weighted to determine an overall concept score. Typically, the criteria are assigned values from 1-5, reflecting low to high scores; each criteria is also assigned a weighting factor that reflects its relative importance. Since some variables are more important than others, they should be assigned a greater weighting in the overall score. The total size of the product category, number of competitors, and promotional spending levels should all be included as criteria in the weighted scoring method.

The ultimate goal in developing must-meet/should-meet criteria or weighted scoring criteria is to evaluate variables that have the greatest influence in the success of the new product concept. These evaluation criteria can be determined in a number of ways, and often include a combination of quantitative and qualitative considerations.

3.6 Test and analysis

In test and analysis several software need to used to complete and hand wrist splint for healing support required to complete a number of software products and product-related analyzes to be performed. At the first step is design 3D CAD modeling to show the actual concept 1 until concept 5. In this software all design will be processed following based on the size of human hand. Faro arm is used to identify the shape of hand so that the products will meet one of the features of the industrial design safety.

Other than that, solid work will also use to design 3D CAD modeling. It is used to identify the strength of the hand and wrist splint. With SolidWork will help to identify finite element analysis. Test and analysis also will be taken after product is completed because to identify whether the user comfortable or not.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter shows result the process to design a “hand and wrist support device” applied according to the equipment’s and methods used. The processes begin with perfect planning made on the sequence process involved in this project from the beginning until the real product is produced. Methodology is a document process for management of project that include procedures, definitions and explains of techniques used to collect, store, analyze and present information about project flow process.

In this project the methodology used to get information and to give an explanation about “hand and wrist healing support” for hand and wrist fracture to come out the result. The project planning of the design and analysis can be easily implemented when the flow chart is drawn. The flow chart of the project is stated in this chapter. Flowchart is used to explain the achievement and procedure needed to make sure the final design will meet the objective of this project and also meet the specific requirement which obtained from the data collection. The flow chart is showing out the process flow accordingly to the sequence. In addition, it becomes the guidelines to the project and each step in the process is state clearly in the flow chart.

By preparing flow charts in Figure 4.1 this project can be reviewed more comprehensibly.

This chapter describes the implementation of the project within one year. This chapter will discuss how the study was conducted and the process of looking up information to design and produce a prototype device of hands. During the process of design development, reverse engineering methods have been used to obtain the geometry of the knee to develop a design support tool new hand more comfortable. Design development process can be divided into two steps, scanning and process redesign. Faro Arm were used during the scan process and combined to form a surface model data. After the data is transferred to CAD software Geomagic Studio redesigned and developed a new painting features. Geomagic Studio and SolidWork software used during the development of the design process. The next process is to develop a prototype using Fused Deposition Modeling (FDM) machine Products manufactured and tested finished to get feedback from users.

4.2 Flow Chart of Project Activity

Figure 4.1 shows the process from beginning of the project until completed that consist of several steps that will be explain details as below.

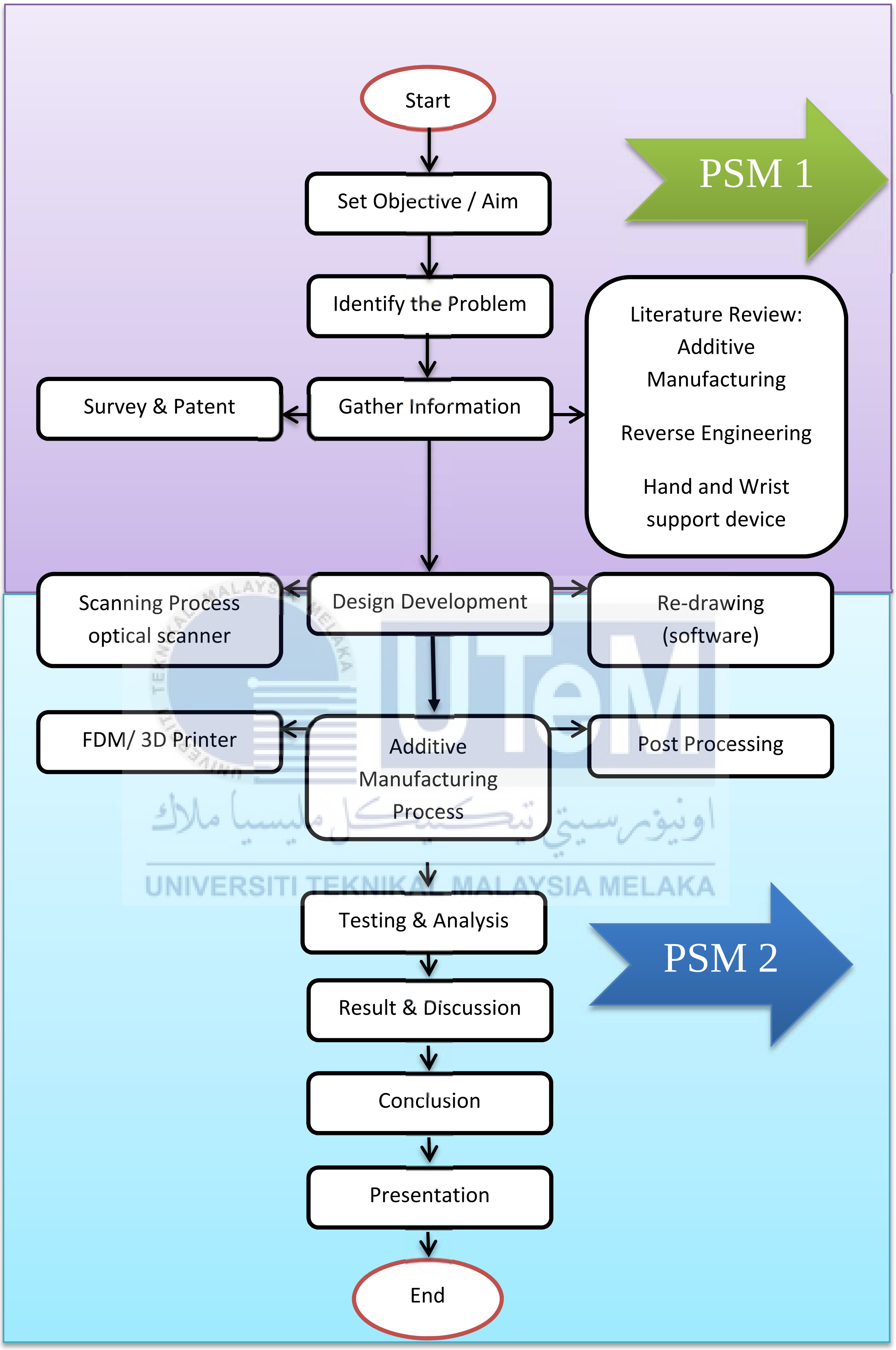


Figure 4.1: Flow Chart of Project Activity

4.3 Survey

4.3.1 Need Statement from Questionnaire

Table 4.1 and Table 4.2 below illustrates the need for each of the questions in this questionnaire. This is to ensure that appropriate questions to get feedback from users. The questionnaire was created is a target to be achieved in which to identify what the customer needs and product specifications to be achieved. Each question can describe any request from customer feedback about device support hand.

Part A

Table 4.1: Respondent Background

Questionnaire Of Project	**Needs Statements**
Gender	Determine the respondent sex.
Faculty	Identify what the respondent's faculty in UTeM

Part B

Table 4.2: Detail Information

No	**Questionnaire Of Project**	**Needs Statements**
1 (B)	Do you usually hear about device support hand or wrist in existing markets?	Identify whether the UTeM students know the existence about the hand and wrist support device.
2 (B)	Where do you usually hear about the device the hand or wrist support available in the market?	Identify whether the UTeM students know the existence about the hand and wrist support device and where the source of information obtained.
1 (C)	I have a hand support device	
If yes so: (circle in the appropriate box only)		
A	Are you comfortable hand support device when in use?	Identify the comfort level of user when wearing existing the hand and wrist support device
B	Is it easy to install and open?	Identify the level how to handle the existing hand and wrist support device.
C	Does the device support your hand to provide effects such as abrasions or other injuries when using it?	Identify the side effects on the user's body either while or after using the

		existing hand and wrist support device.
D	Are you satisfied with your hand support device?	Identify the user satisfaction level to the existing hand and wrist support device.
Ergonomic		
1A (D)	The design of appropriate individual "fit user requirement"	Identify whether the respondents are more comfortable with "standard size" or "user fit requirement" design for hand and wrist support device.
1B (D)	Design "standards" by the average size of Malaysians.	
Method of Installation		
2A (D)	Installation by specialist	Identify whether the respondents more comfortable to wear by their own or need a help from expert to wear.
2B (D)	Can be maintained itself	
Other features that should be on hand support device.		
3A (D)	Light	Identify others characteristics that required by user for hand and wrist support device.
3B (D)	Comfortable	
3C (D)	Easily assembled and disassembled	
3D (D)	Not to interfere with the running	
3E (D)	Not a bodily injury on another and the Surrounding during use,	

3F (D)	Have aesthetic value	
4 (D)	Costs deemed appropriate for a device unit Hand and Wrist Support	Find out the average level of respondents ability to purchase and evaluate in terms of quality and design of product.

4.3.2 Interpretation

The survey was conducted in UTeM and select 30 students which were divided into 17 males and 13 females in the sample population.

4.3.2.1 Questionnaire Part A

Figure 4.2 shows the percentage of respondents by gender. The percentage of men and women taken among students UTeM and taken from various faculties.

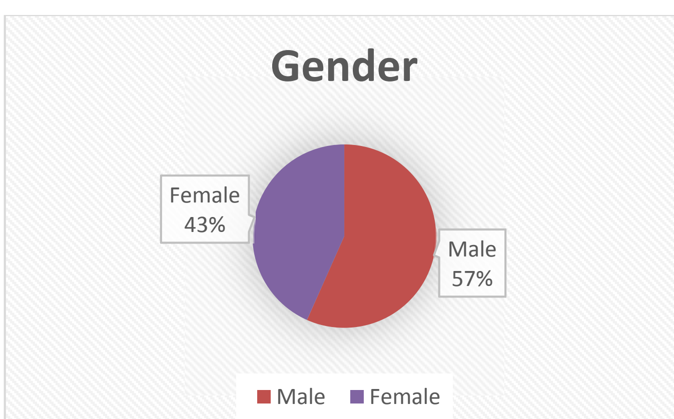


Figure 4.2:Gender

Figure 4.3 shows the percentage of respondents by faculty in UTeM. Disproportionate percentage of the faculty and the faculty FKP more because it is more related to the questionnaire will be conducted.

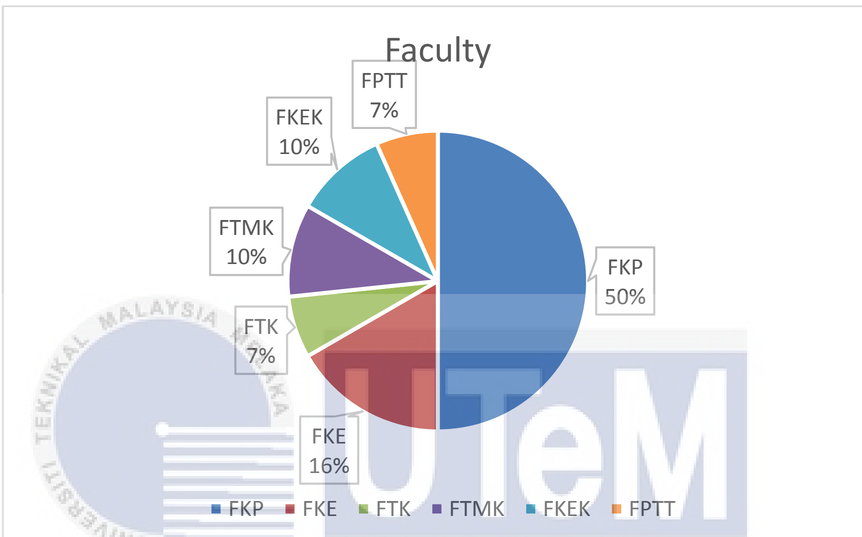


Figure 4.3: Percentage by Faculty

4.3.2.2 Questionnaire Part B

In part B, there are questions that ask for feedback from the respondents. Based on the question, the graph indicated by respondents in Figure 4.4 shows the number of respondents who know the hand support device available in the market.

Question 1: “Do you usually hear about device support hand or wrist in existing markets?"

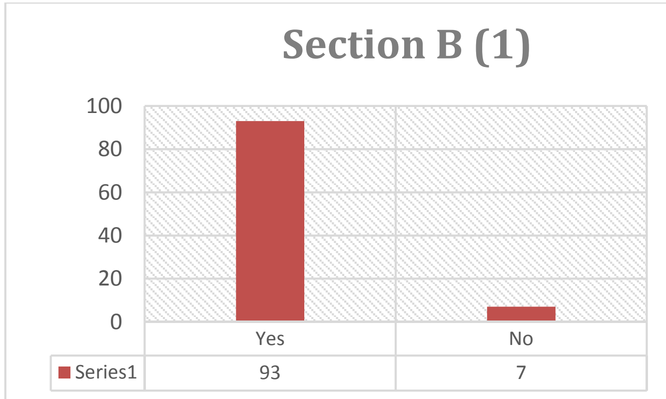


Figure 4.4: Bar Chart for hear about device support hand or wrist in existing markets

Figure 4.4 indicate that a higher percentage of available sources of information about device support came from the hands of the internet, followed by friends, television, and the last is the newspaper.

Question 2: "Where do you usually hear about the device the hand or wrist support available in the market?"

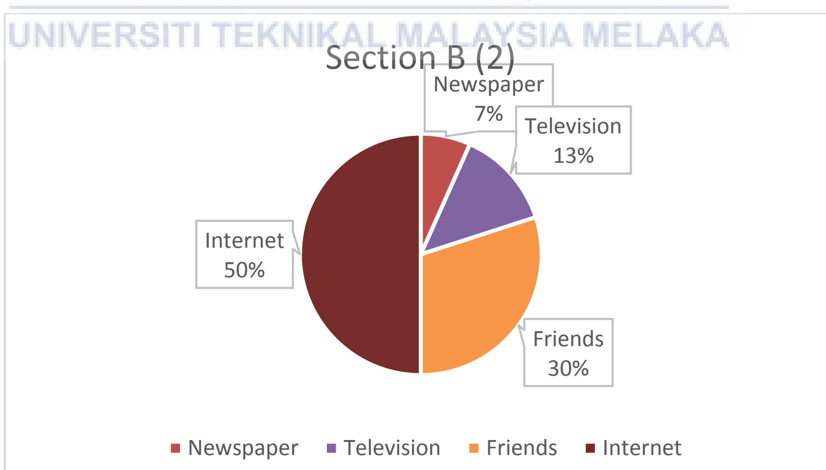


Figure 4.5: Pie chart for where usually hear about the device.

4.3.2.2 Questionnaire Part C

In part C there are questions that ask for feedback from the respondents to know about existing product. The question of the two wants to know what the respondents on the rank level of comfort when wearing hand tool support available if the user has answered "yes" means using an existing hand support device. The graph shown in Figure 4.6 are mostly state customers are usually used the existing design.

Question 3: “I have a hand support device?”

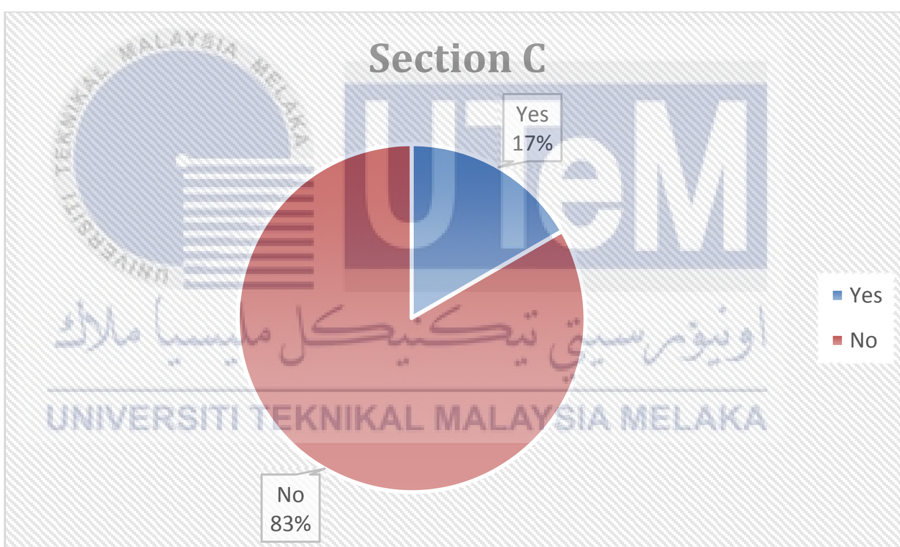


Figure 4.6: Percentage that have a hand support device.

The question of the two wants to know what the respondents on the rank level of comfort when wearing hand tool support available. The bar chart shown in Figure 4.7 are mostly state customers are not satisfied with the existing design to support the design of hand.

Question C: If the respondent selected "YES,"

a) Are you comfortable hand support device when in use?

b) Is it easy to install and open?

c) Does the device support your hand to provide effects such as abrasions or other injuries when using it?

d) Are you satisfied with your hand support device?

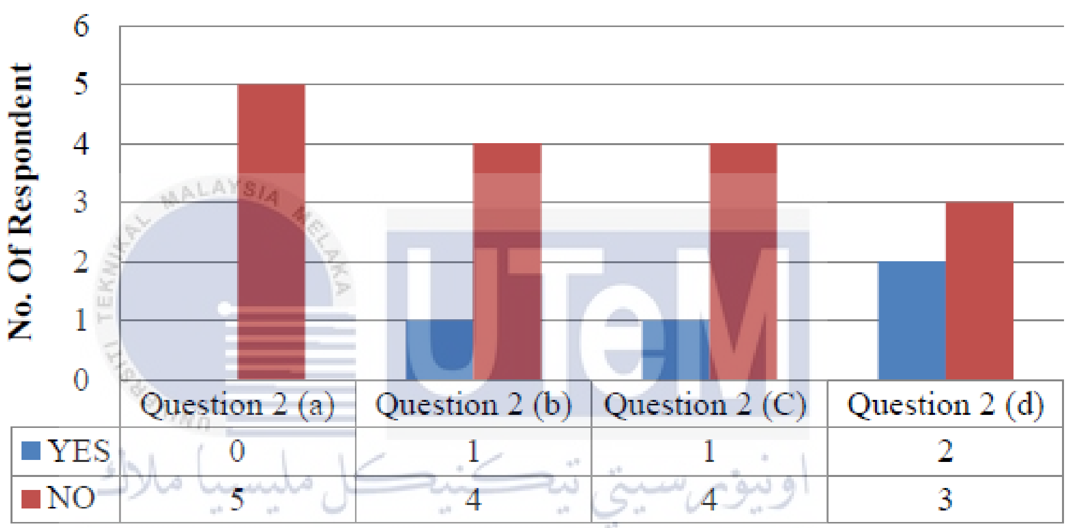


Figure 4.7: Question C if the respondent selected "YES,"

In Figure 4.8 of the survey conducted to find out related to ergonomics for which the majority of users prefer the design of appropriate individual "fit user requirement" of 63% when the designs are made because it would be more comfortable to use. To get "fit user requirement" need using reverse engineering technology to get the right shape and comfortable hand.

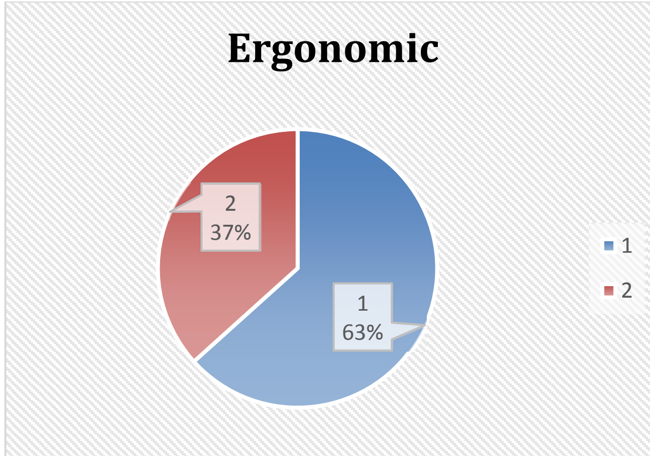


Figure 4.8: Ergonomic

In Figure 4.9 are carried out questionnaires to find out more focused in connection with method of installation for which the majority of users prefer itself can be maintained by 87% when the designs are made because it will make it easier for self-installation by not having to commute to the hospital to remove the hand support devices.

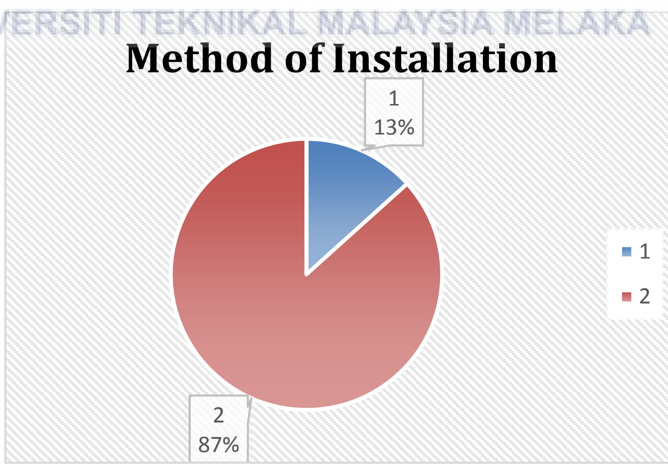


Figure 4.9: Method of Installation

In the questionnaire D just want to know what other things to be added in manufacturing hand support device. So, six things that are important in the manufacture of hand support device made to find out whether appropriate or not made to the product.

a) Light

b) Comfortable

c) Easily assembled and disassembled

d) Not to interfere with the running

e) Not a bodily injury on another and the surrounding during use,

f) Have aesthetic value

In Figure 4:10 shows the results of the first survey question relating should this hand support device light when designing or after the product is completed.

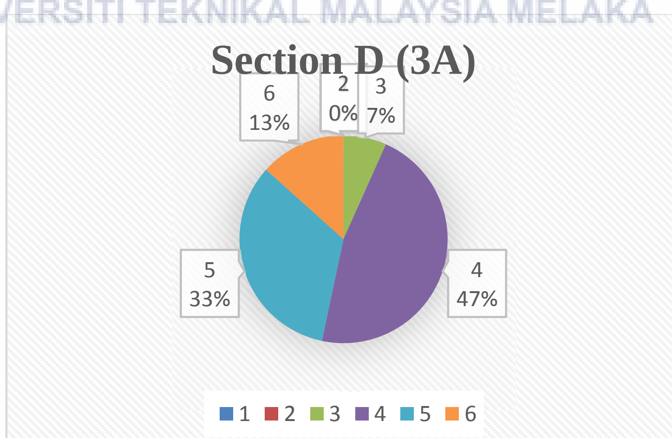


Figure 4.10: Light

In Figure 4:11 shows the results of the survey question relating should this hand support device comfortable when designing or after the product is completed.

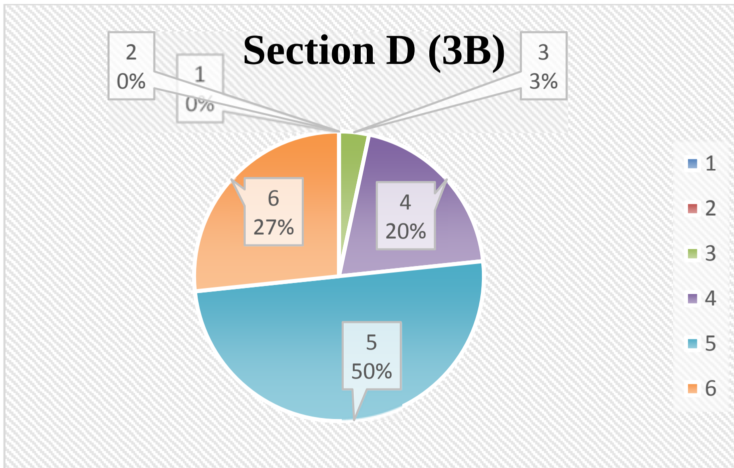


Figure 4.11:Comfortable

In Figure 4:12 shows the results of the survey question relating should this hand support device easily assemble and disassembled when designing or after the product is completed that want to used by user.

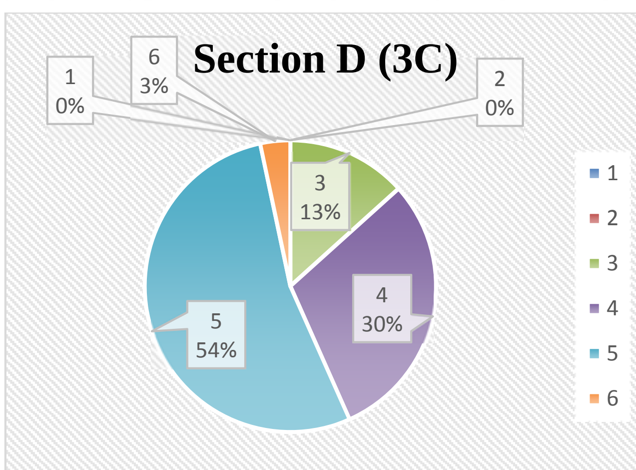


Figure 4.12: Easily Assemble and disassembled

In Figure 4:13 shows the results of the survey question relating should this hand support device not to interfere with the running when designing or after the product is completed.

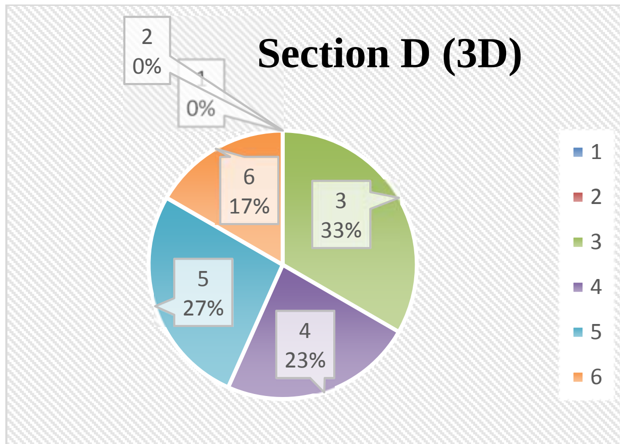


Figure 4.13: No Interfere with the running

In Figure 4:14 shows the results of the survey question relating should this hand support device not a bodily injury on another and the surrounding during use when designing or after the product is completed.

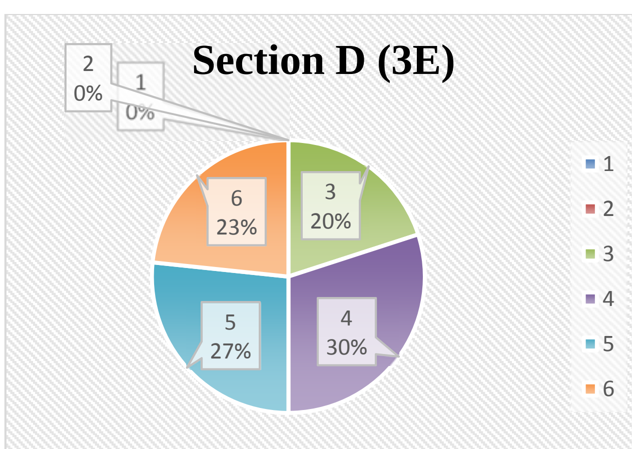


Figure 4.14: Not a bodily injury on another and the surrounding during use.

In Figure 4:15 shows the results of the survey questions where relevant or not have aesthetic value, when designing or after the product is completed and in use by consumers.

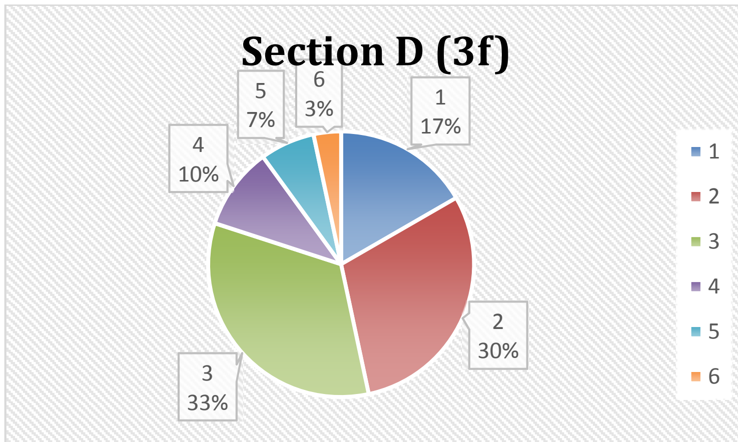


Figure 4.15: Have aesthetic value

4.3.2.3 Summary of Survey

Based on the respondent feedback, it shows that the existing hand support devices still has problem and need some improvement. According to the question number two, it can be concluded that consumers wanted a comfortable hand support device. Referring to the question number three, most user chooses user Fit requirement for hand support devices than the standard size. Besides that, the user also wanted a good hand support device in term of quality, ergonomic, easy to handling, and has a reasonable price within their means.

4.4 Quality Function Deployment

QFD is designed to help planners focus on characteristics of a new or existing product or service from the viewpoints of market segments, company, or technology-development needs. Quality Function Deployment (QFD) was developed to bring this personal interface to modern manufacturing and business.

In today's industrial society, where the growing distance between producers and users is a concern, QFD links the needs of the customer or patient (end user) with design, development, engineering, manufacturing, and service functions.

QFD helps organizations seek out both spoken and unspoken needs, translate these into actions and designs, and focus various business functions toward achieving this common goal, empowering organizations to exceed normal expectations and provide a level of unanticipated excitement that generates value. For hand and wrist support, QFD is used to obtain the results of the questionnaire data are made to enable in preparing the house of quality.

4.4.1 House of Quality

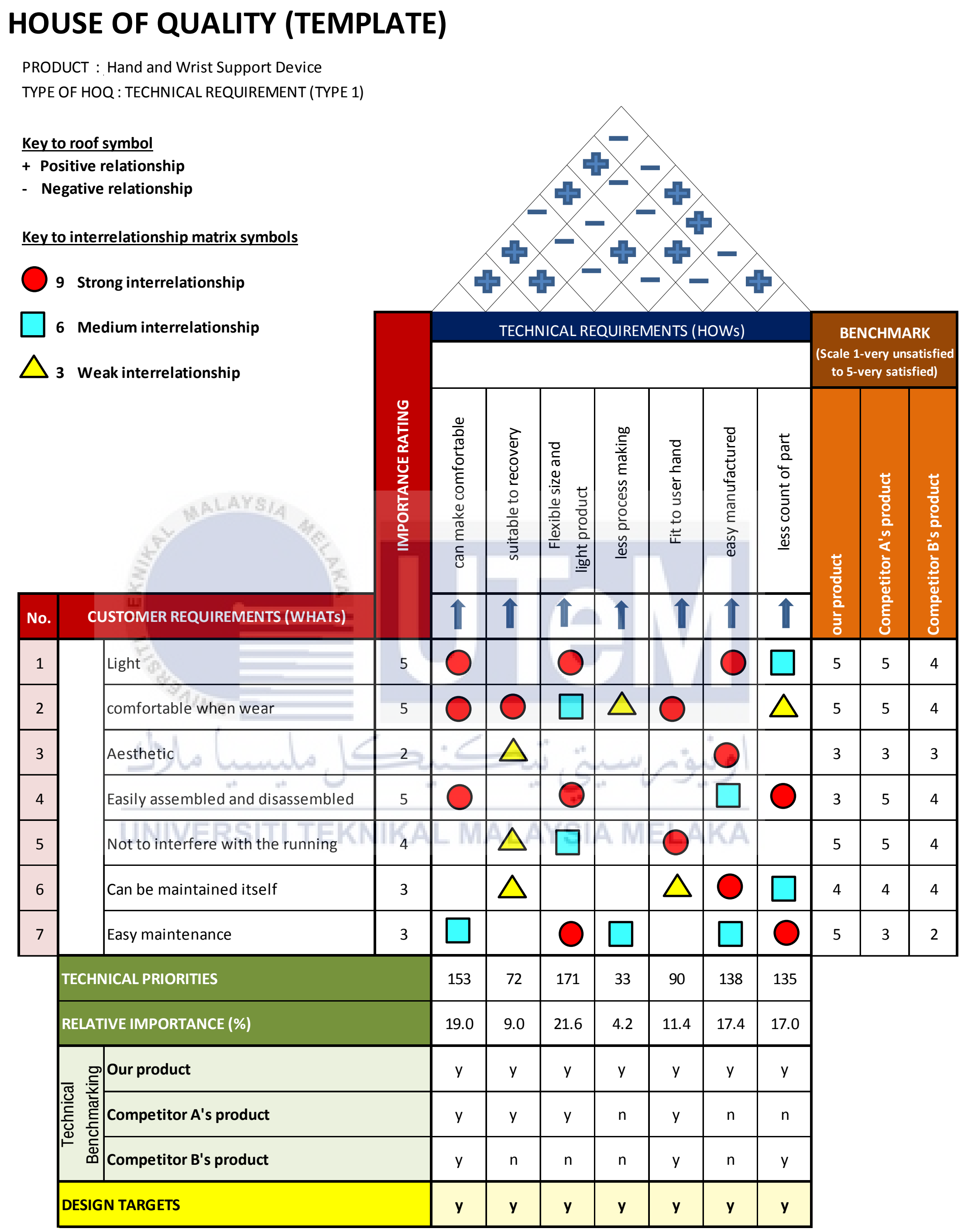


Figure 4.16: House of Quality

4.4.2 Explanation data from House of Quality

Data show home quality (HOQ), which can make some conclusions. From the customer's needs can be explained in seven parts, namely, light, comfortable when wear, aesthetic, easily assembled and disassembled, not to interfere with the running, cans be maintained, and easy maintenance. What is important is rank from 1 to 5; where 1 is the less important and 5 is the most important element. So which has the highest value means that it is most important.

Elements of technical requirements such as cans make comfortable, suitable for recovery, flexible size and light product, less process making, fit to the user hand, manufactured and less easy part is the count of the position of the various interests ranging from 3 to 9. Shows the key elements that required by the customer. The range will change with various shapes such as circles for 9 score, square for score 6 and to triangle for score 3.

The improvement direction row on the chart is used to identify the improvement direction for the design requirement, especially if this is not immediately obvious. For arrow pointing upward means that want to expend additional design effort to increase the target of initial design. For the arrow pointing downward means that we need to maintain the performance of our product.

For the inter-relationship that shows the relationship between customer requirement and design requirement. The matrix is calculated in order to obtain the absolute importance and relative importance of the House of Quality. The rank is then calculated to determine which requirement from customer is the most important.

In conclusion, from the House of Quality, would have been apparent that the flexible size and light are part of great interest, it is absolutely essential is the relative value of 21.6%. while the lowest is less making process that gets relatively important only 4.2%. From the House of Quality, designers have a better understanding of customer needs and understand the need to design good products that satisfy the customers.

4.4.3 Product Specification

Product specifications are to mean the precise description of what the product has to do. There are two stages process for establishing specifications that are, establishing the target specifications and setting the final specifications after the product concept has been selected. It also as limitation before make product concept with considers the needed. Table 4.1 show list of final specification.

Table 4.3: Final Specification

NO	MATTERS	UNIT
1	Type of Product	Hand and wrist support.
3	Weight	200 gram
4	Height	±335 mm
5	Life Time Performance	3 years
6	Material	ABS Plastic
8	Number of Part	3
9	Cost	±RM 100

4.4.4 Concept Generation

After define from questionnaire needs and target a specification, the final selection of product is defined by using concept generation. In this project development about 5 concepts were generate before make a selection of concept. The concept must follow what the customer requirement. Below is a 5 concepts that generate after doing a research from the problem statement and questionnaire.

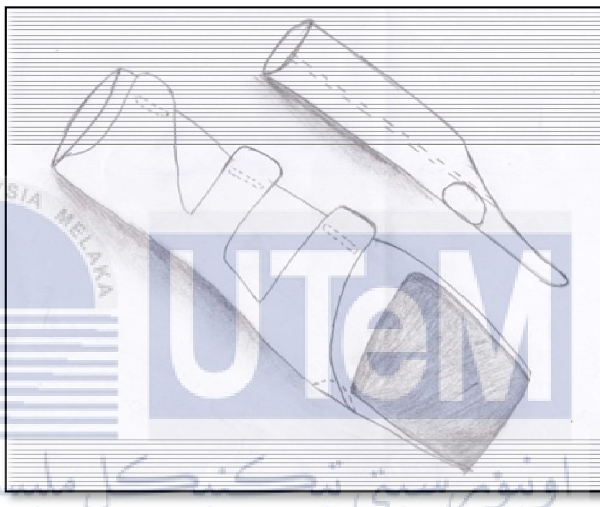


Figure 4.17: Concept 1

Figure 4.17 shows the concept for the completion of the hand and wrist support. For concept one, the whole hand will be wrapped and given free space to do the finger movements.

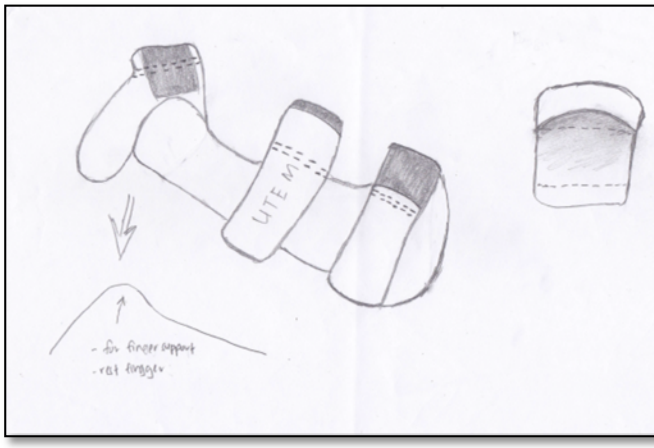


Figure 4.18: Concept 2

Figure 4.18 shows the concept for the completion of the hand and wrist support. This concept more as an opportunity to rest and palms of the hand is not closed to make it easier to open and close.

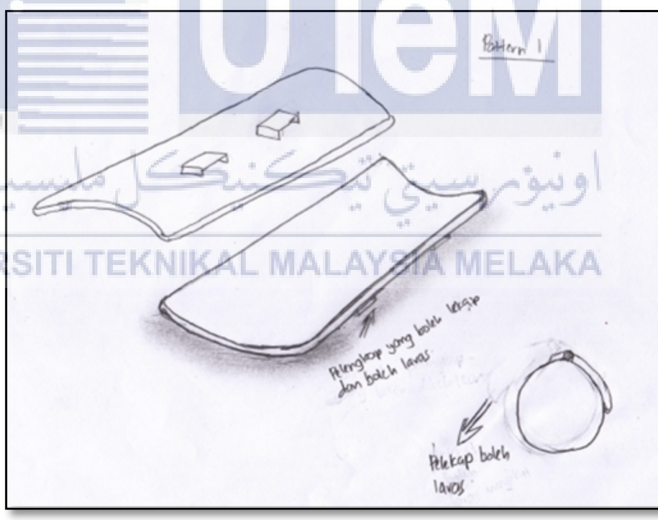


Figure 4.19: Concept 3

Figure 4.19 shows the concept for the completion of the hand and wrist support. This concept is more to support both sides of the hand and will be bound by the binder to support the hand.

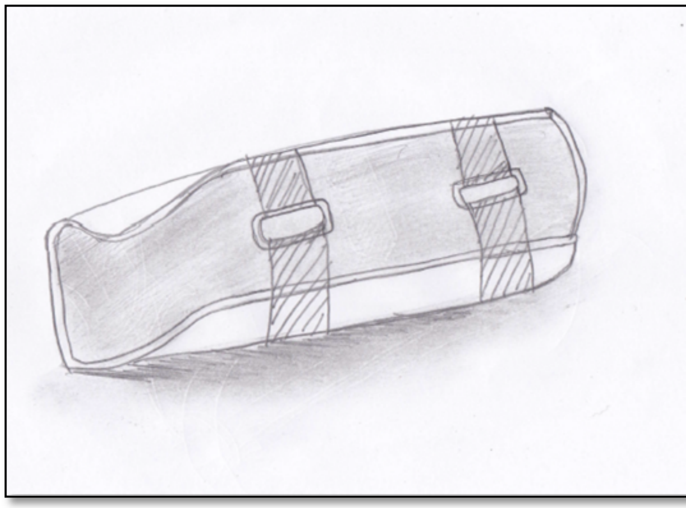


Figure 4.20: Concept 4

Figure 4.20 shows the concept for the completion of the hand and wrist support. This concept is more to support the bottom of the well to expedite the finger.

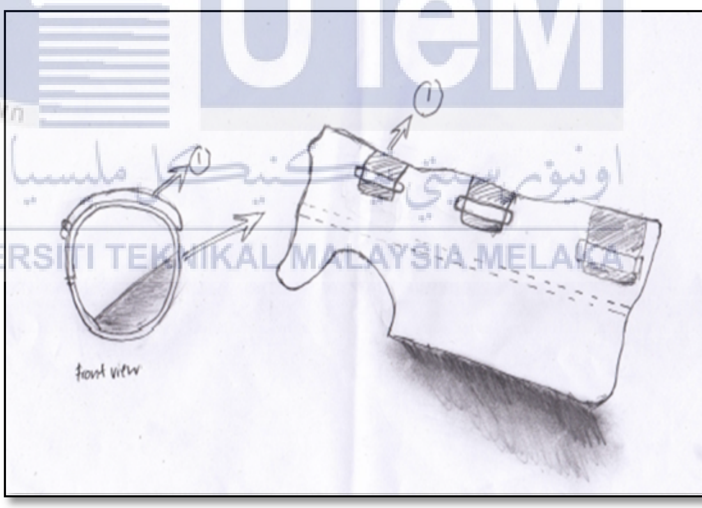


Figure 4.21: Concept 5

Figure 4.21 shows the concept for the completion of the hand and wrist support. This concept is more to cover the surface of the hand and allow the fingers to move while there is also a relaxing hand.

4.4.5 Concept Selection

Concept selection is the process of evaluating concepts with respect to customer needs and other criteria, comparing the relative strengths and weakness of the concepts, and selecting one or more concept for further investigation, testing, or development. Concept selection is an alternative process closely related to concept generation and testing.

The concept selection method used in this project is built around the use of decision matrices for evaluating concept with respect to a set of selection criteria. The concepts are refined and improved by the concept screening and scoring methods. Below is a result about the concept screening and scoring. Table 4.2 show concept screening for hand and wrist support.

4.4.5.1 The Concept Screening.

Table 4.4: Concept Screening

Selection Criteria	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Ergonomic	-	+	-	-	+
Ease to Installation	0	0	0	0	0
Light	+	+	+	+	+
Comfortable	+	++	-	-	+
Not to interfere with the running	0	0	0	0	0
Sum of +	2	4	1	1	3
Sum of 0	2	2	2	2	2
Sum of -	1	0	2	2	0
Net Score	1	4	-1	-1	3
Rank	3	1	4	5	2
Continued	No	Yes	No	No	Yes

4.4.5.2 The concept scoring.

From the data, the concept will redesign and make a final concept before manufacturing process. It for avoid from redesign during manufacturing process. The problem when make a new design is hard to integrate all concepts into one design. Below is a new design after related all concept. Table 4.3 show concept scoring for hand and wrist support. So from the table show that concept 2 need to continue to final concept.

Table 4.5: Concept Scoring

Selection Criteria	**Weight**	**Concept 2**		**Concept 5**	
		Rating	Weighted Score	Rating	Weighted Score
Ergonomic	20%	4	0.8	2	0.4
Ease to Installation	20%	3	0.6	3	0.6
Light	20%	4	0.6	4	0.6
Comfortable	25%	4	1	3	0.75
Not to interfere with the running	15%	4	0.6	4	0.6
Total score		3.6		2.95	
Rank		1		2	
Continue		Yes		No	

4.5 Design Development

Design development is one of the process to get a data. Design development can used reverse engineering to get accurate data so from that can help to redesign a product for improvement.

4.6 Faro arm

Reverse engineering is the most appropriate method to get the original design of a product. As well as to get the shape of human hands, this method is well suited to obtain the original form. There are lots of ways to get original shape and one of them is Faro Arm. Faro Arm this product is portable coordinate machine (CMM) which enables easy measurement quality product manufacturers to perform 3D inspections, tool certifications, CAD comparison, dimensional analysis, reverse engineering, and much more. Figure 4.22 show the apparatus of Faro Arm at lab that used to get data hand shape.

Figure 4.22: Apparatus Faro arm

Figure 4.23 shows the functions that are available in Faro Arm. In this Figure are described for each function makes it easy to understand.

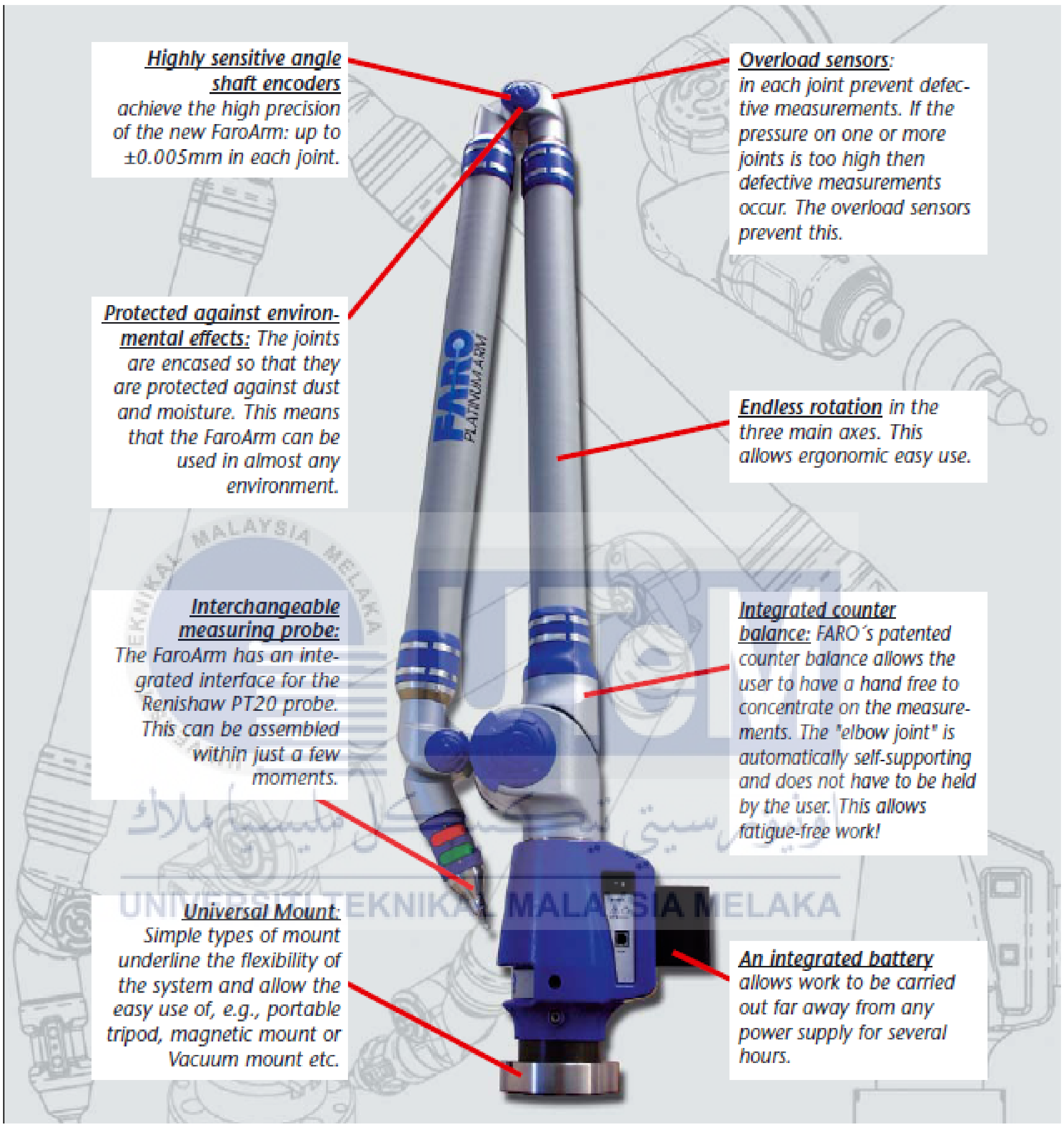


Figure 4.23: Function Faro Arm

4.7 Scanning Procedures

a) Step 1: Get the hand geometry model:

In the first step, to get in shape, hand statue used to obtain the original form of hand for the scanning process. Figure 4.24 show hand statue for scanning process.

Figure 4.24: Hand statue

b) Step 2: The next procedures for the portable CMM Faro Arm are:

Faro Arm calibration. This process is required in order to make sure minimum errors are produced during scanning process. Make sure the green color appear at the calibration box and the 'beep' sound are produced. These two steps should be successfully executed in order to confirm that the calibration is already completed. Figure 4.25 show that apparatus for Faro Arm.

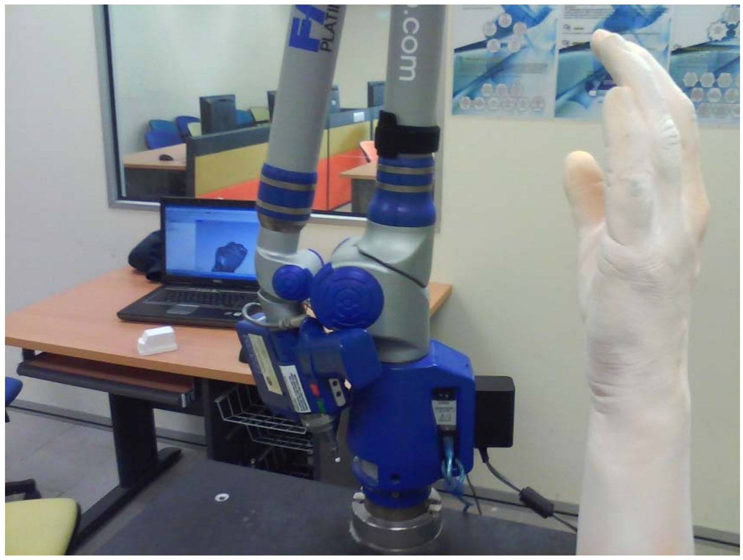


Figure 4.25: Apparatus Faro Arm

c) Step 3: Scan the part:

Scan products using a Faro arm. Make sure the product does not move and the hands do not move to another place until all part of the scan. If moving cause there will be duplication of data. This will cause the product to be scanned does not produce the desired data. Every scanning process, the scanning data will be stored automatically before the final work is done. If there are any defects on the model image while the scanning process, only find the defect file in the storage and delete. Figure 4.26 show that hand statue that used for scanning process

Figure 4.26: Scanning Process

d) Repair and Smooth the Scan data:

After scanning process completed, the next process is repairing and smoothing the surface of the scan data. To repair and smooth process geomagic studio used to obtain smooth surface model. This will help in redesigning the design so as to obtain the desired shape. Figure 4.27 below shows the flow of repair and smooth process.

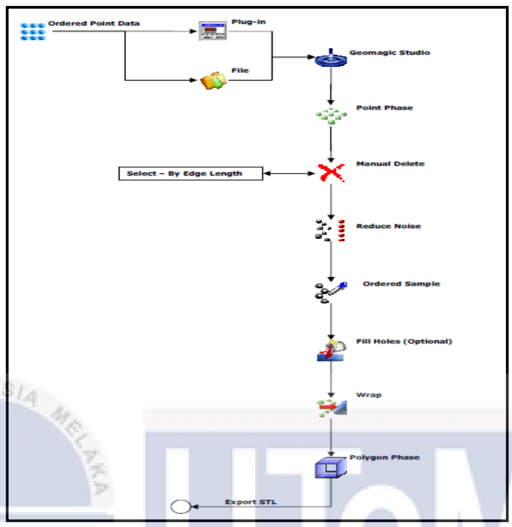


Figure 4.27: Repair and smooth process

4.8 The Improvement Process of CAD Drawing

This section will describe about the process of redesign data obtained from the scanning process. The existing drawing will be updated to improve the geometry before modified as a part of product.

4.8.1 Geomagic Studio 10

Geomagic Studio is a DSSP software platform that enables engineering and design professionals to create accurate digital models from any physical part. Design and manufacturing engineering need to have accurate data for use in further processing. Geomagic Studio is an easy-to-use method to convert 3D scan data into highly accurate dimensions, this is a brilliant solution to generate CAD models for reverse engineering, product design, rapid prototyping and analysis.Figure 4.28 show software for Geomagic Studio 10.

Figure 4.28: Geomagic Studio 10

4.8.2 Improvement Process

Step 1: Open the CAD drawing

Step 2: Fill hole

After the scanning process, there are many holes on the surface caused by the white dot pasted on the model surface during the scanning process before. In this step will be fill the hole. In this step will be run the patching process to covers the hole portion on the surface. The first step is to identify the shape of holes as shown at the Figure 4.29 to facilitate the selection method. Then select the appropriate fill method to done the fill process. After that, click the whole edge on the hole to identify the size of hole and then the hole will be automatically closed. Repeat the process for the other hole until finish.

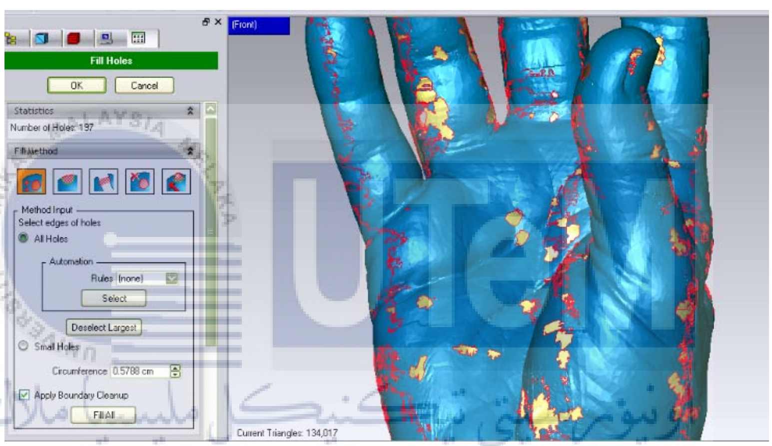


Figure 4.29: Fill hole process

Step 3: Remove the rough surface

The model surface should be leveled by using the sandpaper to get a smooth surface. Click the sand paper icon as shown at Figure 4.30. This process must be done carefully to ensure that the entire surface of the model has been leveled. This rubbing process must be done.

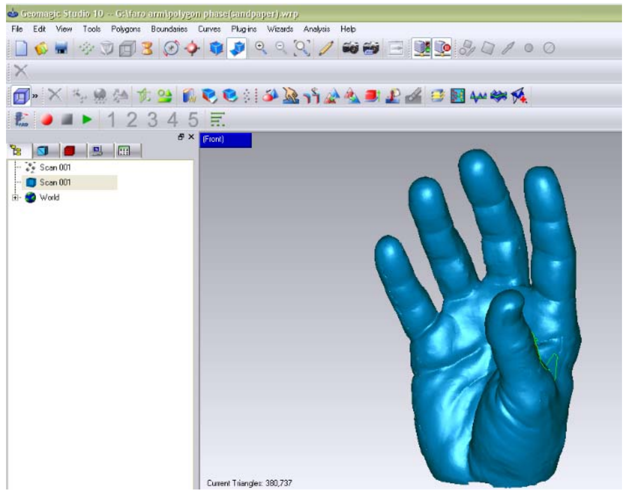


Figure 4.30: Rough surface process

Step 4: Save in STL format

The finished surface model was needs to save in STL format to enable it can be open in other software for the next process improvement.

4.9 Redesign Process

4.9.1 Redesign

In this section will describe in detail about the process of design for hand and wrist support device. The existing drawing from the scanning data will be used as reference to make a new model for hand and wrist support device. The software that will be used to design the model is SolidWork 2013. Figure 4.31 show software SolidWork 2013 that used to make 3D Modelling.

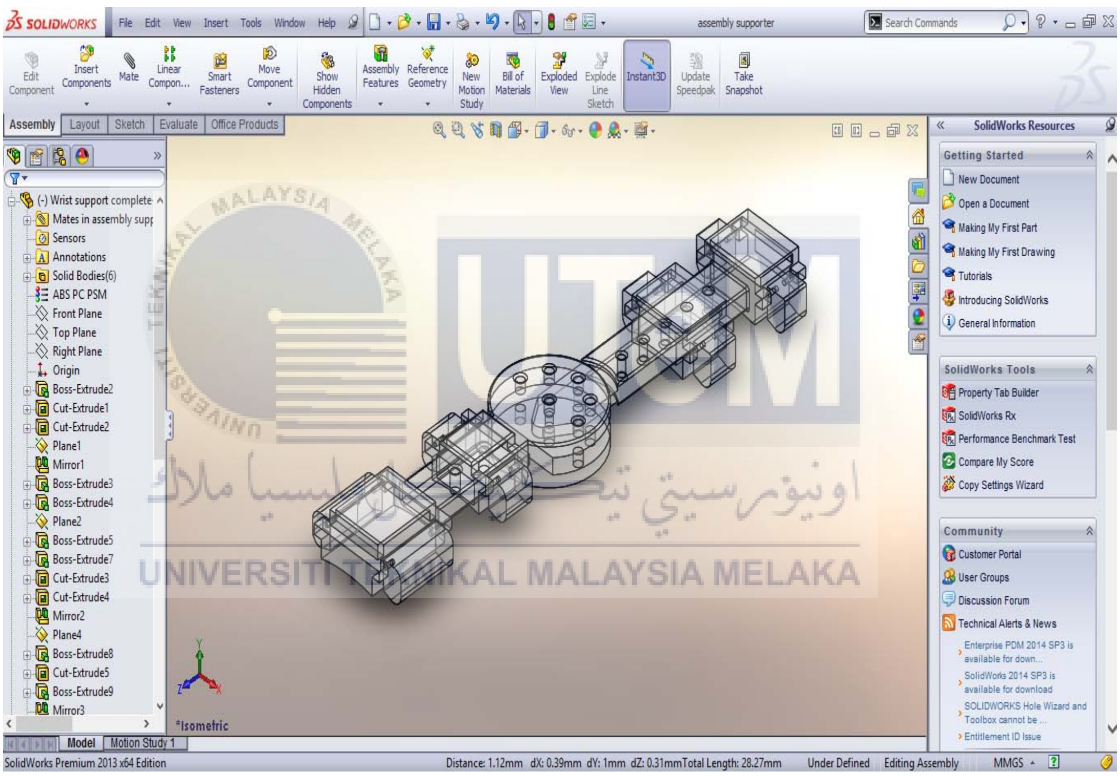


Figure 4.31: Solidwork 2013

4.10 CAD Drawing Model

4.10.1 Supporter wrist

Figure 4.32 show the design model for wrist support device. The information for this part:

a) Part Name: Supporter wrist

b) Material: Plastic ABS

c) Volume: 4.49207e-005 m^3

d) Mass: 48.06 grams

e) Function: To provide traction and support on the thighs to keep the hand and wrist in a straight line during the movement. It will help provide comfort to the wearer, and besides being a supporter on hand.

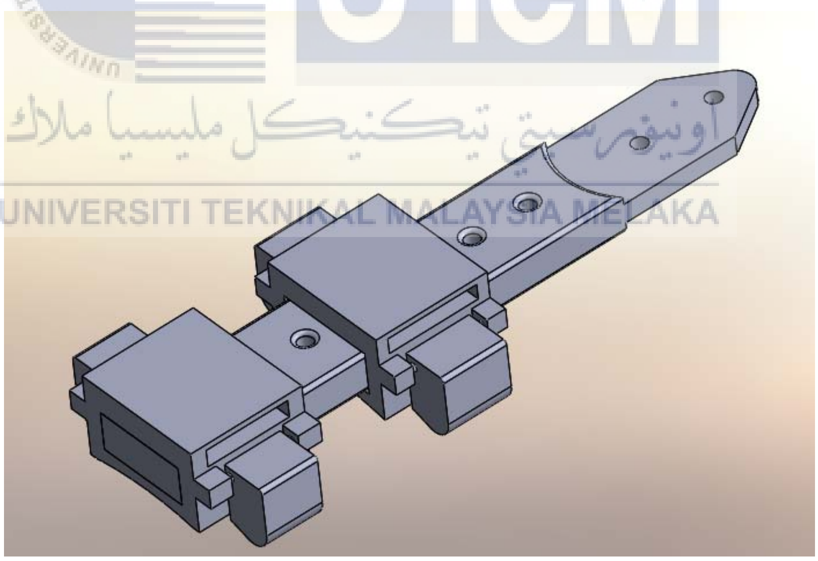


Figure 4.32: Supporter wrist

4.10.2 Supporter Arm

Figure 4.33 show the design model for arm support device. The information for this part:

a) Part Name: Supporter arm

b) Material: Plastic ABS

c) Volume: 7.6862e-005 m^3

d) Mass: 82.24 grams

e) Function: To provide traction and support on the thighs to keep the hand and wrist in a straight line during the movement. It will help provide comfort to the wearer, and besides being a supporter on hand

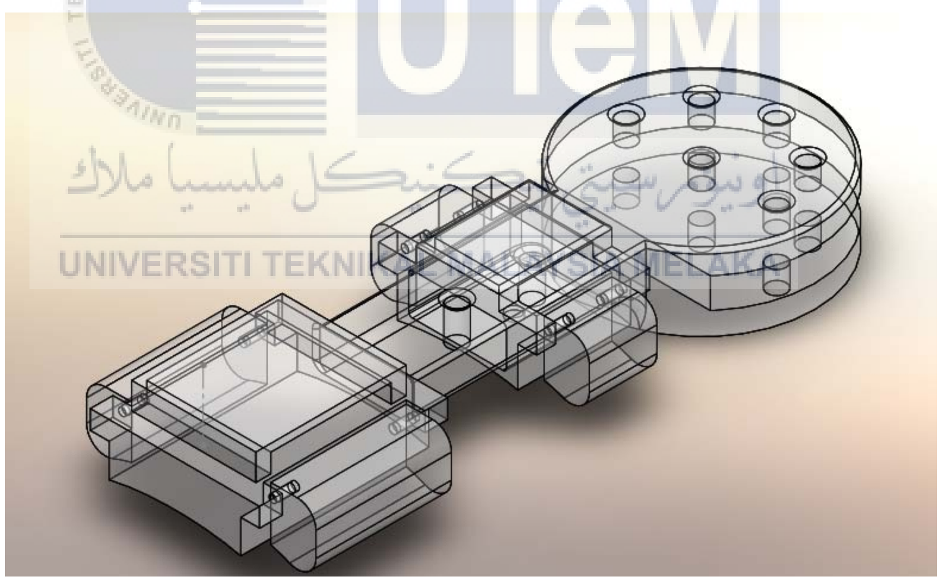


Figure 4.33: Supporter arm

Figure 4.34 and 4.35 show the full assembly design model for hand and wrist support device. It has a pin for connecting two product of arm support and wrist support. Because it is adjustable, stopper need to be used as appropriate and user comfort. It has a sponge to give more comfort to the user.

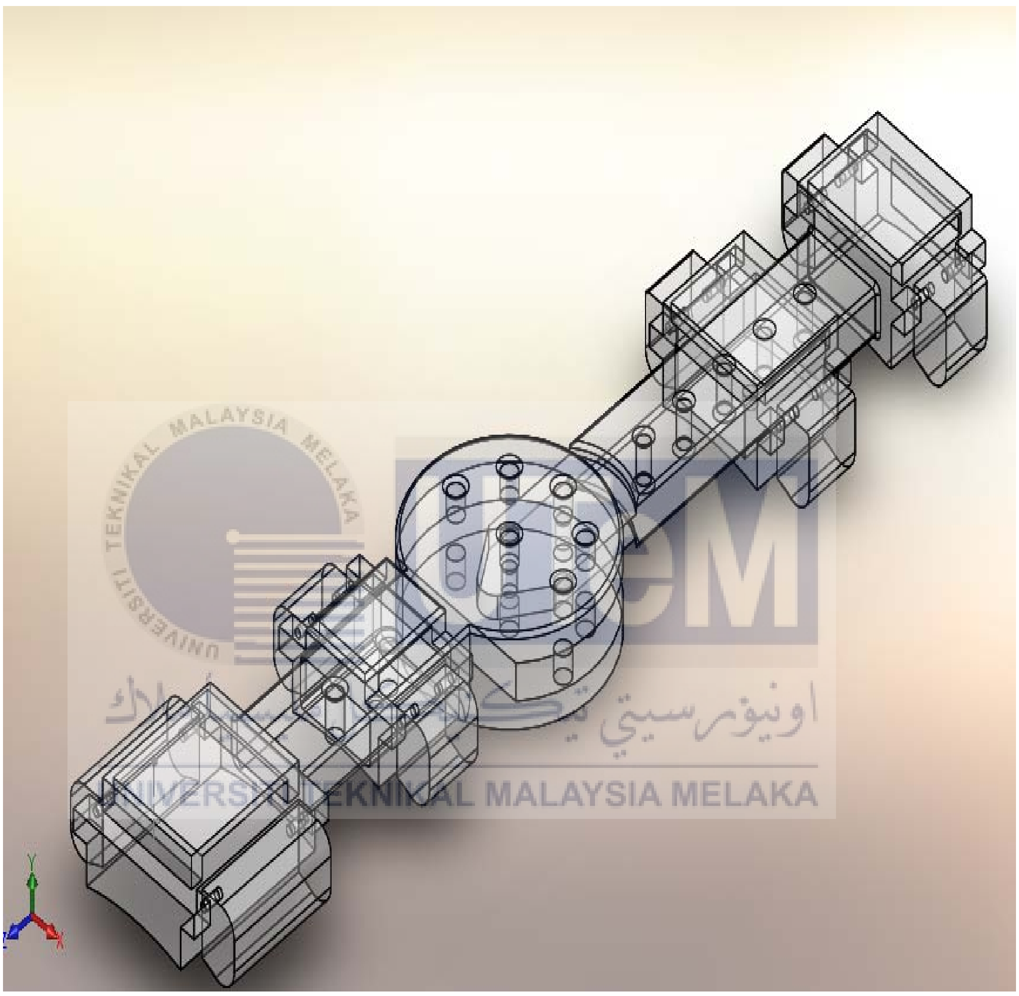


Figure 4.34: Full Assembly

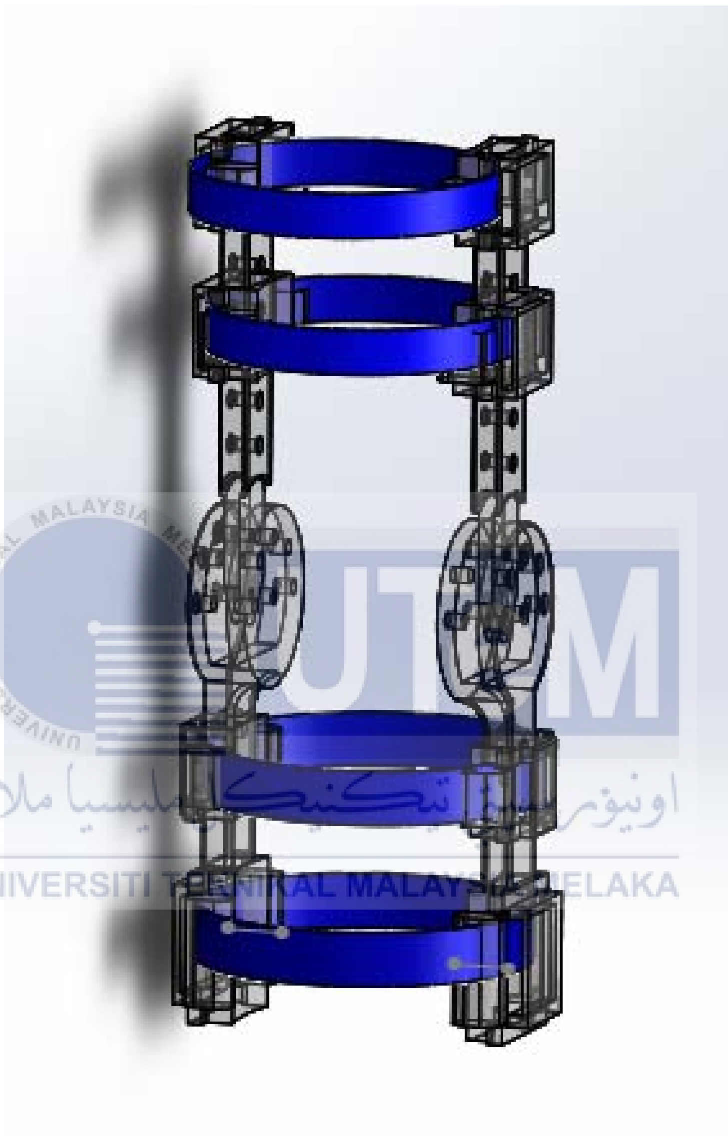


Figure 4.35: Full Assembly

4.11 Detail Drawing

Figure 4.36 and 4.37 show the detail drawing for the supporter-above. The ratio for this drawing is 1:2.

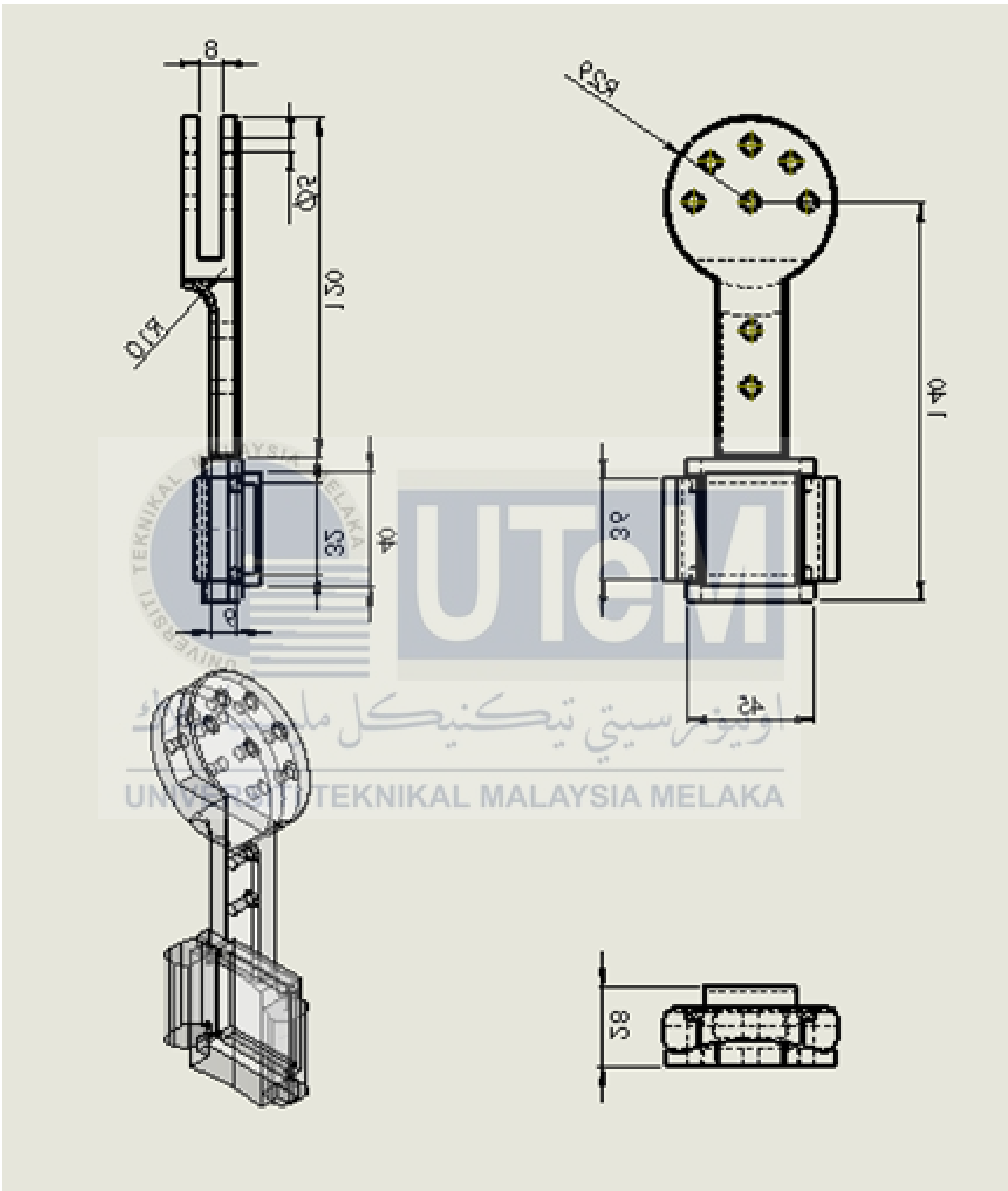


Figure 4.36: Detail Drawing for Arm Support

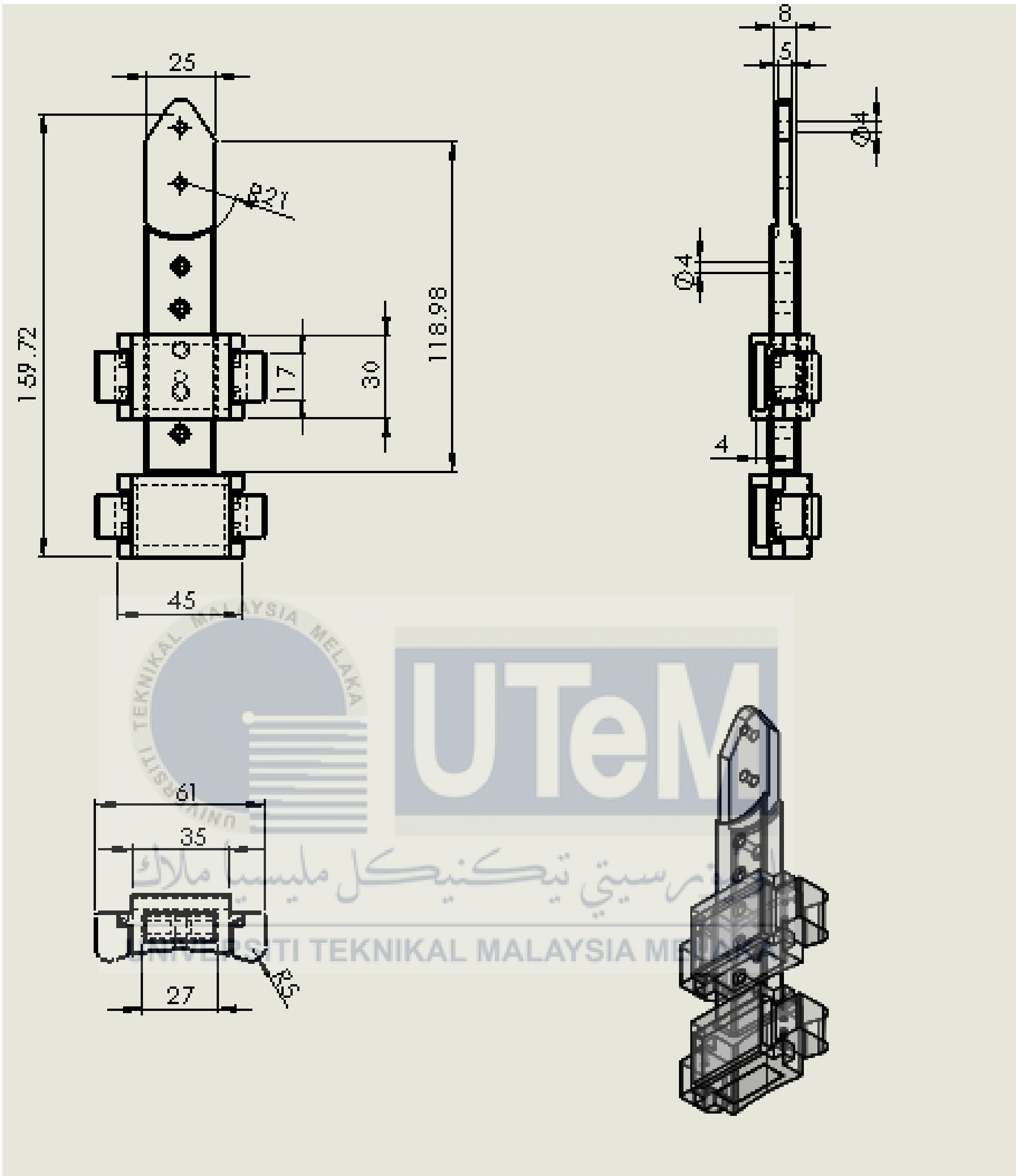


Figure 4.37: Detail Drawing for Wrist Support

4.12 Additive Manufacturing Processes

4.12.1 Convert CAD Data into Stereolithography (STL) Format

The next step, after the drawing was finished editing it will be converted from a CAD file into STL format before transfer into the machine. This format represents a three-dimensional surface as an assembly of planar triangles as facets cut gems. The file contains the coordinates of the vertices and the normal to the outside of each triangle. These STL files are checked for defects like flip triangles, missing facets, overlapping facets, dangling edges or faces etc. and are repaired if found faulty.

At this stage choice of part deposition orientation is the most important factor as part building time, surface quality, amount of support structures, cost etc. are influenced. Once part deposition orientation is decided and slice thickness is selected, tessellated model is sliced and the generated data in standard data formats like SLC (stereolithography contour) or CLI (common layer interface) is stored. This information is used to move to another step to generate physical model. Figure 4.38 and 4.39 shows example of STL file that created by SolidWork 2013 before transfer to FDM machine.

Figure 4.38: Arm support for STL file

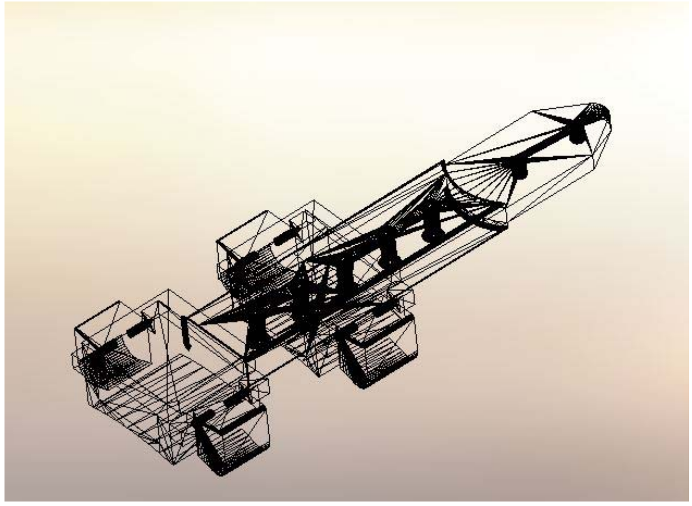


Figure 4.39: Wrist support for STL file

4.12.2 FDM Process

There are several AM technique exist, all employ the same basic five step process. The steps are:

1. Process begins with 3D CAD data. After completion of the drawing using SolidWork 2013 next process is to convert from 3D modeling to STL file. Figure 4.40 show example 3D Modelling before transfer to STL file.

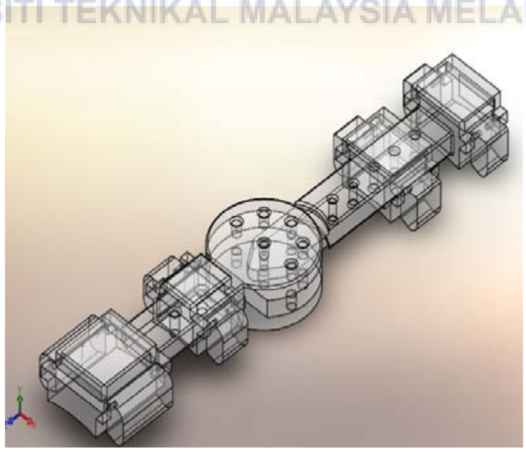


Figure 4.40: 3D Modelling before transfer to STL file

3. STL data is “sliced” with software. After the data should be stored in a STL file to make it easier to be sent to the FDM machine. Figure 4.41 show software that used before produce product using FDM machine.

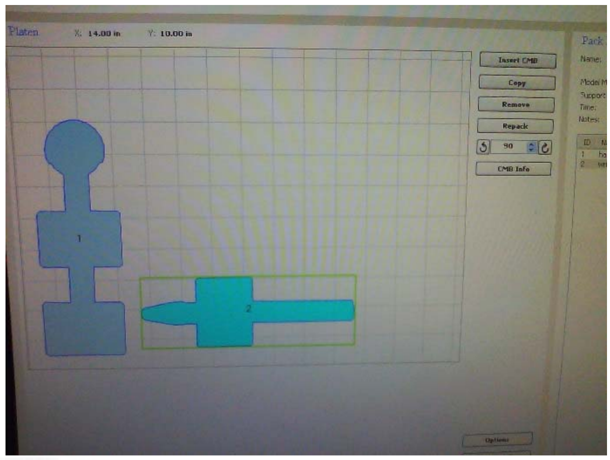


Figure 4.41: Software FDM before transfer to FDM Machine.

3. Dual heated nozzles trace each cross section, depositing thermoplastic material. Figure 4.42 shows the block diagram of the FDM machine found in the machine. Machine will initially be heated before the process of producing the product run.

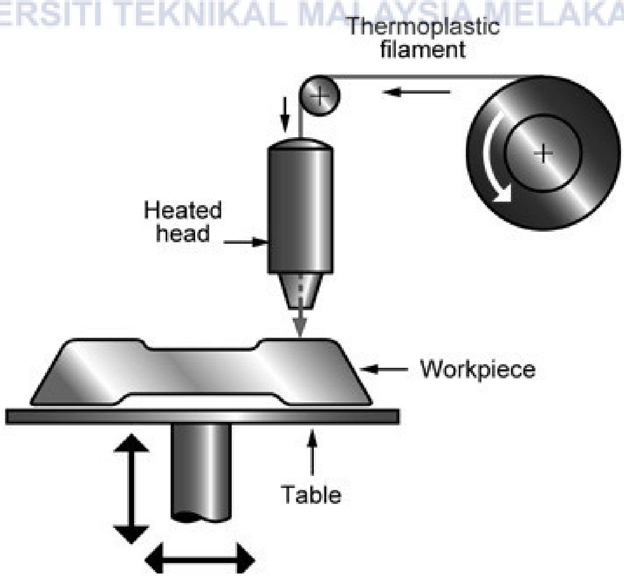


Figure 4.42: Block diagram of the FDM machine.

4. When a cross-section is complete, the build is slightly lowered and the process continues. Figure 4.43 show final product that build by FDM machine.

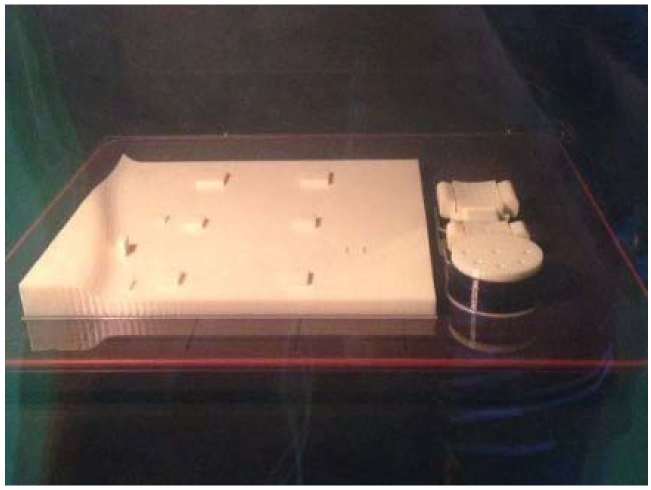


Figure 4.43: Final Product

5. Completed parts are removed and support material is cleaned off. Products that have been created by the FDM machine shall be placed or immersed in the ultrasonic tank to remove the supporter is in the finished product. Figure 4.4 show that ultrasonic tank that used to clean of support material.

Figure 4.44: Ultrasonic tank

4.13 Testing and Analysis

This section discusses in detail the simulated stress analysis is used to model the hand and wrist support. For this analysis, carried out on the two-part analysis of the hand and arm. This analysis was carried out using simulations in software SolidWork 2013. Based on Figure 4.45 shows that the fields marked in red are areas of high pressure and structural material to the area to be changed if a higher power is applied to the product. Applied load of 20 N is applied during analysis. Based on the parameters specified as shown in Figure 4:45 the lowest safety factor (FOS), which is available in designs is 7 that the value is higher than 1. If the value is lower than 1, the design is not safe. So the design is not necessary for safe use of products as well as high load imposed.

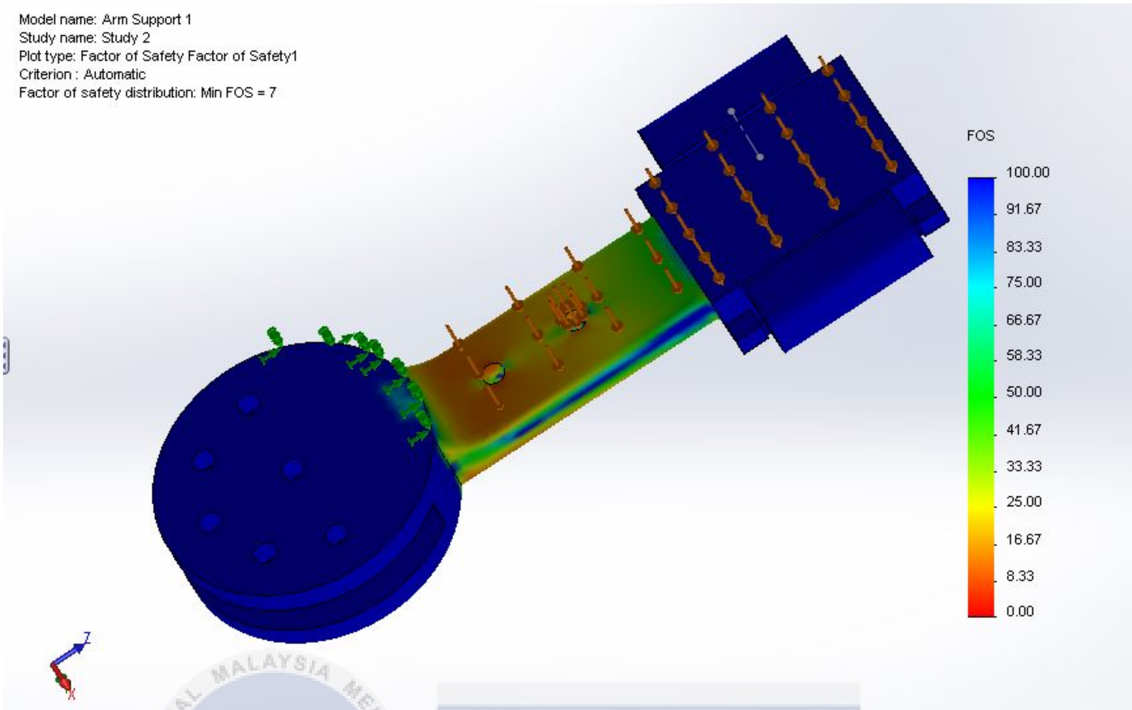


Figure 4.45: Factor of safety for arm support.

Based on Figure 4:46 shows that there are no fields marked in red, indicating that this design can accept a greater power. Load of 20 N is applied during analysis. Static analysis is used to determine the appropriate form with the load applied. Based on the parameters specified the lowest safety factor (FOS), which is available in design is 20 that the value is higher than 1. The design, fewer parts are red due to the relatively thick design in terms of thickness.

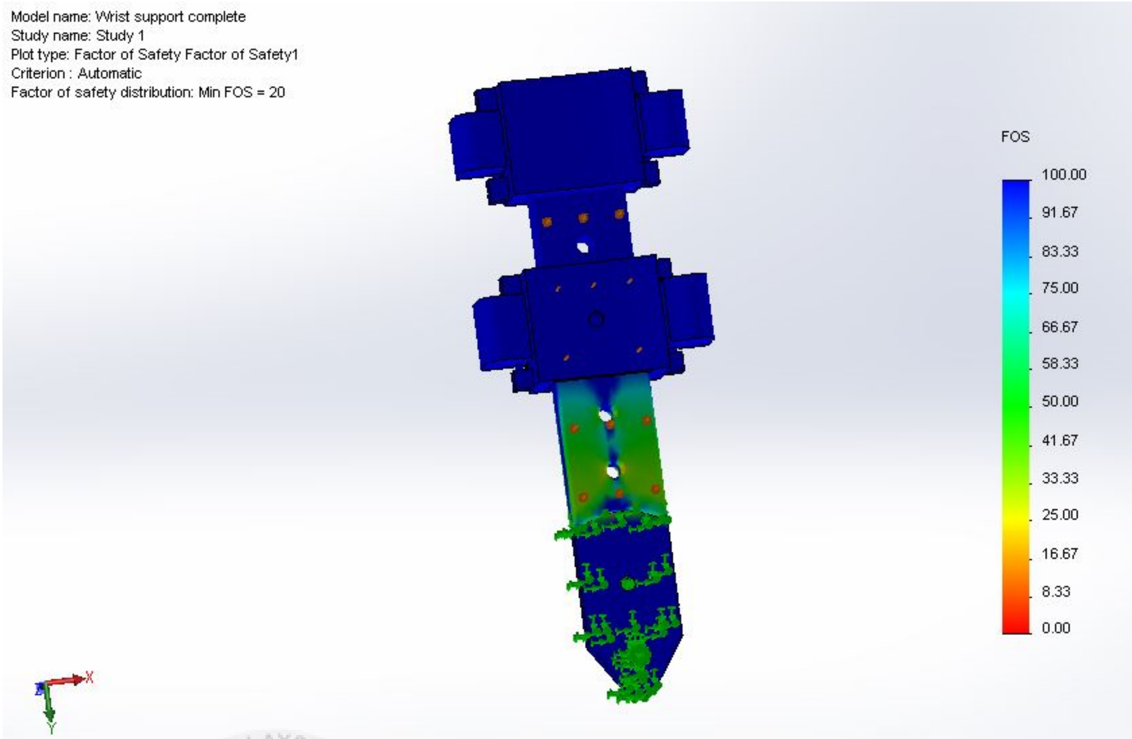


Figure 4.46: Factor of safety for wrist support

4.14 Material Properties

The nature of the material is important information during the selection of materials. Based on the information material properties shown in Table 4.4 can know what the impact on the performance and suitability of the products are designed based on the functions and usage. ABS plastic is used to make hand and wrist support, as the ABS plastic used in the FDM machine for producing prototypes.

Table 4.6: Material properties for ABS plastic

Property	Value	Units
Elastic Modulus	2410000000	N/m^2
Poisons Ratio	0.3897	N/A
Shear Modulus	862200000	N/m^2
Density	1070	Kg/m^3
Tensile Strength	40000000	N/m^2
Thermal Conductivity	0.2618	W/(m.K)
Specific Heat	1900	J/(kg.K)

4.15 Summary

This chapter describes all sequences to develop a prototype device the hand and wrist. There are many processes that need to be done as the scanning process, process improvement, process design, process RP, and process analysis. Scanning process using Faro arm is used because this process is better than the Optical Scanner. Then the next step is to use Geomagic Studio reverse engineering to correct imperfect after the Faro arm. SolidWork 2013 software used to design products in 3D modeling.

After that, the detail drawing process can come out to obtain dimension for manufacturing process later. This software can also help in getting the factor of safety using simulation software in SolidWork 2013. Every process is continuous with the other as to get a better product. Because the products are quite complex FDM machine used to get a good product for its ability to produce complex products and FDM machine more suitable and better. The next process is the finishing by adding the appropriate equipment such as a sponge to get the product for a better product. Below is a more detailed discussion about this product.

a) Reverse Engineering

The proposed approach how to get an accurate reading for the human hand , the first suggestion is to use wax as a mold to make a hand mold . The second is to provide a hand model clay mold . However, because of first aid statue so used hand statue to get a data for reverse engineering.

Actually wanted to use Optical scanner but due to optical scanners have technical problem so this Faro Arm machine is used as a high-tech machine that can provide quick and accurate readings during the scan. However there is a drawback when using the Faro arm, where it can not give an accurate reading when the object moves or vibrates. So hand statue used need to be tied up neatly to ensure the product does not move .

This is because the laser emitted able to read at an opaque object and when the object is moving or vibrating. It will cause duplication of sketches on the drawing. Hand staue can not be touched because it will affect the reading. Due to the high statue hand it difficult to get the data. This causes the surface of the finger does not get good data. But by using geomagic rough surface and perforated resolved.

b) Drawing Process

During the drawing process using solid work 2013 there are some problems that happen because when want to produce the best design it need a few process before comeout a final design. Before drawing produced using solid work, sketching need to do to give a clearer picture before drawing. Concept screening and scoring is used to make it easier to finalize the final drawing. It need several times to be redesigned because the form does not match the size of the other hand and it is not flexible.

c) Test and Analysis

For test and analysis process, solidwork used to get factors of safety. Good factor of safety is greater than 1 and factor of safety in poor and in need of redesign is less than 1. Become analysis methods, analyze only static. Initially factor of safety that made less and to get a good factor of safety of the design made with bold structure to strengthen. as much as 20 N is applied to the product for testing structural strength hand and wrist support.

d) Manufacturing Process

Manufacturing process is quite important in achieving the objectives of the hand and wrist support. for these products is to use the FDM machine. This is an important process before manufacturing process is the design process because if the design is not good and not according to the specifications of the products out continues to be a waste. FDM machine process takes a long time, almost 5 hours to complete this product. It using plastic abs to complete the product. It is capable of producing a complex and able to produce a good finish product. The original design out product should be adjustable but the product out from the machine is fix.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, the technique of RE and the AM is a process that can be used during the development process of the hand and wrist support device. AM is the best method to produce complex models and consumer products fit. This is because the AM can help to improve people's lives and to facilitate the work of human beings, particularly in the manufacturing sector. In addition it requiring little space it is quite useful in producing the product. This process speeds production time because they do not involve a lot of processes such as turning, welding and so on. it only needs to complete the drawing and converts in STL file and then transfer into the machine. after completion of the manufacturing process of this product should be immersed in the ultrasonic.

In addition, Reverse Engineering (RE) methods have been used to develop a product without complete data or from existing products. In UTeM have two machines that have the ability to reverse engineer the optical scanner and Faro arm. for hand and wrist support, Faro arm applied using data from the hand statue. Before starting the scanning process should dispray hand statue with Magnaflux Spotcheck Developer.Adding more than a thin coat of developer impact cans a part's thickness

When scanning.The thinner coating, will get the better the data. Prototypes of hand and wrist support device was successfully performed using both FDM and material products have been tested to evaluate their performance. It took almost 5 hours to complete both of these products. With the ability to produce complex products it has become the primary choice other than using ABS plastic material as the main material in producing the product.

Testing and analysis to support the hand and wrist was performed using the simulation analysis software SolidWork 2013. From the analysis, design, hand and wrist support device is safe to use based on the FOS provided. Design had to be changed to achieve the good FOS which is more than 1. Accordingly, AM process is better than the normal process in the production of hand and wrist support device for reducing the number of processes, time and costs and then to maximize product quality and ergonomic improvements.

5.2 Recommendation

Once the AM to develop these products is using selective laser sintering (SLS). This is because, the final product has been produced from the SLS machine is very tough, good tensile strength and surface roughness better than the final product of FDM and 3D printers. In addition, product will be used for the actual experiments to determine the different between the experimental and the actual product. Besides that good data can be improved by getting data from patients that used existing product. This is because the product is suitable for patients for recovery hand injury. The need for reduction of bureaucratic rules, to facilitate and getting better data.