UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE DEVELOPMENT OF SCAFFOLD DESIGN SELECTION SYSTEM

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

By

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2013

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **The Development of Scaffold Design Selection System**

SESI PENGAJIAN: 2012/13 Semester 2

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APPROVAL

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

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(DR. SHAJAHAN BIN MAIDIN)

ABSTRAK

Kecacatan Ostheochondral adalah luka di atas rawan artikular yang berlaku disebabkan oleh lutut yang terseliuh atau daripada hentakan secara tiba-tiba pada lutut semasa aktiviti sukan. Oleh kerana rawatan untuk jenis kecederaan yang menggantikan rawan artikular dengan aloi Titanium ini mempunyai terlalu banyak kelemahan telah menyebabkan para penyelidik untuk membangunkan rawatan alternatif. Walau bagaimanapun, terdapat terlalu banyak reka bentuk Scaffold dan pengguna tidak jelas mengenai apa jenis reka bentuk yang sesuai dan yang terbaik. Oleh itu, hasil daripada konflik ini, satu program untuk membantu dalam menentukan reka bentuk telah dibangunkan dengan menggunakan program pengaturcaraan asas iaitu Microsoft Visual Basic,.Scaffold, yang diperlukan untuk mempunyai struktur berliang, telah direka dengan bantuan Solidworks. Dengan menggunakan contoh daripada empat rekabentuk yang ringkas, program ini akan sepadankan keadaan kesihatan dan gaya hidup pesakit dengan reka bentuk yang dikira akan sesuai berdasarkan pengesahan yang dibuat di dalam program ini. Walau bagaimanapun, disebabkan banyak kelemahan yang dijumpai semasa proses pembuatan program ini, aspek seperti menggunakan program pengaturcaraan berasaskan web dan analisis yang betul telah dicadangkan untuk penambahbaikan bagi kajian masa akan datang.

ABSTRACT

Ostheochondral defects are a lesion on the articular cartilage which happened due to severe twisted knee or a sudden direct impact on the knee during sporting activities. Since, the treatments for this type of injuries which is replacing the articular cartilage with Titanium Alloy has too many disadvantages had caused the researchers to develop alternative treatment of scaffolding application. However, as the result, there were too many scaffold designs without a clear conscious on what kind of design suits the best. Therefore, as a result from this conflict, a program to assist in determining the design has been developed by using Microsoft Visual Basic programming tools. Scaffolds, which are required to have porous structure, were designed with the aid of Solidworks. By using examples of four simple scaffolds, this program will match the health condition and lifestyle of the patient with the design that is calculated to be fitting based on the clarification made in the program. However, due to many flaws found during the development, areas such as using a web based programming tools and proper analysis have been suggested for future study improvements.

DEDICATION

Dedicated to me beloved mother

Dearest siblings

Honourable lecturers

Loyal friends

My prayers upon you will be embedded in my heart wherever I go and whenever I think of you

ACKNOWLEDGEMENT

Alhamdullilah, for I am grateful to ALLAH S.W.T for giving me enough strength and courage to finally finish up this final year project and its report. For without the help He has given along with His permission, all may not have been completed.

With a sincere heart, I would like to thank to my dear supervisor, Dr. Shajahan Bin Maidin with all his guidance and commitment in guiding and supporting me in completing this study. Dr. Shajahan has given me a lot of innovative ideas in solving all the obstacles which rises. Once again I would like to thank him for all the comments and amendments he has given me with his patience towards my deficiency.

I also would like to express my greatest gratitude for my entire classmate especially Wan Nasuha W Malek and Nor Ashraf Muhtar for their assistance, and to those who have been helping directly or indirectly in completing this final year project as well as its report. All of my hard work will meant nothing without the inspirational and motivational from all of them.

And lastly, I would like to give my thanks to the patience and the support from my mother, Sarimah Binti Dollah as well as to my beloved family. For they, has given me the strength to complete this report entirely and I will always be grateful for having them as my family.

Thank You

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

cm	-	centimetre
GPa.	-	Giga Pascal
kg	-	kilogram
kg/m^3	-	kilogram per meter cube
mg/dL	-	milligrams per decilitre
mm	-	millimetre
mm^2	-	millimetre square
mm^3	-	millimetre cube
ng/dL	-	nanograms per decilitre
nmol/l	-	nanomole per litre
pg/dL	-	picograms per decilitre
IU/L	-	International Unit per litre
#C	-	C Sharp programming language
2D	-	Two Dimensional
3D	-	Three Dimensional
AM	-	Additive Manufacturing
ACI	-	Autologous Chondrocytes Implantations
ALP	-	Alkaline phosphate
BMI	-	Body mass index
C++	-	C plus plus programming language
CPP	-	Calcium Polyphosphate
CAD	-	Computer Aided Design
CATIA	-	Computer Aided Three-dimensional Interactive Application
CMM	-	Coordinate Measuring Machine
ECM	-	Extracellular Matrix
FEM	-	Finite Element Mesh
FF	-	Freeform Fabrication
FDM	-	Fused Deposition Modelling

GH	-	Growth Hormone
HA	-	Hydroxyapatite
HLA	-	Human Leukocyte Antigens
LOM	-	Laminated Object Manufacturing
LSA	-	Linear Static Analysis
MIT	-	Massachusetts Institute of Technology
NC	-	Numerical Control
PCL	-	Poly - Ɛ -Caprolactone
PH	-	Parathyroid Hormone
PLA	-	Poly-Lactic Acid
PLA/HA	-	Poly-Lactic Acid/Hydroxyapatite
PLGA	-	Poly Lactic-Co-Glycolic Acid
PLLA	-	Poly-L-Lactic Acid
RP	-	Rapid Prototyping
SLS	-	Selective Laser Sintering
SGC	-	Solid Ground Curing
SLA	-	Stereolitography
SQL	-	Structured Query Language
STL	-	Stereolitography file
SW	-	Solidworks
TE	-	Tissue Engineering
THR	-	Total Hip Replacement
TKR	-	Total Knee Replacement
UV	-	Ultraviolet
UCSF	-	University of California San Francisco
VB	-	Visual Basic

CHAPTER 1
INTRODUCTION

This chapter introduces the project as well as briefly describe the aims, objectives and its scope. This chapter will also provide an overview of the project's implementation.

1.1. Introduction

Additive manufacture (AM) of scaffolds to promote the regeneration of human tissue is a study which will help to understand the characteristics for a scaffold in order to decide the design of the scaffold according to the customer's preferences or suitability. Typically, the fabrication or production of these scaffolds will be done by using the AM technologies specifically with the laser sintering AM system.

Curl et al. (1997) has previously mentioned that more than 31,000 knee arthroscopies were needed in order to cover the Osteochondral or Chondral injuries which commonly and typically will affect the athletes who is active. In Figure 1.1, the picture show one of the types of fracture on the articular cartilage. This injury usually caused when the athlete twisted his or her knee badly. Direct trauma (sudden, forceful injury) to the inner or outer part of the femur at the knee also can lead to these lesions (Anatomy - Cartilage, 2008).

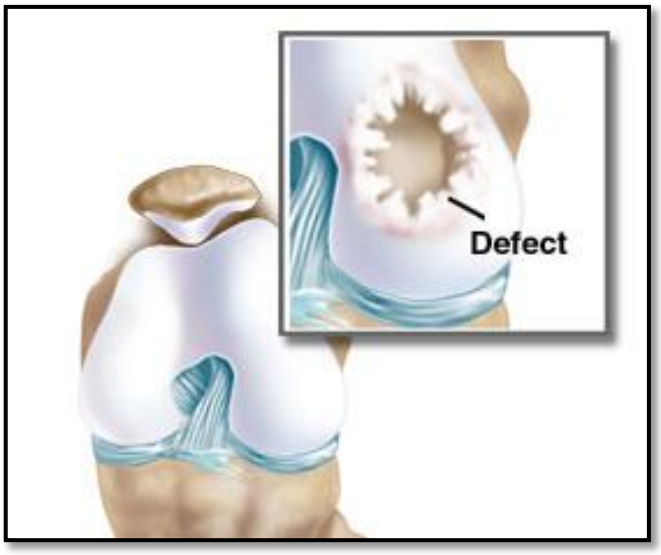

Figure 1.1: Osteochondral Defect

1.0 (Source :< http://www.cartilagerepaircenter.org/patient-education/anatomy-cartilage.html>Accessed on: 7 November 2012, 2008)

These injuries are the result of when the articular cartilage (the smooth part of the bone) cracked into fragment or in the worst case scenario is when the bone breaks into the joint. When the bone breaks into the joint, the only possible treatment for this injury is a surgery on the knee in order to replace the cartilage with a knee implant made out of Titanium Alloy. However, this implant has a high risk of rejection, inflammatory responses and subsequent surgeries for implants replacement and adjustment (Batista et al., 2004).

Due to too many disadvantages and flaws to the implants surgeries, researcher has developed another alternative of inserting a temporary support called scaffold to the cartilage to encourage the bone cell to regenerate in order to fix the injuries his or herself (Granchi et al., 2008 and Outerbridge, 1995). However, the scaffold needs to be biocompatible to avoid stimulation of unwanted immune response from the human body (Hutmacher, 2000). The scaffold also has to fulfil a certain structure which will be reviewed later on in this report.

Osteochondral scaffold which will hold a unique feature of structures that can support multiple tissue types had caused the scaffold fabrication quite impossible using the technologies commonly used in this tissue engineering field such as the

material injection, solvent casting and others to be used (Hutmacher, 2000). This is where the AM plays an important role. The method of layered manufacturing has allowed AM to be used to produce the scaffold in varying layer of characteristics.

With fixed constraints for the design of the scaffold, a few structure of scaffold will be discussed and compared in order to determine the structure of the scaffold which will be in high potential of assisting the bone tissue regeneration in the aspect of minimal time of regenerating and degradable with fulfilling the mechanical properties of the bone itself.

1.2. Problem Statement

Since the injuries of Osteochondral defect have affected many athletes, the scaffold of the articular cartilage has been widely used abroad. However, due to its wide usage, many types of scaffold design have been produce. The scaffolds in the market have different types and structure. This study of the different types of scaffold will help to determine which of the structures will be best and most helpful in the bone tissue regeneration and also will be able to sustain the force and pressure from the human activity while the bone tissue regenerates.

1.3. Aims

The aim of this project is the development of scaffold design selection system based on the manufacturing process of AM.

1.4. Objectives

The objectives of the project are;

a) To study the AM systems and the types of bone scaffold design
b) To design four bone scaffolds design using Solidworks (SW)
c) To develop, test and validate the system for the selections of the scaffold

1.5. Scope

Scope of this study covers the AM system such as the Selective Laser Sintering (SLS), Fused Deposition Modelling (FDM) system and the SW (Computer Aided Design) CAD software for the test and simulations of the scaffold structures. From four suggested designs, each design will be matched to the most suitable patient criteria according to the age, weight, total load and the hormone response from each patient by using a web based programme as the interface in order to ease up the scaffold selection.

1.6. Project Planning

Figure 1.2 shows the overall planning for this project. After the selection of titles, the objectives and scope for this study was identified and the information related to the title was gathered. This involves with the reading and understanding any reading material which is related and help to further understands the selected topics. After the proof reading and information gathering processes was done, the existing design of the scaffold was identified and has been redrawn in order to provide a clear insight on how the scaffold works. The drawn scaffolds will go through few simulations in order to determine its characteristic. The result will be used to categorize the scaffold into few categories which will be the help of the selection program later on. Based on the categorized scaffold, the programme will be developed and will be discussed. Any recommendation and further improvement will be discussed in the conclusion part as well as the measurement on whether the objective of this project is achieved or not.

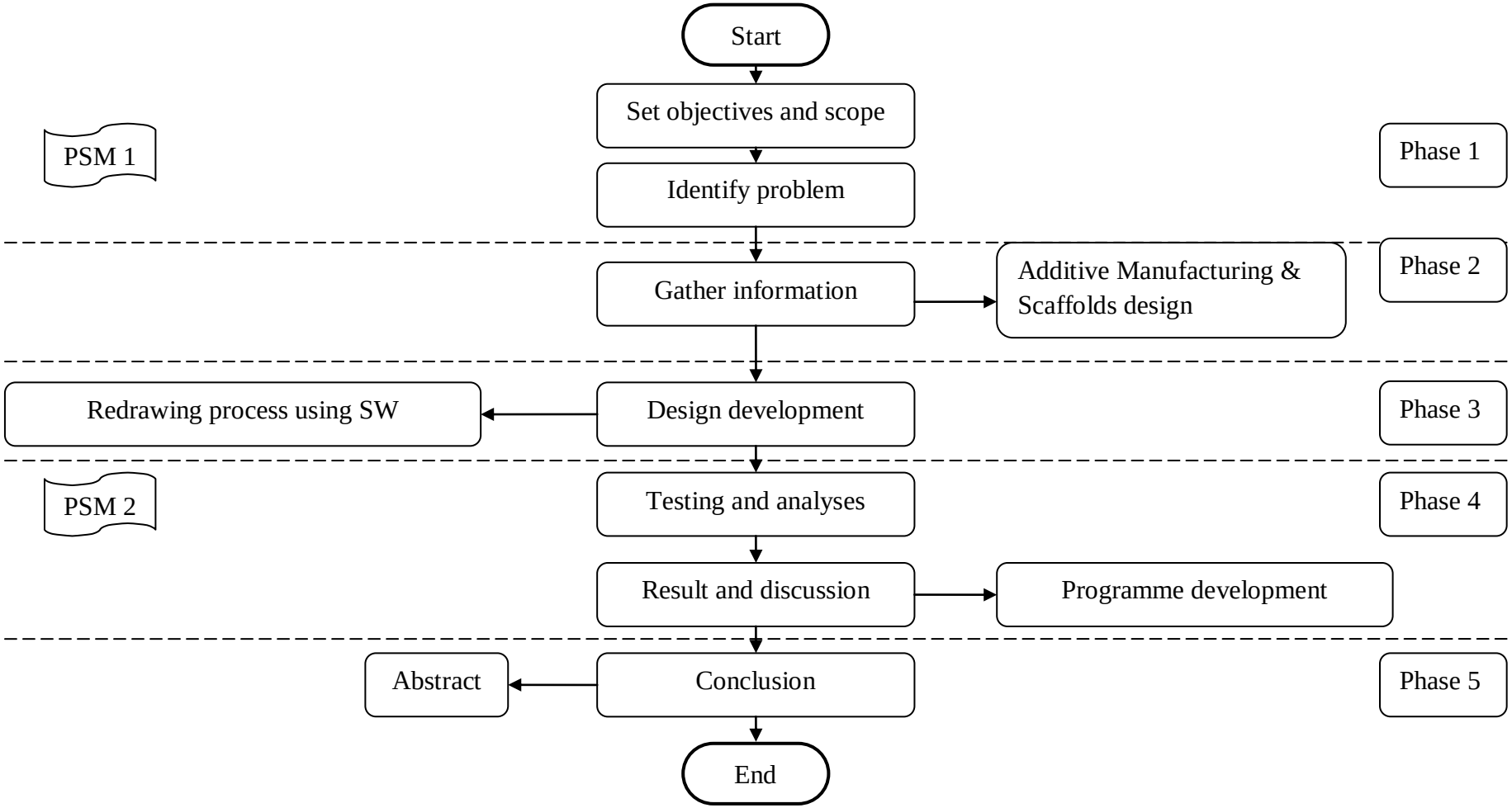

Figure 1.2: Project Planning

CHAPTER 2
ADDITIVE MANUFACTURING

This chapter will provide a preliminary insight regarding the history of AM, basic steps in AM system, and the techniques known to the public. This chapter also will provide information on the benefits of AM along with the limitations of AM.

2.1. History

According to Harris (2011), AM is "the process of joining materials to make objects from 3D model data, usually layer upon layer as opposed to subtractive manufacturing technologies". Bourell et al. (2009) has mentioned that AM is known to be related to topography and photo sculpture. Both methods can be traced back to almost 150 years ago. Nowadays, the evolution of these methods has caused the birth of Freeform Fabrication (FF). According to Wohlers (2009), FF is the collection of technologies namely as rapid prototyping, rapid manufacturing and solid freeform fabrication.

2.1.1. Topography

In 1980, Joseph Blanther has created a method of layering for making a mould for topography relief maps (Blanther, 1982). According to the United States Geological Survey (2011), topography is a map that represents the Earth. Topography map usually will show the contours of Earth surface representing the elevation on the

surface of the land. Blanther (1982) explains that the topography was made by impressing topographical contour lines on a series of wax plates. Figure 2.1 shows the contour drawing to represent a hill based on the different state of its height.

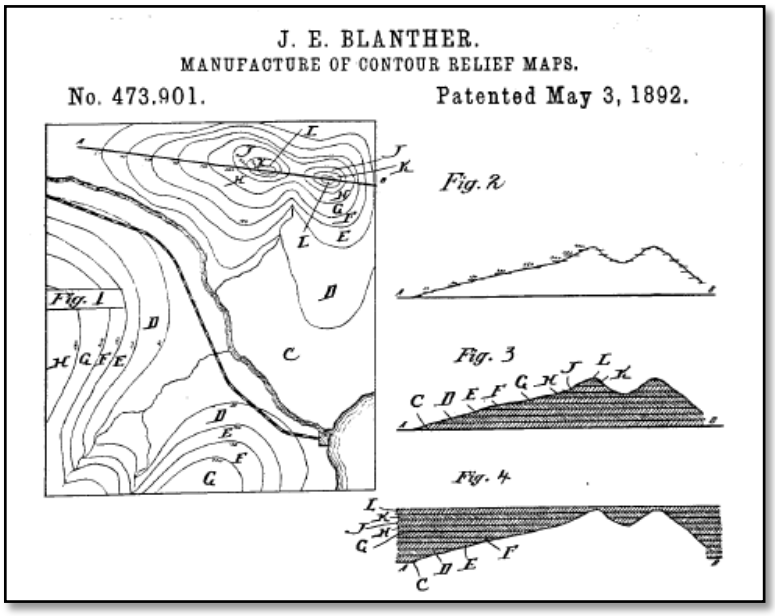

Figure 2.1: Blanther patent to fabricate 3D relief map with layered method (Blanther, 1982)

In 1940, by following the same method, B.V Perera proposed the usage of cardboards stacked and pasted together to form a three dimensional map (Perera, 1940). In 1972, K. Matsubara of Mitsubishi Motors suggested the usage of photo-hardening materials for the topographical process (Matsubara, 1974). Photo-hardening is a process where refractory particles such as sand or graphite powder were coated with photopolymer resin. These particles then spread into layers and heated to form a coherent sheet. By using the mercury vapour lamp, the scanned sheet will harden a define portion of the sheet and the un-scanned or un-hardened portion will be dissolved by using solvents

In 1974, DiMatteo has recognizes the same stacking technique could be used for fabricating complex surfaces that made impossible by standard machining (DiMatteo, 1976). By the year of 1979, Professor Nakagawa of Tokyo University produces the actual tools such as blanking, press forming and injection moulding