DETERMINE THE EFFECT OF CHEMICAL TREATMENT TO THE MECHANICAL PROPERTIES OF PARTS PRODUCED USING FDM

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

by

NUR LIYANA BINTI HASAN

B051510190

960723-11-5150

FACULTY OF MANUFACTURING ENGINEERING

2019

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **DETERMINE THE EFFECT OF CHEMICAL TREATMENT TO THE MECHANICAL PROPERTIES OF PARTS PRODUCED USING FDM**

Sesi Pengajian: **2018/2019 Semester 2**

Saya **NUR LIYANA BINTI HASAN (960723-11-5150)**

mengaku membenarkan Laporan Projek Sarjana Muda (PSM) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. *Sila tandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Disahkan oleh:

_____ _____

Alamat Tetap: Cop Rasmi:

_____

_____

_____

Tarikh: _____ Tarikh: _____

*Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled "Determine the Effect of Chemical Treatment to the Mechanical Properties of Parts Produced using FDM" is the result of my own research except as cited in references.

Signature : ……

Author's Name : NUR LIYANA BINTI HASAN

Date : 26 June 2019

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

…….....

(Ruzy Haryati binti Hambali)

ABSTRAK

Tujuan kajian ini adalah untuk mengkaji kesan perawatan kimia terhadap sifat mekanikal bahagian yang dihasilkan oleh FDM. FDM adalah *Fused Deposition Modelling* iaitu satu aplikasi dari AM teknologi. *Additive Manufacturing* (AM) adalah proses menghasilkan objek 3D model data dari proses lapisan demi lapisan. Teknologi AM adalah berbeza dengan *subtractive manufacturing* iaitu tidak melibatkan proses pemesinan. Bagaimanapun, disebabkan oleh *staircase effect*, FDM mempunyai permukaan yang teruk dan menyebabkan perlunya proses rawatan pasca. Di samping itu, didapati kurangnya kajian terdahulu yang menumpukan sifat fizikal dan mekanikal bahagian FDM yang mengikut piawaian ISO. Perawatan kimia terlibat dalam proses pasca pemprosesan telah dicadangkan dan proses ini dapat memberikan peningkatan sifat fizikal yang baik seperti permukaan luar bahagian FDM. Sifat mekanikal adalah sifat fizikal yang menggambarkan kelakuan bahan atau bahagian sebagai contoh kekuatan, plastik dan kemuluran. Objektif kajian ini adalah untuk menghasilkan bahagian spesimen dengan menggunakan FDM berdasarkan piawaian ISO. Objektif kedua adalah untuk mengkaji kesan perawatan kimia terhadap kekasaran permukaan dalam bentuk mampatan, kekerasan dan ujian impak. Objektif ketiga adalah untuk menganalisa sifat dalaman bahagian tersebut dengan keputusan eksperimen dalam bentuk mampatan, kekerasan dan ujian impak. Akhir sekali, pemerhatian visual dilakukan menggunakan Mikroskop Stereo untuk mengkaji sifat dalaman bahagian FDM. Berdasarkan keputusan, nilai purata kekasaran menaik dari spesimen yang tidak dirawat kepada dirawat. Untuk ujian mekanikal, kekuatan impak dan nilai kekerasan menaik tetapi nilai maksimum tekanan menurun dari spesimen yang tidak dirawat kepada dirawat. Kesimpulannya, keputusan tersebut boleh memberi penambahbaikkan aplikasi FDM dalam industri pembuatan. Tambahan lagi, ia berguna untuk jurutera, pereka dan pengguna untuk merangkul kebolehgunaan AM khususnya dalam FDM.

ABSTRACT

The aim of this study is to determine the effect of chemical treatment to the mechanical properties of parts produced using FDM. FDM stands for Fused Deposition Modelling that is one of application from AM technology. Additive Manufacturing (AM) is a process of build an object from 3D model data, which from layer by layer process. AM technology is opposed subtractive manufacturing that are not involved in any machining processes. However, due to staircase effect, FDM obtained bad surface finish and this require post treatment process. In addition, there are a limited number of previous studies focusing onto the physical and mechanical properties of FDM parts that followed the ISO standards. Chemical treatment involves in post-processing process suggested to give good physical properties improvement such as surface finish to FDM parts. Mechanical properties are properties, which describe the behaviour of material or part for example strength, plastically and ductility. The objective of this study is to fabricate specimen parts using FDM according to respective ISO standards. Second is to determine the influence of chemical treatment to the surface roughness and mechanical properties for the parts includes compression, hardness and impact tests. Third is to analyse the internal behaviour of parts with the result of the compression, hardness and impact tests. Lastly, the visual observations for all specimens using Stereo Microscope were conducted in order to analyse internal behaviour of FDM parts. Based on the result obtained, value of average roughness increases from untreated to treated specimens. For mechanical tests, hardness value and impact strength are increases but the maximum stress in compression stress is decreases from untreated to treated specimens. In conclusion, these results provide comprehensive data of improvement and advancement of FDM application to manufacturing industries. This benefit to engineers, designers and consumers to embrace the usability of AM specifically in FDM.

DEDICATION

This Thesis is dedicated to:

The sake of Allah, my Creator

My beloved parents, Hasan bin A.Rahaman and Selma binti Othman

My lovely sisters, Nurul Nadia Farhana, Siti Nursyahirah and Nuraini

My trusted friends

and to all people whom dearest to me

For their cooperation, encouragement and also understanding along this project

ACKNOWLEDGEMENT

In the name of Allah SWT, the most merciful, the Ever-Magnificent, the Ever-Thankful, for His help and bless that I manage to complete this final year project.

My respected supervisor, Puan Ruzy Haryati binti Hambali for her guidance, patience and kindness for always support me through up and down in completing this research. Without her, I would not be able to complete this project within the allocate time.

I would like to express my thanks to my family who are never tired from keep supporting me. Lastly, my friends and also for technicians who are really important for me to gain some ideas and knowledge about this Final Year Project. Thank you very much.

TABLE OF CONTENT

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASTM	-	America Society for Testing and Materials
ISO	-	International Standards Organization
STL	-	Standard Triangulation Language
SL	-	Stereolithography
SLS	-	Selective Laser Sintering
ULTEM	-	Polyetherimide
ABS	-	Acrylonitrile Butadiene Stryene
PLA	-	Polylactic acid
FTMK	-	Fakulti Teknologi Maklumat dan Komputer
FKP	-	Fakulti Kejuruteraan Pembuatan
UTeM	-	Universiti Teknikal Malaysia Melaka
RP	-	Rapid Prototyping
RM	-	Rapid Manufacturing
FDM	-	Fused Deposition Modelling
AM	-	Additive Manufacturing
2D	-	2 Dimension
3D	-	3 Dimension
FEA	-	Finite Element Analysis
PPSF	-	Polyphenylsulfone
PC	-	Polycarbonate

LIST OF SYMBOLS

kN	-	Kilo Newton
s	-	Second
’	-	Inch
Ɛc	-	Nominal compressive strain
mm	-	Millimetre
ml	-	Millilitre
%	-	Percentage
MPa	-	Mega Pascal
kJ	-	Kilo Joule

LIST OF EQUATIONS

CHAPTER 1
INTRODUCTION

In this chapter contains background of study which is about the overview for Additive Manufacturing and Fused Deposition Modelling. Besides, this chapter also will be covered about Rapid Manufacturing, Rapid Prototyping and also Acrylonitrile Butadiene Stryene, type of material that been used in this research. This chapter also will be explained problem statement, objective, scope of research and project significance.

1.1 Background of Study

This research is focused on Additive Manufacturing (AM) technology which is one type of technology for producing a product. AM is a process of joining a material generate a part from 3D model data from layer by layer. AM technique used three dimensional Computer Aided Design (CAD) data. Referring to ASTM F2792, AM is a process of joining the material from 3D model data, layer by layer which opposed to subtractive manufacturing in order to produce an object. This technology involves a used of computer, design the parts by software and then continue with product development. AM is a process that takes the information from CAD and converted it into STL file. After converting the file, the part will be print out for the product development.

Fused Deposition Modelling (FDM) is an extrusion-based AM technique which based on layer manufacturing process to build a part that is usually used in modeling, protyping and production application. FDM involves three steps which are pre-processing, production and post-processing. Pre-processing which is a step for build the part by using software and convert it into STL file. In this step also need to calculate the path for extruding and any related parameter that been used. Next, production step is for producing

the part using FDM. Post-processing step is a step after produced a part in order to remove the support structure. Recently, the end used product that suitable for this AM technologies is called Rapid Manufacturing (RM).

RM is a direct production of a product from a Rapid Prototyping (RP) device (Bak, 2003). This is the application of 3D printing technologies, which give RP capabilities with the high-volume throughput of conventional manufacturing. RM can produce complex parts geometry with low cost compared to conventional manufacturing. RP is a process to produce a prototype quickly with low cost. RP technique consists of several classifications that are solid based RP, liquid based RP and powder based RP system. The commonly system that been used is solid based RP because of its effectiveness and the ability to produce any geometric parts compared to the other types of systems.

Acrylonitrile Butadine Styrene (ABS) is type of material that commonly used for FDM machines besides Polylactide (PLA). ABS is better than PLA because of several characteristics. ABS is more flexible while PLA is more brittle. ABS is suitable for FDM machine. Next, ABS can work well without cooling compared to PLA. Next, International Standards Organisation (ISO) is one of standards which define the requirements and methods for a product to be tested. Referring to Brown (2002), there are three groups of standards which are international organisations, national organisations and individual organisations. Standards are important for laboratory test in order to avoid any misunderstanding over terminology.

1.2 Problem Statement

From the literature review, researchers found that FDM parts and having difficulty in improving the surface properties and mechanical properties of FDM parts. FDM fabrication part should have a good surface roughness with the good strength. Referring to Hambali *et al*. (2017), staircase effect make FDM has a bad surface quality and post treatment is required. Chemical smoothing is one of method that can give good surface finish to the parts. Besides, chemical treatment is introduced in order to have a good surface roughness of FDM parts (Galantucci *et al*., 2010). Furthermore, several factors that influence surface finish and mechanical properties of FDM parts (Domingo-Espin *et al.*

2015). Next, further studies need to do in term of solution concentration and process time using dimethyl-ketone solvent (Galantucci *et al*., 2009). Lastly, a study need to be conducted in order to determine effect on material behaviour with influence of time between treatment and the test (Galantucci *et al*., 2010).

Previous researches have been done which related to chemical smoothing and mechanical properties of FDM part. A study from Percoco *et al*. (2012) is about compression test for FDM parts using low cost chemical finishing and comparing the result with untreated parts. Besides, a study from Singh *et al.* (2017) is observed the improvement of surface finish of FDM parts where here the study used the vapour smoothing process, focusing more on surface roughness of FDM parts concentrating on external behaviour of part compared to the internal behaviour. In addition, reported that the chemical exposure could improve surface finish of FDM (Singh *et al*. 2017).

However, there are limitations of previous research that reported only focused on physical and external mechanical properties of FDM parts, as well does not referring to any ISO standards. Therefore, this research aim is to determine the effect of chemical treatment concentrates on the internal behaviour of FDM part using chemical treatment solvent. Some mechanical properties also been analysed in order to determine the effect of chemical treatment to mechanical properties of parts produced by FDM process. ABS materials are suitable to be treated with a several type of chemical substances which are Methylene Chloride, Trichlorethane and Acetone. This research used the acetone solvent which is suitable for ABS material and FDM process. When the part has been reacted with chemical solvent, the structure of part was changed. In order to know the effect of chemical solvent (acetone) towards FDM parts, several testing tests were conducted. This research is focused on compression test, hardness test and impact test. Further simulation will be done to validate all the data obtained and compared with the experimental result.

1.3 Objective

The aim of this project is to determine the effect of chemical treatment to the mechanical properties of the parts produced by FDM in RP and analyse internal behaviour of the parts. The objectives for this research are as follows:

1. To fabricate specimen parts using Fused Deposition Modelling (FDM) according to ISO standards.

2. To determine the influence of chemical treatment to the surface roughness and mechanical properties for the parts in term of compression, hardness and impact tests.

3. To analyse the internal behaviour of parts with the result of the compression, hardness and impact tests.

1.4 Scope of Research

This research focused on the end used parts that produced by FDM in RM technology. The material used is Acrylonitrile Butadiene Styrene (ABS) and dimethyl-ketone (acetone) for chemical treatment. The specimen parts designed by commercially available 3D design SolidWorks software. The dimensions of the parts are referring to the available standard for compression (ISO 604), hardness (ISO 868) and impact testing (ISO 180). The design from SolidWorks transfered into STL file and then fabricated using FDM machine in Rapid Prototyping Lab that located at FTMK, UTeM. To determine the influence of chemical treatment, parts treated with acetone and test all the parts for surface roughness using Mitutoyo Surface Roughness Tester, compression test using Universal Testing Machine, hardness test using Shore D Durometer hardness testing equipment and impact test using Izod impact testing equipment. To analyse internal behaviour of parts, parts that been treated analysed using Stereo Microscope and compare the structure of specimens without chemical treatment. Next, analysis of deformation of the specimens from physical testing and compared with the simulation using Finite Element Analysis in SolidWorks.

1.5 Project Significance

The aim of this study is to determine behavior of ABS FDM parts by optimizing the post processing the part. The chemical treatment is a process that provides a value towards the end parts for FDM parts. Chemical treatment reported to increase the quality of surface finish of the parts. This research is to determine the effect of chemical treatment to the mechanical properties of FDM end used parts. To obtain the best characteristics of the parts, understanding methods to produce and test the parts are important. The result of this study can give a guidelines for the engineers, designers and consumers that commonly use AM in with the value of physical and mechanical properties of this part.

1.7 Project Planning and Execution

In this project, Gantt chart is constructed which shows the flow and progress from start to the completion of project. Gantt chart consists of all related task to this project. The project schedule as presented in Appendix A and Appendix B.

CHAPTER 2
LITERATURE REVIEW

This chapter began with the overview and definition of Additive Manufacturing (AM). Besides, the development of Rapid Manufacturing (RM) and Rapid Prototyping (RP) in the industry also was explained in this chapter. Next, the overview of Fused Deposition Modelling, material and the processes to do the research also been stated in this chapter.

2.1 Overview of Additive Manufacturing

Additive Manufacturing (AM) is a process that fabricated the parts layer by layer. Referring to Thompson *et al*. (2016), products is produced from digital information piece by piece, line by line, surface by surface or layer by layer by AM technologies. In detail, as above mentioned definition, referring to ASTM F2792, AM defines as a process of joining the material from 3D model data, layer by layer which opposed to subtractive manufacturing in order to produce an object (ASTM, 2010). Parts have be fabricate when AM processes place, bond, transform volumetric primitives of raw materials. Additive Manufacturing produce part from raw material by a digital data flow that generates the instructions for the AM machine.

According to Gibson *et al*. (2015), AM technologies are applied in medical, automotive and aerospace applications. This supported by Royal Academy of Engineering (2013), three sectors that needs AM which including medical, automotive and aerospace sectors. AM has the ability to produce prosthetics implants, replacement tissues and body parts in medical sector. Hearing aids, dental crowns, implants and dentures, biomedical implants for hard and soft tissues, customized casts, splints, orthotics and prostheses are some parts that produce by AM technology (Thompson *et al*. 2016). In automotive sector,

AM usually used in order to make bespoke and non-bespoke parts. AM is giving advantages of speed, cost and materials rationalisation in aerospace sector. In placing more emphasis, Wong and Hernandez (2012), claimed that AM technologies are suitable to aerospace industry because of light weight and easy to design.

The advantage of AM is suitable for cheap, low-volume production. AM technologies is not expensive and increases of users (Singh *et al*., 2017). AM can shorten the development cycle time of the product. Compared to traditional manufacturing process AM gives faster lead time (Royal Academy of Engineering, 2013). AM can produce more complex geometries and create pre-assembled items with multiple moving parts compared to traditional manufacturing. This is supported by Thompson *et al*. (2016) that AM has ability to produce unique and attractive geometric forms which can help the designer to make the product. AM can improve performance of parts by create the internal features. Figure 2.1 shows the digital and physical workflow for Additive Manufacturing.