



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**ADDITIVE MANUFACTURING FOR ERGONOMIC  
IMPROVEMENT OF KNEE SUPPORT DEVICE**

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

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**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). The member of the supervisor is follow:

.....

## **ABSTRAK**

Tajuk bagi projek ini ialah Pembuatan Tambahan Untuk Pembaikan Ergonomik Pada Alat Sokongan Lutut. Tujuan projek ini dilakukan adalah untuk mereka bentuk semula alat sokongan lutut dengan menggunakan kaedah Kejuruteraan Songsang dan proses Pembuatan Tambahan. Matlamat projek ini adalah untuk menghasilkan satu alat sokongan lutut dengan meningkatkan tahap ergonomik dan memberi selesa kepada pesakit. Projek ini memberi tumpuan kepada rekabentuk prototaip alat sokongan lutut berdasarkan geometri lutut pesakit dan jenis kecederaan yang dialami. Kebanyakannya, alat-alat sokongan yang sedia ada untuk lutut terutama bagi pesakit yang mengalami kecederaan teruk seperti patah tulang atau retak mempunyai saiz yang tetap mengikut kepada umur mereka. Peranti ini boleh dilaraskan berdasarkan saiz kaki dan keselesaan kepada pengguna. Walau bagaimanapun, pengguna akan berasa tidak selesa jika alat sokongan ini dipakai untuk jangka masa yang lama. Ini adalah disebabkan oleh permukaan peranti tidak dapat menutup sepenuhnya antara permukaan peranti dan permukaan kaki. Selain itu, kos yang diperlukan untuk menghasilkan sokongan lutut yang sedia ada ini adalah lebih mahal kerana ia memerlukan lebih daripada satu proses mesin dan bahan-bahan yang digunakan untuk membangunkan peranti. Dalam projek ini, beberapa kaedah telah digunakan dalam proses pembangunan alat sokongan lutut. Sebagai permulaan, satu kajian awal telah dijalankan untuk mendapat maklum balas daripada pengguna mengenai alat sokongan lutut yang sedia ada dan keperluan mereka untuk rekabentuk peranti yang baru. Kebanyakannya, responden telah memilih untuk konsep mesra pengguna daripada saiz sedia ada untuk alat sokongan lutut. Perisian 3D CAD seperti Geomagic Studio 10 dan SolidWork 2010 telah digunakan untuk membangunkan rekabentuk baru untuk menyokong peranti lutut berdasarkan data yang diberikan dari proses imbasan dengan menggunakan peranti pengimbas optik. Analisis Unsur Terhingga (FEA) bagi analisis tekanan telah dilakukan untuk menilai tahap kekuatan

rekabentuk baru bagi alat sokongan lutut dan untuk mengenal pasti bahagian kritikal pada rekabentuk tersebut. Prototaip bagi alat sokongan lutut telah dihasilkan dengan menggunakan mesin Model Pengendapan Terlatur (FDM) dan mesin pencetak 3D. Terdapat dua bahan yang telah digunakan untuk membangunkan prototaip untuk peranti dimana plastik ABS telah digunakan sebagai bahan mesin FDM dan serbuk mengikat telah digunakan sebagai bahan mesin 3D pencetak. Ujian kekasaran permukaan telah dilakukan untuk kedua-dua bahan untuk mengenal pasti tahap kelicinan pada permukaan. Berdasarkan keputusan yang diperolehi, reka bentuk baru untuk alat sokongan lutut adalah selamat untuk digunakan kerana berdasarkan bacaan parameter yang dinyatakan menunjukkan nilai FOS terendah yang terdapat pada rekabentuk kedua-duanya adalah lebih daripada nilai satu. Sebaliknya, jika nilai FOS adalah kurang daripada satu menunjukkan bahawa rekabentuk adalah tidak selamat dan memerlukan pembaikan. Seterusnya, hasil daripada ujian kekasaran menunjukkan bahawa produk yang dihasilkan daripada mesin pencetak 3D mempunyai permukaan yang licin berbanding dengan produk yang dihasilkan daripada mesin FDM. Sebagai kesimpulan daripada projek ini, teknik kejuruteraan terbalik dan proses pembuatan tambahan dapat difahami dan digunakan semasa proses pembangunan bagi alat sokongan lutut. Prototaip bagi alat sokongan lutut telah berjaya dibina dengan menggunakan mesin RP dan kedua-dua bahan yang digunakan untuk membina produk telah diuji untuk menilai prestasi mereka. Walau bagaimanapun, proses yang sebenar telah dipilih bagi projek ini adalah dengan menggunakan mesin Pensinteran Laser Terpilih (SLS) tetapi mesin tidak terdapat di makmal-makmal UTeM.

## **ABSTRACT**

The title for this project is about Additive Manufacturing for Ergonomic Improvement of Knee Support Device. The purpose of this project is to design a knee support device with using Reverse Engineering (RE) methods and Additive Manufacturing (AM) process. Aims of this project is to produce a knee support device with improve ergonomics and comfortably to a patient. This project focused to design a prototype of knee support device based on the geometry of patient knee and type of injury sustained. Mostly, the existing support devices for knee especially for patients that suffers from severe injuries such as bone fractures or cracks have standard size according to their age. The device can be adjusted based on the size of feet and comfort to user. However, users will feel uncomfortable if it is worn for a long time. This is due to the surface of the device does not close completely between the device surface and the foot surface. Besides that, the cost required to produce an existing knee support is quite expensive because they are require more than one process machines and materials use to develop a device. In this project, there several method had been used to done the process development of knee support device. As starting, a preliminary survey was been conducted to gained the feedback from the consumer about the existing knee support device and their requirement for new device. Mostly, the respondents were been choose for user fit concept than the standard size for knee support device. 3D CAD software such as Geomagic Studio 10 and SolidWork 2010 had been used to develop a new design for knee support device based on the data given from the scanning process by using the optical scanner device. The Finite Element Analysis (FEA) for stress analysis was be done to evaluate the strength for the new design of knee support device and to identified the critical section on the design. The prototype for knee support device was be produced using the Fused Deposition Modeling (FDM) machine and 3D printer machine. There are two material were been used to develop the prototype for device which ABS plastic for FDM machine material



and bind powder for 3D printer machine material. The surface roughness test had been done for both material to identify their smooth level. As a result, the new design for knee support device is safe to use because the specified parameter as shown the lowest FOS found in the both design are more than one. Otherwise, if the FOS value is less than one show that the design is unsafe and need some improvement. Then, for the surface roughness test the result shows that the 3D printer product has smoother surface compare to the FDM product. As the conclusion from this project, the RE technique and AM process were understood and was applied during the development process for knee support device. The prototype for knee support device was successfully done by using the FDM machines and the both product materials had been tested to evaluate their performance. However, the actual process was selected for this project is using the Selective Laser Sintering (SLS) but this machine is not available in UTeM's lab.

## **DEDICATION**

To my beloved parents, my supervisor and friends.  
All the guidance, wisdom and strength you guys, give me a passion to be the best  
and help in giving inspiration to complete this project.

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# TABLE OF CONTENT

Abstrak	i
Abstract	iii
Dedication	v
Acknowledgement	vi
Table of Content	vii
List of Tables	xi
List of Figures	xii
List of Abbreviations, Symbols and Nomenclature	xv
<b>CHAPTER 1: INTRODUCTION</b>	<b>1</b>
1.1 Project Background	1
1.2 Problem Statement	2
1.3 Objectives	3
1.4 Scope of Work	4
<b>CHAPTER 2: LITERATURE REVIEW – ADDITIVE MANUFACTURING</b>	<b>5</b>
2.1 Chapter Overview	5
2.2 Introduction	6
2.3 Additive Manufacturing Techniques	7
2.3.1 Process Involving Discrete Particles	8
2.3.1.1 Fused Deposition Modeling (FDM)	8
2.3.2 The Advantages of Using FDM Technology	10
2.3.3 The Disadvantages of Using FDM Technology	11
2.4 AM Basic Process	12
2.4.1 CAD Model Creation	13
2.4.2 Conversion to STL Format	13
2.4.3 Slice the STL File	14
2.4.4 Layer by Layer Construction	15
2.4.5 Clean and Finish	15
2.5 Reverse Engineering (RE)	16

2.5.1	Introduction for RE	16
2.5.2	3D Scanning Technology	18
2.5.3	Generation of a 3D CAD Model from Scanning Data	19
2.6	Advantages of Additive Manufacturing (AM)	19
2.6.1	Direct Benefit	19
2.6.2	Indirect Benefit	20
2.7	Summary	20
<b>CHAPTER 3: LITERATURE REVIEW – KNEE SUPPORT DEVICE</b>		<b>21</b>
3.1	Chapter Overview	21
3.2	Introduction	21
3.2.1	Human Knee	21
3.3	Knee Support Device	23
3.3.1	Knee Support Device Functions	23
3.3.1.1	Scope of Knee Support	23
3.3.1.2	Salient Features	23
3.3.2	Existing Product	24
3.3.2.1	Patent 1: Knee Support	25
3.3.2.2	Patent 2: Adjustable Knee Support	25
3.3.2.3	Patent 3: Orthopedics Knee Support	27
3.3.2.4	Other Patents Design	27
3.4	Summary	29
<b>CHAPTER 4: METHODOLOGY</b>		<b>30</b>
4.1	Introduction	30
4.2	Flow Chart of Project Activity	31
4.3	Survey	32
4.3.1	Need Statement from Questionnaire	32
4.3.2	Interpretation	34
4.3.2.1	Questionnaire Part A	34
4.3.2.2	Questionnaire Part B	34
4.3.2.3	Summary of Survey	38

4.4	Design Development	39
4.4.1	3D Optical Scanner Used In This Study	39
4.4.2	Scanning Procedures	40
4.4.3	The Improvement Process of CAD Drawing	44
4.4.3.1	Geomagic Studio 10	44
4.4.3.2	Improvement Process	44
4.4.4	Redesign Process	48
4.4.4.1	Redesign	48
4.4.4.2	CAD Drawing Model	48
4.4.3.3	Detail Drawing	51
4.5	AM Process	53
4.5.1	Convert CAD Data into Stereolithography (STL) Format	53
4.5.2	FDM Process	54
4.5.2.1	Flow Process of FDM Machine	54
4.5.2.2	Procedures	54
4.5.3	3D Printer	55
4.5.3.1	Flow Process of 3D Printer	56
4.5.3.2	Procedures	56
4.6	Testing and Analysis	58
4.6.1	Material Properties	58
4.6.2	Stress Analysis	59
4.6.2.1	Supporter-Above	59
4.6.2.2	Supporter-Below	61
4.6.3	Surface Roughness Test	62
4.7	Summary	63
<b>CHAPTER 5: RESULT AND DISCUSSION</b>		<b>64</b>
5.1	Introduction	64
5.2	Scanning Process	64
5.2.1	Use Cement as a Mold Material	64
5.2.2	Surface Improvement	66
5.3	Render for Assembly Drawing of Knee Support Device	67
5.4	RP Process	68

5.4.1	FDM Machine	69
5.4.2	3D Printer	69
5.4.3	Comparison Between FDM and 3D Printer	69
5.5	Test and Analysis	70
5.5.1	Stress Analysis for Supporter-Above	70
5.5.2	Stress Analysis for Supporter-Below	70
5.5.3	Surface Roughness Test	71
5.6	Comparison between the Existing Knee Support Device and New Knee Support Device	
5.7	Summary	72
<b>CHAPTER 6: CONCLUSION AND RECOMMENDATION</b>		<b>73</b>
6.1	Conclusion	73
6.2	Recommendation	73
<b>REFERENCES</b>		<b>75</b>
<b>APPENDICES</b>		<b>77</b>

## LIST OF TABLES

4.1	Respondent Background	32
4.2	Detail Information	32
4.3	Material properties for ABS plastic	59
4.4	The surface roughness for FDM and 3D Printer product	63
5.1	Comparison between faro arm and optical scanner machine	66
5.2	The comparison for existing and new design of knee support device	71



## LIST OF FIGURES

2.1	Example of AM model	6
2.2	FDM Machine	8
2.3	Schematic diagram of Fused Deposition Modeling	9
2.4	FDM Model	10
2.5	CAD Model	13
2.6	STL format	14
2.7	Slicing of STL file	14
2.8	Layer by layer construction	15
2.9	Clean and finish	16
2.10	3D Digitizing process	17
2.11	Surface modeling procedure from scanned data	19
3.1	Structure of Human Knee	22
3.2	Patent 1	25
3.3	Patent 2 (a)	26
3.4	Patent 2 (b)	26
3.5	Patent 3	27
3.6	Patent 4	28
3.7	Patent 5	28
3.8	Patent 6	29
4.1	Flow chart of project activity	31
4.2	Gender	34
4.3	The source of information obtained	35
4.4	Customer feedback for existing knee support device	36
4.5	Question 3(a) Respondent requirement	36
4.6	Question 3 (b) & (c) Knee support device operation	37
4.7	Question 3 (d) other characteristics for knee support device	37
4.8	Cost per unit of knee support device	38

4.9	Image of instrument	39
4.10	Setup fringe	39
4.11	Working distance for scanning	40
4.12	Mounted clay on knee	41
4.13	Geometry model of knee	41
4.14	Spray process	41
4.15	After spray	41
4.16	White dot position	42
4.17	Model position distance	42
4.18	Scanning display	42
4.19	Merge process of data collection	43
4.20	Fill method	45
4.21	Fill holes	45
4.22	Fill process	45
4.23	Sand paper	45
4.24	Rubbing process	46
4.25	Bumps on surface	46
4.26	Crease angle mode	47
4.27 (a)	Select bumps	47
4.27 (b)	Remove bumps	47
4.28	Final improvement of model surface	47
4.29	Drawing for supporter-above	48
4.30	Drawing for supporter-below	49
4.31	Drawing for assembly	50
4.32	Detail drawing for supporter-above	51
4.33	Detail drawing for supporter-below	52
4.34	Converting format from CAD to STL file for supporter-above	53
4.35	Converting format from CAD to STL file for supporter-below	53
4.36	Flow chart for FDM process	54
4.37	Ultrasonic tank	55
4.38	3D Printer Machine	55
4.39	Flo chart for 3D Printer	56
4.40	Model position in machine	56

4.41	Remove impurities	57
4.42	Cleaning	57
4.43	Powder lever	57
4.44	Printing process	58
4.45	Stress analysis result for supporter-above	59
4.46	Stress area	60
4.47	Displacement area for supporter-above	60
4.48	Stress analysis result for supporter-below	61
4.49	Displacement area for supporter-below	62
5.1	Cement	65
5.2	The broken cement	65
5.3	Skin shrinkage	65
5.4	Model surface before improvement	67
5.5	Model surface after improvement	67
5.6	Rendering	67
5.7	Detail drawing for full assembly of Knee Support Device	68
5.8	Prototype for Supporter-Below	69
5.9	Reject part	70

## LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ABS	-	Acrylonitrile Butadiene Styrene
AM	-	Additive Manufacturing
BASS	-	Break Away Support System
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
CNC	-	Computer Numerical Control
DSSP	-	Secondary Structure Assignments
FDM	-	Fused Deposition Modeling
FOS	-	Factor of Safety
J	-	Joule
K	-	Kelvin
kg	-	kilograms
m	-	meter
mm	-	millimeter
N	-	Newton
RE	-	Reverse Engineering
RM	-	Ringgit Malaysia
RP	-	Rapid Prototyping
SLA	-	Stereolithography
SLS	-	Selective Laser Sintering
STL	-	Stereolithography
W	-	Watt
3D	-	Three Dimensional
°C	-	Celsius
^	-	Exponential
%	-	Percentage
$\lambda$	-	Lamda

$\mu$  - micro  
< - Less than

# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 Project Background**

This report presents the Additive Manufacturing (AM) for ergonomics improvement of Knee Support Device. Chapter 2 will describe in detail about Additive Manufacturing (AM) and knee support device. Chapter 3 describes both of these subjected because it will be used during the process of Reverse Engineering (RE). RE was applied to redesign the current product without need to develop a new drawing from any CAD software but the CAD data can be obtained directly from the scanning process. In this project, an optical scanner was used to get the geometry of knee to develop a new knee support device that more comfortable for specific patient. Chapter 4 in this report describe in detail about the process development of knee support device using the RE method and AM process. SolidWork 2010 CAD software was used to complement the design shape of the knee support device couple with Geomagic Studio 10. Finally the finish knee support device was made using the Fused Deposition Modeling (FDM) machine.

## 1.2 Problem Statement

Mostly, the existing support devices for knee especially for patients that suffers from severe injuries such as bone fractures or cracks have standard size according to their age. The device can be adjusted based on the size of feet and comfort to user. However, users will feel uncomfortable if it is worn for a long time. This is due to the surface of the device does not close completely between the device surface and the foot surface. Besides that, the material such as steel was used to support the position of bones from the larger movement.

In manufacturing process to produce a support device for knee have to undergo several processes such as injection molding, stamping process, stitching, finishing and assembling process. The assembly process of device requires fastener such as screws and nuts to assemble two different of components. Therefore, the cost required to produce a device support is quite expensive. In contrast this project will study on how to improve the manufacturing process in order to reduce knee support device manufacturing cost and time by using AM.

### **1.3 Objectives**

- 1.3.1 To study about Additive Manufacturing (AM).
- 1.3.2 To implement Reverse Engineering (RE) technique to redesign the knee support device.
- 1.3.3 To produce a new design of knee support device that will improve the comfort and ergonomic.
- 1.3.4 To test and validate the prototype.