FUSED DEPOSITION MODELING AND VAPOUR SMOOTHING PROCESS FOR SURFACE FINISH IMPROVEMENT OF BIOMEDICAL IMPLANT REPLICAS

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

by

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2018

DECLARATION

I hereby, declared this report entitled "Fused Deposition Modeling and Vapour Smoothing Process for Surface Finish Improvement of Biomedical Implant Replicas" is the results of my own research except as cited in reference.

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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 Degree of Manufacturing Engineering with Honours. The member of the supervisory is as follow:

………………………………

(Associate Professor Dr. Shajahan bin Maidin)

ABSTRAK

Additive pembuatan adalah teknologi yang biasa digunakan. Tujuan projek ini dijalankan adalah untuk menyiasat tindak balas kimia ke permukaan kekasaran dengan menggunakan proses pelicinan wap. Tujuan projek ini adalah untuk mengurangkan kekasaran permukaan dengan menggunakan tindak balas kimia. Replikasi implan biomedik dibuat menggunakan mesin pemodelan pemendapan yang digunakan untuk membandingkan dengan kaedah konvensional. Projek ini memberi tumpuan kepada permukaan replika implan pinggul dan bahan kimia akan digunakan untuk mengurangkan kekasaran permukaan pada permukaan replika. Bentuk kompleks implan pinggul boleh menyebabkan peningkatan kekasaran permukaan jika gagal mencari gabungan parameter sempurna. Reka bentuk percubaan (DOE) adalah alat yang berkesan untuk mengoptimumkan kualiti produk atau proses. DOE juga melihat bagaimana mengubah reka bentuk pelbagai dan kesan pemboleh ubah proses untuk mencapai hasil terbaik. Produk ABS yang dihasilkan oleh Pemendapan Pemodenan Terlakur (FDM) mempunyai hasil tersendiri yang berbeza-beza dengan perubahan parameter proses mesin seperti sudut orientasi, ketebalan lapisan dan sudut raster. Selepas bahan kimia telah dipilih proses penyulingan wap dilakukan. Bahan kimia itu mestilah sifat pelarut untuk mengurangkan kekasaran permukaan. Kemudian replika diperhatikan untuk kekasaran permukaan yang diuji menggunakan Mitutoyo Surftest SJ 301. Hasilnya diperoleh dan data dianalisis. Perubahan peratusan maksimum dalam kekasaran permukaan telah mengurangkan kekasaran permukaan. Keputusan mendapati bahawa perubahan peratusan maksimum dalam kekasaran permukaan untuk permukaan kritikal pertama adalah tetrahydrofuran telah mencatatkan permukaan halus pada replika 21 dengan 30 minit masa pelicinan wap. Tetrahydrofuran mempengaruhi kekasaran permukaan berbanding dengan aseton pada bahan ABS

ABSTRACT

Additive Manufacturing is a technology that is use commonly nowadays. The purpose of this project is to investigate the chemical reaction to surface roughness by using a vapour smoothing process. The objective of this project is to improve the surface roughness by using chemical reaction. Biomedical implant replicas is fabricated using fused deposition modeling machine to compare with the conventional method. This project focuses on the hip implant replicas surface and the chemical will be used obtain better surface roughness on the replicas surface. The complex shape of the hip implant can causes increasing the surface roughness if fail to find the prefect parameter combination. Design of experiment (DOE) is an effective tool to optimization of a product or process quality. DOE is also to see how changing multiple design and process variables effects to achieves the best results. The ABS product produced by Fused Deposition Modeling (FDM) has its own unique result which varies with the changes of the process parameters of the machine such as orientation angle, layer thickness and raster angles. After the chemical has selected the vapour smoothing process is done. That chemical must be a solvent properties to reduce the surface roughness. Then the replicas were observed for tested surface roughness using Mitutoyo Surftest SJ 301. The results were obtained and data was analysed. Maximum percentage change in surface roughness has reduce surface roughness. Results have found out that the maximum percentage change in surface roughness for is tetrahydrofuran has recorded the smoothest surface on replicas 21 (98.55%) with 30 minutes vapour smoothing time.

DEDICATION

I would like to dedicate this work to my

My beloved parent:

Kadir Naina bin Abu Muhammad & Ahsiah binti Ariffin

Dearest siblings

Honourable Supervisor and lecturers

My friends and technician

ACKNOWLEDGEMENT

I would like to thank my supervisor, Associate Professor Dr. Shajahan bin Maidin from the Faculty of Manufacturing Engineering Universiti Teknikal Malaysia Melaka (UTeM) for the continuous encouragement, support, invaluable supervision, timely suggestions and inspired guidance in towards the completion of this Final Year Project to a successful completion.

In addition, I would like to express my gratitude to technicians for guide me use the facilities available in the laboratory to carry out the project successfully. Last but not least, to my family, especially my parents that continuously give me moral support while doing this project and I want to express my sincere thanks to all my friends and who have patiently extended all sorts of help for accomplishing the Final Year Project.

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3D	-	3 Dimensional
ABS	-	Acrylonitrile Butadiene Styrene
ANOVA	-	Analysis of variance
CAD	-	Computer aided design
CAE	-	Computer aided engineering
CAM	-	Computer aided manufacturing
CNC	-	Computer numerical control
(CH3)2CO	-	Acetone
C4H8O	-	Tetrahydrofuran
DOE	-	Design of experiment
DOF	-	Degree of freedom
EBM	-	Electron beam melting
FEA	-	Finite element analysis
FDM	-	Fused deposition modeling
PET	-	Polyethylene terephthalate
PLA	-	PolyLactic Acid
PLC	-	Programmable logic controller
PMMA	-	Poly(methyl methacrylate)

Ra	-	Surface Roughness
SEM	-	Scanning electron microscope
SLA	-	Stereolithography
SLM	-	Selective laser melting
SLS	-	Selective laser sintering
STL	-	Stereolithography
VS	-	Vapour Smoothing

CHAPTER 1

INTRODUCTION

This chapter introduces the project and briefly describes the project background, problem statement, objective, and scope of a fused deposition modelling and vapour smoothing process for surface finishing for surface of biomedical implant replicas.

1.1 Background of Study

Additive Manufacturing (AM) is a process that build 3D objects by adding layer by layer of material without conventional tooling. This method of manufacturing could improve the process manufacturing in biomedical implant replicas where it will reduced manufacturing time. Fused Deposition Modelling (FDM) is one of the most extensively used additive manufacturing technique which can construct physical models from computer aided design (CAD) software automatically by using layer deposition of extrusion materials and it also can shortened the product development time and cost. FDM printers use a thermoplastic filament, which is heated to its melting point and then extruded, layer by layer, to create a three dimensional object. The technology behind FDM was invented in the 1980s by Scott Crump, co-founder and chairman of Stratasys Ltd., a leading manufacturer of 3D printers. The application has been extended to fabricate biomedical implants through investment on casting process. The FDM replicas shows a poor surface finish and poor surface quality which requires further post finishing. Thus, it is very difficult to achieve adequate dimensional accuracy as surface finishing techniques resulted in material removal and erosion of upper surface.

The vapour smoothing (VS) is a solvent smoothing utilize a chemical agent which act as an agent to smooth a surface. This process can improve the surface of FDM part by eliminating layer lines while preserving feature detail and part accuracy. There are two type of smoothing agent that can be applied either liquid or vapour. In present research, the efforts are made to explore the influence of FDM and VS process parameters in dimensional features of complex design.

Medical application of rapid prototyping is feasible for specialized surgical planning and prosthetics applications and has significant potential for development of new medical applications. One of the area that are not widely explored in the manufacturing of biomedical implant using additive manufacturing. Method that commonly in biomedical field is casting, molding and machining.

This project will determine the possibility and benefit of using AM, which focusing on fused deposition modelling and vapour smoothing process for biomedical field. This project also is to identify the best combination of parameters which are divided into two fused deposition modelling and two vapour smoothing. FDM parameter is focusing on the orientation angle and type of material while the VS is smoothing time and type of chemical. This parameter influence the surface roughness of fused deposition modeling produced in biomedical. The experiment will be conducted using design of experiment with three level for each factor.

1.2 Problem Statement

Majdi *et al.* (2017) discussed that AM technology is not competitive compare to conventional method such as injection moulding, casting and CNC machining. Conventional manufacturing method is one of the suitable method to fabricating biomedical implants but not effective on complex shape. The orientation angle, layer thickness, and material is the parameter that will influence the surface roughness. The combination of the machining parameter can be determine by the surface roughness of the product to ensure the quality of the product surface finish (Ahilan *et al*., 2013).

Royal Academy of Engineering (2013) pointed out that the design of experiment is use to determine best combinations of parameter and the amount of runs of the experiment will be carried out. The best combinations of the different settings on the parameter in fused deposition modeling machine is to determine the surface roughness. When the product produce, finishing activities is needed this is depending on the complexity of the product. Secondary processing is needed such as chemical finishing and mechanical finishing to improve the surface roughness (Syed, 2015).

The application of FDM for rapid casting for biomedical applications is required to test the surface roughness techniques on real replicas of implants. Conventional method can be change to AM technology but the time needed to improve the surface roughness is longer. Vapour smoothing process can replace traditional method in term of time, cost and accuracy. This is to study the surface finish (Chohan and Singh, 2017).

The surface of the specimen will undergo vapour smoothing process by the two chemicals, to improve the surface finish on the specimen. The best chemical will have lower surface roughness and it's selected.

1.3 Objective

The objective of this project are:

1. To fabricate biomedical replicas by using Fused Deposition Modelling.
2. To optimize the fused deposition modeling process parameter by using design of experiment (DOE) method.
3. To investigate the effect of using 2 chemical to improve the surface roughness.

1.4 Scope

This project covers the study of how the combination of different parameters such as type of material, orientation angle, type of chemical and smoothing time affects the manufacturing time, surface roughness and surface hardness of the hip implant replica produced using FDM process. Hip implant replicas is selected in this project study is to identify either the surface roughness affected with the complex shape of this replicas. The hip implant is drawn by using Solidwork 2016 and converted to STL files to make sure it can able read by FDM machine. During the project the FDM process is at FTMK ground floor, Lab rapid prototyping. The material use for the hip implant replicas is ABS-M30i thermoplastic materials. The chemical test is based on two different of chemicals used acetone and tetrahydrofuran. The surface roughness of the hip implant are measured in Mitutoyo Surftest SJ-301 in FKP ground floor, Block B, Metrology Laboratory. Than each area of the hip implant is repeated three times to obtain more precise average surface roughness $R\alpha$ value. Than the weight of the specimen/replicas is measure, before and after the chemical treatment. The process parameters are optimized using Design of experiment (DOE) method. Applying DOE in the experiment can determined the best combinations of process parameters in which the combination has the shortest time, cost and the best surface finish.

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss about the related knowledge of fused deposition modelling and vapour smoothing process for surface finishing for surface of biomedical implant replicas.

2.1 Additive Manufacturing (AM)

Additive manufacturing (AM) is well technology that is discover by the French scientist Alain Le Mehaute. AM is also known as 3d printing that create products through the additional of material with different method in place of the subtraction of material from a raw part. AM allows complex design that are impossible or difficult to design via conventional method. Conventional method need more time to generate compare to AM (Brischetto *et al.*, 2017).

AM standard within the manufacturing industry, defines additive manufacturing as a process joining material to make objects from 3D model data, for making object layer directly from a computer aided design (CAD) data file. The CAD-based 3D model is typically save as standard tessellation language (STL) file (Syed, 2015).