UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Bone Scaffold Design Selection by Using Analytical Hierarchy Process (AHP)

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

by

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DECLARATION

I hereby, declared this report entitled “Bone Scaffold Design Selection by Using Analytical Hierarchy Process (AHP) Tool” is the results of my own research except as cited in references.

Signature	:	………………………………………….
Author’s Name	:	…………………………………………
Date	:	…………………………………………

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Design) (Hons.). The member of the supervisory is as follow:

………………………………

(Dr Shajahan bin Maidin)

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ABSTRAK

Perancah tulang (Bone scaffold) digunakan untuk menggantikan tisu rosak sewaktu tulang di badan manusia patah. Sebab yang mengakibatkan tulang patah adalah daripada daya terkejut yang mengenakan pada bahagian tulang atau daripada penyakit tulang, osteoporosis. Oleh demikian, perancah tulang diperlukan untuk menyediakan keselesaan kepada pesakit and menggantikan implan tulang yang traditional. Objektif untuk projek ini adalah mempelajari aplikasi *Additive Manufacturing (AM)* dan reka bentuk perancah tulang dalam aplikasi perubatan. Tambahan pula, bahan yang digunakan untuk aplikasi ini juga membuat perbandingan antara satu sama lain. Terdapat empat reka bentuk yang dicadangkan dan simulasi dijalankan untuk ujian pemampatan dan ujian kilasan. Reka bentuk untuk perencah tulang direka menggunakan perisian CAD. Untuk mendapatkan reka bnetuk perencah tulang yang terbaik, *Analytical Hierarchy Process (AHP)* digunakan untuk membantu proses pemilihan. Berdasarkan analisis perbandingan, keputusan didapati adalah Rekabentuk 1 dijadikan sebagai reka bentuk yang terbaik. Ini disebabkan corak oleh blok yang susunan teratur dan telah menjadikan perencah tulang reka bentuk 1 sebagai perencah tulang yang mendapat kekuatan yang tertinggi berbanding dengan perencah tulang yang lain. Tambahan pula, terdapat tiga jenis bahan yang dicadangkan iaitu: Alumina Bio-ceramic, Bio-active Glasses and Calcium Phosphate Bio-ceramic. Analisis perbandingan merujukan Alumina Bio-ceramic adalah bahan yang terbaik kerana ia mempunyai kekuatan yang paling tinggi (dapat mengekalkan daya yang dikenakan dan juga memenuhi keutamaan yang ditetapkan sebagai tujuan utama. Manakala, bahan ini adalah yang paling mahal antara bahan yang dicadangkan. Kesimpulannya, semua objektif dicapaikan.

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ABSTRACT

Bone scaffold is used to aid the regenerative of human organ tissues that causes bone fracture. Bone fracture is normally caused by the exertion of exceeding force to the bone that can't be borne or bone disease such as osteoporosis. Hence, the use of bone scaffold is needed to provide comfort to the patient and to slowly replace the metal plate for bone implants. Since there are demands in the market for an effective bone scaffold design, the objective of this project is to study about the application of additive manufacturing (AM) and bone scaffold design in medical application as well as to compare the effectiveness of several materials for its application. Four design of bone scaffolds had been proposed and simulated for compression test and torsional test. The four different designs of bone structural was designed using a CAD software. In order to select the best bone scaffold design, Analytical Hierarchy Process (AHP) was used as the method to aid the selection process. Based on comparative analysis, it was found that Design 1 was the best design. This was mainly due to the orderly design arrangement that permits higher strength compared to other arrangement of the design of bone scaffold. Furthermore, this project compares three different types of materials namely Alumina Bio-ceramic, Bio-active Glasses and Calcium Phosphate Bio-ceramic. The comparative analysis shows that the best material is Alumina Bio-ceramic. This material has the highest strength compared with other materials due to its capability to sustain the force exerted on it and hence fulfil the priority of setting the strength as the main rating purpose. However, this material is the most expensive material compared to other two materials. In conclusion, all of the objectives are achieved.

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DEDICATION

This project is dedicated to

My beloved parents

Dearest Siblings

Honourable Supervisor, Panels and other lecturers

Loyal friends

My prayer upon You will be embedded in my heart wherever I go and whenever I go and whenever I think of You

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Last but not least, I would like to give my thanks to the support from my parents as well as my beloved family. They always give me the mentally encouragement to complete this project entirely and I will always feel grateful that I having them as my family.

Thank You

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CHAPTER 1

INTRODUCTION

This chapter will introduce the core of the study, Additive Manufacturing (AM) and the product to be designed, Scaffold. The problem statement, objective and scope also will be discussed in this chapter.

1.1 Background

Additive manufacturing (AM) which defined by the American Society for Testing and Materials (ASTM) is the process of making objects from 3D model data by joining the materials layer by layer. It is opposed to subtractive manufacturing technologies, such as traditional machining. The application of the AM have functional models, direct part production, fit and assembly, pattern and prototype, visual aids and others. Application of AM help to enable the final product are geometrical freedom and multiple material combination. The geometrical freedom included design complexity, parts consolidation, part customization and multiple assemblies.

The medical device is one of the application of the AM and this field already become a leader in the use of AM. In year 2012, medical application accounted 16.4% of the overall revenue from the AM market (Snyder, Cotteleer, & Kotek, 3D Oppoturnity in Medical Technology, 2014). Medical devices such as hearing aids, dental crowns and surgical implants are small in size and hence it is suitable to use the AM technology to

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customize the parts. In the term, AM had accelerate the product development, offer design freedom, optimizes part structures and allows for a high degree of functional integration.

Scaffold (as shown in Figure 1.1), is one of the application in Additive Manufacturing (AM) has introduced to help to regenerate the tissue and bone, including limbs and organs (Salgado, Coutinho, & Reis, 2004). The scaffold is a three dimensional structure composed of polymer fibers. The scaffold is inserted and grip with the damaged cells and begin to rebuild the missing bone and tissue through the tiny holes. As the bone and tissue generate, the scaffold is absorbed into the body and disappears completely. The design of the scaffold basically is complex in geometry and customize. Hence, the manufactured of scaffold depend on the Additive Manufacturing (AM) and the production rate is low.

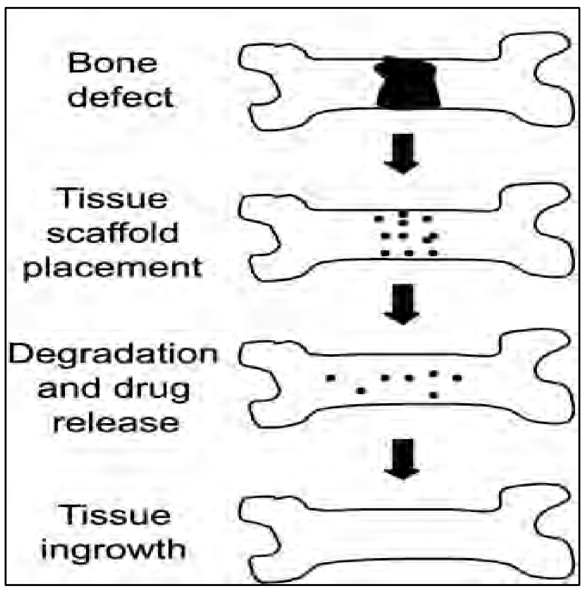

Figure 1.1: Biodegradable, polymeric scaffold

(Retrieved September 17, 2015, from http://link.springer.com/chapter/10.1007%2Fb137205)

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1.2 Problem Statement

A lot of people will have problem with their bones. It could be due to disease, injury due to accident, or as well as bone defects since we are born. The fracture usually will heal itself for a minor defect problem but it is difficult for the major defect. Usually, some implantation process need to carry out for major problem. Since there are demands in the bone implantation, there will be market demand for the bon scaffold. There are variety of design of bone scaffold available in the market with wide range of properties and price. In this project, four different designs of bone scaffold will be proposed with different geometrical shape and material. By understanding and undergoing necessary simulation, the best scaffold design with the most advantage in helping the tissue regenerative process will be determined. The design that chosen must be good quality in term of the strength that can sustain the force and pressure that exerted by the patient during daily activities.

1.3 Objectives

The objectives of this project as below:

1) To study about the Additive Manufacturing (AM) and bone scaffold design in medical application.
2) To design four different structural form of bone scaffold to aid the tissue regenerative process using CAD software.
3) To run the compression and torsional simulation by correlate the design of the bone scaffold and the selected bio-material.
4) To use the Analytical Hierarchy Process (AHP) Tool to select the best bone scaffold design and material.

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1.4 Scope

This project, is about the design selection of bone scaffold. The design of bone scaffold was done with a CAD software (CATIA). Few aspects was considered while designing the scaffold such as the patient’s body part that the scaffold to be inserted, Achilles tendon (lower body part) and the body weight of the patient is set as 50kg. After the design process was done, the simulation was run to analyze are compression and torsional test. The simulation system used in this project was ANSYS system.

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CHAPTER 2

LITERATURE REVIEW

This chapter discuss about the reference that we used to refer for further research. The reference may be in the form of books, journal, articles and conference paper. The major topic that we discuss in this chapter have Additive Manufacturing (AM), Additive Manufacturing in Medical Field (implants), Human Bone Structure and Scaffold.

2.1 Additive Manufacturing (AM)

AM is defined by ASTM as the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing technologies (Harris & Director, 2011). According to Gibson, Rosen, & Stucker (2010), the basic principle of this technology is that the drawing initially produced using three dimensional Computer Aided Design (3D CAD) system and fabricated directly from CAD data without process planning. Bourhis et al., (2014) had mentioned that the AM technologies nowadays allow us to fabricate products that in high added value and this process called as "clean" processes as this process only apply the precise amount of stuff. In summation, the energy consumption also limited when compared with the machining procedure. In fact, AM is a process which can instantly obtain the functional part from CAD model with only one manufacturing step. Meanwhile, the machining process needs to consider few step of manufacturing step to complete the fabrication of a product.

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2.1.1 Process flow of AM

Based on the Figure 2.1, the AM process begins with the foundation of the three-dimensional (3D) model through the utilization of computer-aided design (CAD) software such as SolidWork, AutoCAD and CATIA. To fix the drawing that draw triangulated representation of the mannequin, the CAD-based 3D model, then requires to be saved as standard tessellation language (. STL) file. The draft that is drawn need to arrive at some simulation analysis to assure the model that will be produced is compatible with the parameter properties.

Side by side, the draft from the STL file which in CAD based will sent to the AM device. In this process, the software will slides the data file into individual layers, which are sent as instructions to the AM device. The drawing will support the generation which is auto built by the system itself. At that time, the AM device started to operate and creates the model by adding the material on top from one to another top until the object is the buildup. Once the model created, there is needed the process of cleanup and post curing to clean the surface of the model created. There are forms of finishing activities may be required, which, depending on the material used and complexity of the wares. Some of the parts of the object may require the secondary processing which include sanding, filing, polishing, material fill or painting.

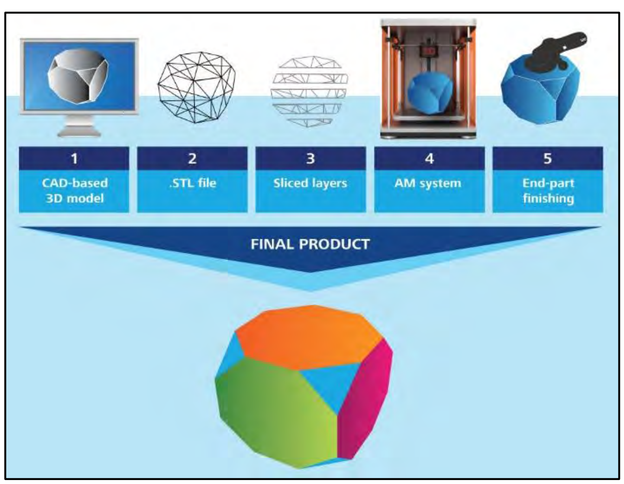

Figure 2.1: Basic process flow of AM

(Cotteleer, Holdowsky, & Mahto, 2013)

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2.1.2 Methods of AM

According to the Figure 2.2, we can conclude that there are three layers distributed under Additive Manufacturing (AM): AM Category, process type and material type. Basically, AM are divided into 4 categories which are powder bed processes, material deposition processes, 3D printing and liquid. In the figure, different colors represent the different categories. Few types of processes and material that can be used for the particular groups are grouped under these categories. In this sub chapter, we are discuss only four of the process type under different categories.

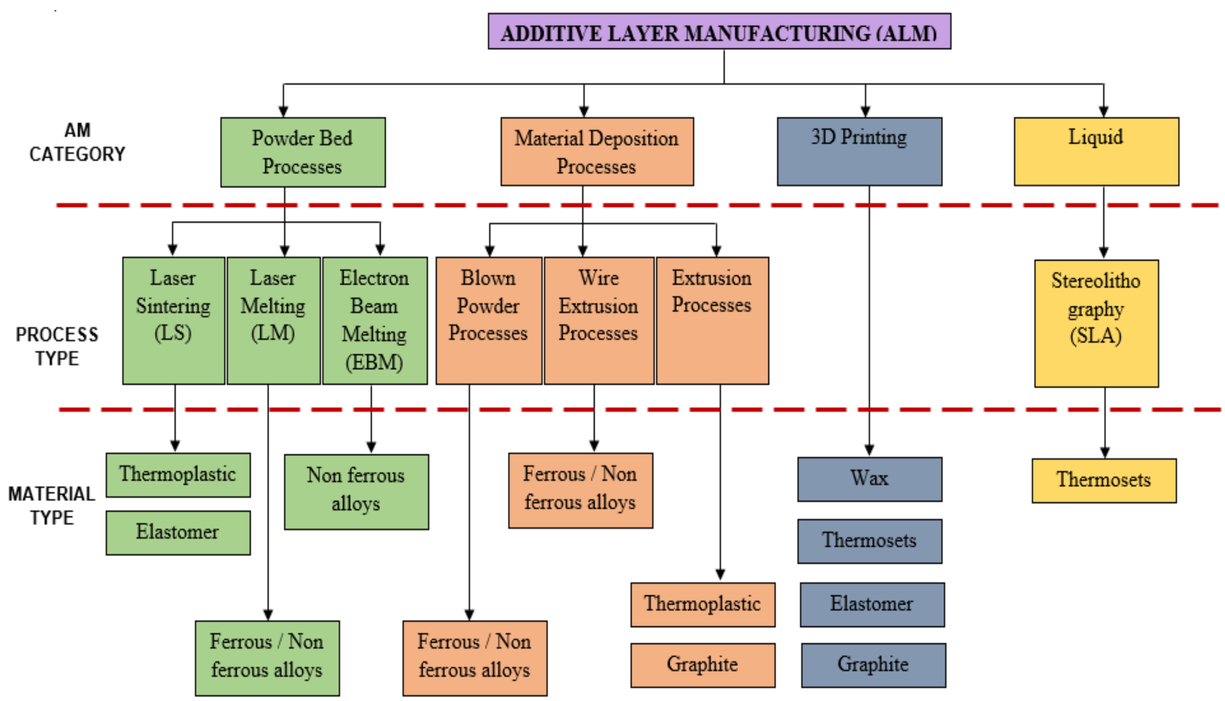

Figure 2.2: AM System Classifications

(Retrieved September 27, 2014, from http://amcrc.com.au/wp-content/uploads/2013/03/ADDITIVE-MANUFACTURING-CATEGORIES-PROCESSES.pdf)

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2.1.2.1 Stereolithography (SLA)

Stereolithography also known as laser lithography, which this approach is the most popular AM technologies among others (Bartolo & Gibson, 2011). Lithography emphasizes on the art of reproduction of graphics objects and includes different techniques, example of photographic reproduction, photo sculpture, xerography and Microlithography. On the other hand, the modern type of photolithography AM system has tackled the theory of the computer generated graphics mixed with photosensitive materials to endorse the 3D products. The initial project of modern AM systems was presented by a patent of the system which the phase change of material (photochemical cross-linking or degrading a polymer) by the intersection of two radiation beam and form a 3D object. This essential feature called photochemical machining (as shown in Figure 2.3).

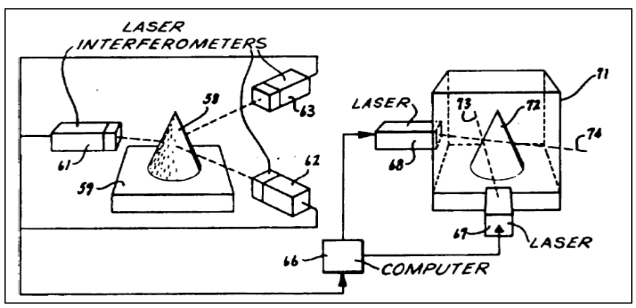

Figure 2.3: Photochemical Machining Process
(Retrieved September 27, 2014, from
http://osp.mans.edu.eg/shazem/NTM/NonTraditionalMachining.html)

With the tradition of photolithography idea, Hull had recovered an idea of modern stereolithography. The 3D object is formed through the solidification of material upon the layering process when the exposure to the ultraviolet (UV) radiation. The non-transformed layers typically stick to the previously formed layers through the natural adhesive properties of the photosensitive polymer upon solidification. In addition, Hull also conceives another stereolithography strategy which the physical object is pulled up from the liquid resin and to the liquid photopolymeric system. The radiation passes through a UV transparent window.

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