UNIVERSITI TEKNIKAL MALAYSIA MELAKA

A STUDY TO DETERMINE THE BEST COMBINATION OF FDM PROCESS PARAMETERS USING TAGUCHI METHOD TO OPTIMIZE THE BUILD TIME AND SURFACE QUALITY

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

by

NG MEE CHIN

B051210015

921222-07-5478

FACULTY OF MANUFACTURING ENGINEERING

2016

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: A Study To Determine The Best Combination Of FDM Process Parameters Using Taguchi Method To Optimize Build Time And Surface Quality

SESI PENGAJIAN: 2015/16 Semester 2

Saya NG MEE CHIN

mengaku membenarkan Laporan 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:

8-7-13, Persiaran Paya Terubong

Satu, Ralau, 11900 Bayan Lepas

Pulau Pinang.

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 "A Study To Determine The Best Combination Of FDM Process Parameters Using Taguchi Method To Optimize The Build Time And Surface Quality" is the results of my own research except as cited in references.

Signature	:	…….
Author's Name	:	NG MEE CHIN
Date	:	25 JUNE 2016

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:

……

(DR. SHAJAHAN BIN MAIDIN)

ABSTRAK

Kaedah Taguchi adalah alat yang berkesan diperkenalkan untuk pengoptimuman produk atau proses kualiti. Produk yang dihasilkan oleh ABS Fused Deposition Model (FDM) mempunyai hasil yang tersendiri yang berbeza dengan perubahan parameter proses mesin seperti orientasi membina, ketebalan lapisan dan sudut raster. Prestasi bahagian yang dihasilkan melalui Stratasys FDM 400 mesin MC diperhatikan masa membina dan diukur untuk kekasaran permukaan. Dalam usaha untuk mencapai prestasi optimum bahagian yang dihasilkan, Kaedah Taguchi telah dilaksanakan. Dalam projek ini, pelbagai ortogon daripada L_9 (3^3) telah digunakan dan 9 keping sampel telah dibina untuk 3 parameter iaitu: membina orientasi, ketebalan lapisan dan sudut raster dengan 3 tahap setiap parameter. Sampel itu direka menggunakan SolidWorks dan dibina menggunakan Stratasys FDM 400 mesin MC. Sampel diperhatikan masa membina dan kemudian diuji untuk kekasaran permukaan menggunakan Mitutoyo Surftest SJ 301. Keputusan telah diperolehi dan data dianalisis. Data menunjukkan bahawa sampel dengan kombinasi parameter XY orientasi, ketebalan lapisan 0.03302 cm dan sudut raster 90^0 mencapai masa membina yang paling singkat manakala data yang menunjukkan bahawa sampel dengan kombinasi parameter XY orientasi, ketebalan lapisan 0.01778 cm dan raster sudut 30^0 mencapai kekasaran permukaan purata yang paling rendah mengikuti nilai Ra masing-masing. Oleh itu, keputusan ini menunjukkan bahawa ciri-ciri produk yang dihasilkan menggunakan Stratasys FDM 400 MC berbeza dengan kombinasi yang berbeza parameter proses dan Kaedah Taguchi menyediakan penyelesaian untuk menentukan kombinasi yang optimum dengan jumlah minimum eksperimen.

ABSTRACT

Taguchi Method is an effective tool introduced for the optimization of a product or process quality. 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 build orientation, layer thickness and raster angles. The performance of the part produced via Stratasys FDM 400 MC machines was observed for build time and measured for surface roughness. In order to achieve the optimum performance of the produced part, the Taguchi Method was employed. In this project, an orthogonal array of L_9 (3^3) was used and 9 pieces of samples were determined for 3 parameters namely: build orientation, layer thickness and raster angles with 3 levels each. The sample was designed using SolidWorks and fabricated using Stratasys FDM 400 MC machines. The samples were observed for build time and then tested for surface roughness using Mitutoyo Surftest SJ 301. The results were obtained and data was analysed. The data shows that the samples with parameters combination of XY orientation, layer thickness of 0.03302 cm and raster angle of 90^0 achieved the shortest build time while the data shows that the samples with parameters combination of XY orientation, layer thickness of 0.01778cm and raster angle of 30^0 achieved the lowest average surface roughness, Ra value respectively. Hence, this results show that the properties of the product produced using Stratasys FDM 400 MC vary with the different combination of process parameters and the Taguchi Method provides the solution of determining the optimum combination with minimum number of experiment.

DEDICATION

I would like to dedicate this work to my

Beloved parents

Dearest siblings

Honorable supervisor and lecturers

Supportive friends and mates

ACKNOWLEDGEMENT

I would like to express my gratitude to my supervisor, Dr. Shajahan bin Maidin for the continuous encouragement, invaluable supervision, timely suggestions and inspired guidance in bringing the Final Year Project to a successful completion.

In addition, I would like to express my gratitude to technicians for permitting me to make use of the facilities available in the laboratory to carry out the project successfully. Last but not least, I express my sincere thanks to all my friends and parents who have patiently extended all sorts of help for accomplishing the Final Year Project.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ABS	-	Acrylonitrile butadiene styrene
Adj MS	-	Adjusted Mean Square
Adj SS	-	Adjacent Sum of Squares
AM	-	Additive manufacturing
AMC	-	Advanced Manufacturing Center
ANOVA	-	Analysis of Variance
BASS	-	Break Away Support System
BS	-	British Standard
CAD	-	Computer-aided Design
CAM	-	Computer-aided Manufacturing
CNC	-	Computer Numerical Control
DOE	-	Design of Experiment
EtO	-	Ethylene oxide
FDM	-	Fused Deposition Modeling
FKP	-	Fakulti Kejuruteraan Pembuatan
GA	-	Genetic Algorithm
ISO	-	International Standard Organisation
OA	-	Orthogonal Array
PC	-	Polycarbonate

PC-ABS	-	Polycarbonate-Acrylonitrile butadiene styrene
PC-ISO	-	Polycarbonate ISO
PPSF	-	Polyphenylsulfone
Ra	-	Roughness Average
S/N	-	Signal to Noise
SOP	-	Standard Operating Procedure
STL	-	Stereolithography
ULTEM 9085	-	Polyetherimide
US	-	Unites States
UTeM	-	Universiti Teknikal Malaysia Melaka
3D	-	3 Dimension

CHAPTER 1

INTRODUCTION

This chapter introduces the project and briefly describes about the objectives and the scope of the study. This chapter will give an overview on the implementation of the project.

1.1 Introduction

Resit and Edwin (1991) proposed that Taguchi Method is a popular method used to provide systematic and efficient methodology for design optimization. Therefore, an efficient way to enhance competitiveness in improving the quality of products is to conduct Taguchi Methods to make products and processes robust during early product design and development stage. Taguchi method focuses on four business objectives in market which are short development time, low cost, high performance and high quality.

On the other hand, Omar *et al.* (2015) presented that fused deposition modeling is an additive manufacturing technology which can construct physical models from computer-

aided design (CAD) software automatically by using layers deposition of extrusion materials. In fact, fused deposition modeling is one of the additive prototyping processes which can generate a prototype from plastic material by laying track of semi molten plastic filament on to a platform in a layer wise manner from the top to bottom. The layer generation result from solidification is because of heat conduction. In fact, reduction of product development cycle time is a major consideration in industries to remain competitive in the market place. Therefore, traditional product development technology has been changed to rapid fabrication techniques, for instance, additive prototyping processes.

The main purpose of the project is to determine how the best combination of the parameters which are the layer thickness, raster angle and build orientation influence the build time and surface roughness of Fused Deposition Modeling produced test specimen. Experiments will be conducted using Taguchi's design of experiments with three levels for each factor. The combined set of different parameters can be produced using Orthogonal Arrays. Furthermore, the project studies the significance parameters that affect the build time and surface roughness of the FDM process using Analysis of Variance respectively.

1.2 Problem Statement

Ranjit (2001) pointed out that the build time of a certain additive manufactured part or product is concerned by industry due to it affects the lead time of the product. The shorter the build time of the product, the better is the benefit to the company. Bharath *et al.* (2000) discussed that surface quality plays a very important role in manufacturing precise parts, for instance, aerospace components and parts with critical dimensions. This is because product with good surface finish can ensure dimensional accuracy and

eliminate cost for post-processing processes to obtain desired surface quality. In addition, Royal Academy of Engineering (2013) proposed that AM technology is not as competitive as a conventional method such as injection moulding, casting and CNC machining. In fact, build orientation, layer thickness and raster angle are those process parameters that will influence the build time and surface roughness. The combinations of the different settings of the parameters will produce parts with different build time and surface roughness. Design of experiment using Taguchi methods to determine best combinations and the number of runs of the experiment will be carried out. The best combinations of the different settings of the parameters for build time and surface roughness are then identified.

1.3 Objective

The objective of this study is as follows:

i. To optimize the fused deposition modeling process parameters by using Taguchi's method.
ii. To produce CAD model of FDM test specimen and build them on a FDM machine using ABS material.
iii. To determine combinations of the different settings of the FDM parameters in which it can produce the shortest build time and best surface quality.
iv. To determine the optimum parameters which will influence the build time and surface roughness.

1.4 Scope

This project covers the study of how the combination of different parameters such as build orientations, layer thickness and raster angle affects the build time and surface roughness of the mounting bracket produced using FDM process. The mounting bracket is drawn using Solidwork 2012 and converted to STL files to be readable by FDM machine. Then, the FDM process will be carried out at FKP Ground Floor, Block B, AMC laboratory using Stratasys FDM 400 MC. The material used in the FDM process is ABS-M30i thermoplastic materials. Then, the mounting brackets produced are measured for surface roughness using Mitutoyo Surftest SJ-301 in FKP Ground Floor, Block B, Metrology Laboratory. Each area of the mounting bracket is repeated three times to obtain much more precise average surface roughness Ra value. In addition, macroscopic inspection will be carried out to examine the surface quality of the part produced. Two mounting brackets produced which have the best and the worst surface quality are examined under Meiji Stereo Microscope located in FKP Ground Floor Block B, Metrology Laboratory to see their difference in structure. The process parameters are optimized using Taguchi Method. By applying Taguchi in the experiment, we can determine the best combinations of process parameters in which the combination has the shortest build time and the best surface finish.

CHAPTER 2

LITERATURE REVIEW

This chapter discusses about the related knowledge of the project which cover the introduction of the additive manufacturing, fused deposition modeling and Taguchi Method.

2.1 Additive Manufacturing (AM)

Omar *et al.* (2015) have presented that additive manufacturing is one of the advanced manufacturing technologies employed for making object layer upon layer directly from a computer aided design (CAD) data file. Additive Manufacturing (AM) allows customized design to be made. Hence, shape complexity is not an issue. We will consume less time if we use AM to generate the part compared to conventional method. Moreover, AM product will result in lower cost due to the absence of tooling needs. FDM is one of the systems widely applied in additive manufacturing.

Furthermore, Pandey *et al.* (2006) have presented that AM is not similar compared to lathing, milling and grinding as they will use material removal process to produce the shape of the product.

2.2 Eight Generic AM Processes

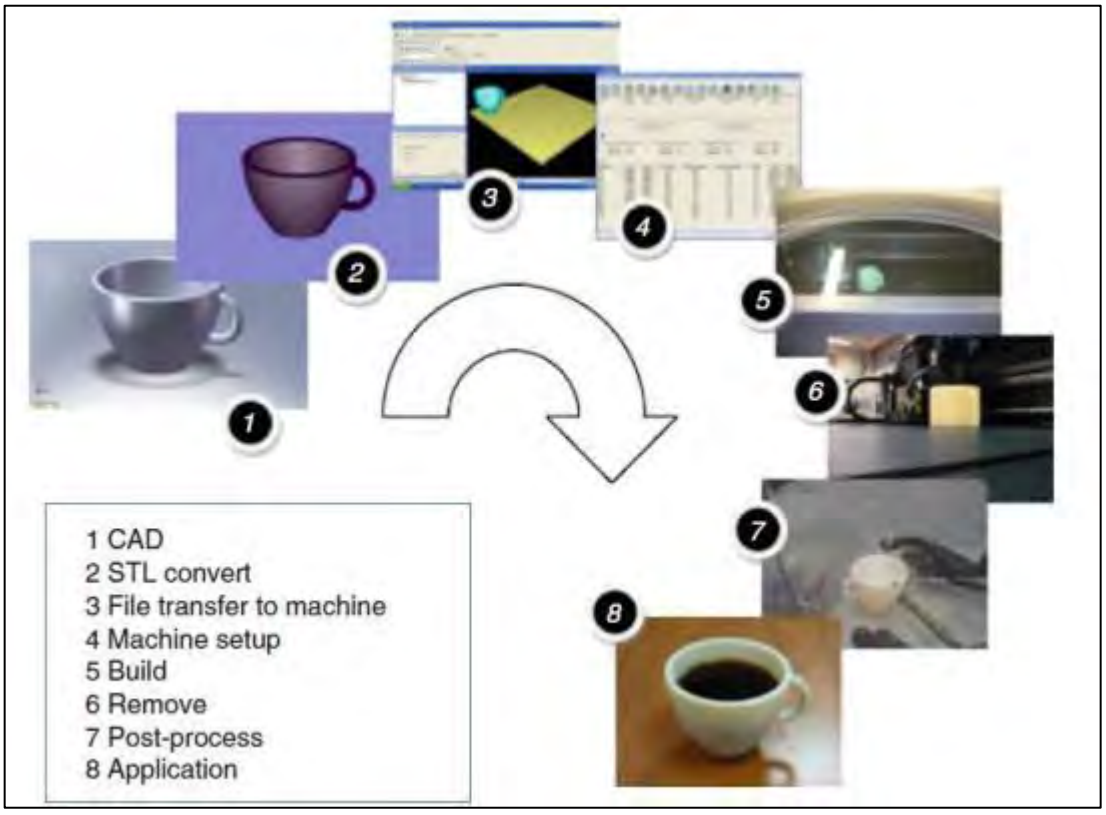

Figure 2.1: Eight Generic AM Processes (Gibson *et al*., 2010)

From the Figure 2.1, it is clearly shown that there are eight steps needed to produce a part for FDM machine.