PROCESS OPTIMIZATION TO IMPROVE SURFACE FINISH IN FUSED DEPOSITION MODELING

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

by

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I hereby, declared that this report entitled "Process Optimization to Improve Surface Finish in Fused Deposition Modeling" is the results of my own research as cited in reference.

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Author's Name : NOR FARAHIN AIDA BINTI ADNAN

Date : 25 MAY 2018

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering Of UTeM as partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons). The members of the supervisory committee are as follow:

……………………………………….

Supervisor

(DR.MOHD SHAHIR BIN KASIM)

ABSTRAK

Pada masa kini, "Fused Deposition Modeling” (FDM) merupakan salah satu teknik yang terkenal dalam teknologi pengilangan tambahan (AM). "Fused Deposition Modeling” (FDM) adalah salah satu kaedah di bawah “Rapid Prototyping” (RP). “Rapid prototyping” (RP dan “Rapid Tooling” (RP) digunakan secara meluas dalam pembangunan dan pembuatan bahagian. Dalam proses ini, ia akan dibuat berlapis dengan lapisan yang dikenali sebagai lapisan pembuatan (LM). Untuk proses ini, beberapa bahan biasanya digunakan seperti Acrylonitrile Butadiene Styrene (ABS), polikarbonat (PC), ULTEM 9085 dan akhirnya adalah Polyphenylsulfone (PPSU). Kemudian, dalam proses mencipta prototaip ini di FDM, bahan yang akan digunakan adalah ABS kerana harga yang berpatutan dan mudah diperoleh manakala bahan-bahan lain terkadang lebih mahal dibandingkan dengan ABS. Selain itu, ABS juga mempunyai kekuatan dan kekerasan yang sama walaupun ia lebih murah. Kualiti prototaip yang dihasilkan dari FDM bergantung kepada parameter proses yang berbeza dari proses FDM. Oleh itu, projek ini akan memberi tumpuan kepada parameter proses untuk mendapatkan kemasan permukaan yang cemerlang untuk prototaip dan melihat kesan parameter yang digunakan pada kemasan permukaan prototaip. Hasilnya boleh diperoleh dengan menggunakan kaedah Taguchi dan Analisis Varians (ANOVA). Jumlah eksperimen adalah 9 eksperimen menggunakan Taguchi Trapezium berbentuk ABS dicetak dengan menggunakan perisian SolidWorks. Daripada eksperimen, nilai parameter optimum yang dipilih berdasarkan graf nisbah S/N ialah kelajuan pemendapan (100mm), infill atas (15%) dan ketumpatan mengisi (100%). Sementara itu, faktor dominan yang mempengaruhi kemasan permukaan adalah mengisi ketumpatan dan diikuti dengan kelajuan pemendapan dan infill atas. • Nilai Ra terbaik untuk 3 bahagian yang berlainan ialah RaH (1.560 μm), RaV (13.810 μm) dan terakhir, untuk RaS (14.670 μm). Akhir sekali, peratusan kesilapan antara nilai ramalan dan nilai percubaan ialah 0.41% yang boleh diterima kerana nilai adalah di bawah daripada 10%.

ABSTRACT

Nowadays, fused deposition modeling (FDM) is one of the famous technique in additive manufacturing addictive manufacturing (AM) technologies. Fused deposition modeling (FDM) is one of the methods under rapid prototyping (RP). Rapid prototyping (RP) and rapid tooling (RP) is widely used in development and creating part. In this process, it will done layered by layered where it is known as layered manufacturing (LM). For this process, a few materials usually used such as Acrylonitrile Butadiene Styrene (ABS), polycarbonate (PC), ULTEM 9085 and lastly is Polyphenylsulfone (PPSU). Then, in process of creating this prototype in Fused Deposition Modeling (FDM), the material will be used is ABS due to it is price that affordable and easy to get while the other materials sometimes more expensive compare to ABS. Besides, ABS also has the same strength and hardness despite it is cheaper. The quality of prototype fabricated from FDM is depending on different process parameters of FDM process. Thus, this project will be focus on the process parameter in order to obtain excellent surface finish for prototype and observe the effect of the parameter on surface finish of the prototype. The results can be obtained by using Taguchi method and Analysis of Variance (ANOVA). The total number of experiment is 9 experiments using the Taguchi. The trapezium shaped of ABS printed was created by using SolidWorks software. From the experiment, the value of optimum parameter choose based on the S/N ratio graph are speed of deposition (100mm) , top infill (15%) and fill density (100%) . Meanwhile, the dominant factor that affected the surface finish is fill density and followed by speed of deposition and top infill. The best Ra value for 3 different parts are RaH (1.560 µm), RaV (13.810 µm) and lastly, for RaS (14.670 µm) respectively Last but not least, the percentage of error between predicted value and experimental value is 0.41 % which is acceptable due to the value is below than 10%.

DEDICATION

I am dedicating this work to my beloved parents, Adnan Bin Idris and Nor Haliza Bt Hashim, who always give me support endlessly in everything I do. I am also would like to thank to my caring supervisor, panels and friends for the helped and support that they always give along this project journey.

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LIST OF ABBREVIATIONS AND SYMBOLS

RP	-	Rapid Prototyping
LM	-	Layered Manufacturing
ABS	-	Acrylonitrile Butadiene Styrene
PC	-	Polycarbonate
PPSU	-	Polyphenylsulfone
FDM	-	Fused Deposition Modeling
ABSi	-	Acrylonitrile Butadiene Styrene – Biocompatible
3D CAD	-	Three-dimensional Computer-Aided-Design
STL	-	Standard Triangulation Language
3D	-	Three-dimensional
AM	-	Additive manufacturing
ANOVA	-	Analysis of variance
DoE	-	Design of experiment
IM	-	Injection Moulding
CAD	-	Computer-Aided-Design
CNC	-	Computer Numerical Control
SL	-	Stereolithography
LS	-	Laser Sintering
LOM	-	Laminated Object Manufacturing
DLP	-	Digital Light Processing
CT	-	Computer-Assisted Tomography
MRI	-	Magnetic Resonance Imaging
RPT	-	Rapid Prototyping Tooling
PPS	-	Pusat Pasca-Siswazah
SAN	-	Styrene Acrylonitrile
Y – axis	-	Vertical axis
X – axis	-	Horizontal axis
S/N ratio	-	Signal-Noise Ratio
RaH	-	Surface Roughness for Horinzontal

RaV	-	Surface Roughness for Vertical
RaS	-	Surface Roughness for Slanted
dB	-	Decibels
mm	-	Millimetre
µm	-	Micrometer
˚C	-	Degree Celcius
°	-	Degree
%	-	Percentage

CHAPTER 1
INTRODUCTION

In this chapter 1 contains the background of study, problem statement, scope, objectives, important of study and organization of report.

1.1 Background of Study

In this modern technology, mostly of the traditional product development has changed from traditional process to rapid prototyping because it can save time and cost of production. rapid prototyping (RP) and rapid tooling (RP) is widely used in development and creating part. The best surface finish on the parts helps wipes out dimensional mistake and expenses because of consequent post-processing of the part to attain the desired surface finish. Basic surface imperfections involve the staircase effect, support structure burrs and failure because of the beginning and ending of deposition (Vasudevarao *et al*., 2000). In this process, it will be done layered by layered where it is known as layered manufacturing (LM) as a direct or indirect technique. Then, there are a few materials can be used such as Acrylonitrile Butadiene Styrene (ABS), Polycarbonate (PC) and lastly is Polyphenylsulfone (PPSU). Moreover, in process of creating the prototype in Fused Deposition Modeling (FDM), the material will be used is ABS due to its advantages where it is affordable compare to the others materials but still have the same hardness and strength. Each of FDM model has different types of process parameters for different applications. Thus, this project will be focus on the process parameter in order to obtain excellent surface finish for prototype as well as the good result at the end of the process. The layer thickness is one of the most influencing parameter for the surface finish. So, layer thickness will be use as constant parameters in this project followed with other two fixed parameters which are part angle and temperature.

1.1.1 Fused Deposition Modeling (FDM)

Fused Deposition Modeling (FDM) is sort of additive manufacturing technologies that empower the development of three-dimensional items, models and products through a computer-aided or driven manufacturing assembling process. Other than that, FDM also known as fused filament fabrication or fused deposition method. The filament of heated material being extruded through a nozzle then will deposited onto the platform that have lower temperature so it can made the models become hardens immediately. In FDM machine, the nozzle will move in X and Y direction. Moreover, as RP technique procedure said before, a layer will be creating on top of other by one by one until the model is completed. Lastly, the materials used depend on the model's function and criteria such as elastomer, polycarbonate, Acrylonitrile Butadiene Styrene (ABS) or ABSi (high impact ABS).

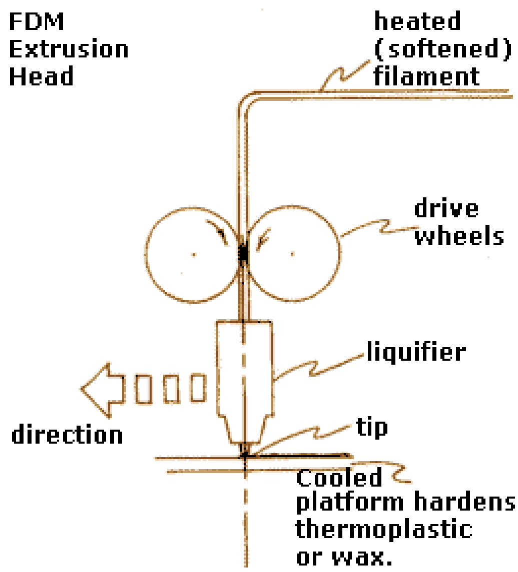

Figure 1.1: Schematic diagram of fused Deposition Modeling (FDM).

1.1.2 Rapid Prototyping (RP)

Rapid Prototyping (RP) is known as a technology that used to produce prototype or any physical model from three-dimensional Computer-Aided-Design (3D CAD) drawing that had been save in STL file format in a very short time. Thus, RP always been used in vary industry such as medical, jewellery and mobile phone. A layer of material used such as thermoplastic or polycarbonate is layer one by one on top of previous layer until the design of the model is completed. Besides, any model from simple and complex design can be fabricated within hours and this can make increase the productivity of the product. Three-dimensional (3D) printing is a better among the most flexible and progressive additive manufacturing (AM) method to make 3D objects with one of a unique structure and varied properties (Stansbury & Idacavage, 2016).

1.2 Problem Statement

In this modern era, an additive manufacturing of fabrication process that builds a part, models or components usually used Rapid prototyping (RP) compared to the traditional ways. This is because rapid prototyping is most flexible and it can produce prototype in a short time compared to the other process. Furthermore, the surface finish of the pattern sometimes will affect the surface finish of the investment casting. But unfortunately, by using FDM to produce parts sometimes does not give a good surface finish compared to the wax pattern, which are commonly used in investment casting (Singh Bual & Kumar, 2014). Besides, some researched also had done an experiment in order to find out the process of optimization by using FDM but most of them only focused on part orientation, layer thickness, temperature, part angle and environmental factors and mostly of the researched used Taguchi method. RP process is naturally performed by layered manufacturing, those surface finishes of the RP part will be unavoidably excessively rough. The part that extremely become defect on the slanted surfaces of the parts known as the "stair stepping effect". As the surface finish of the parts is not satisfying for normal engineering purposes and this make the surface roughness become an issue in RP (Ippolito *et al*., 1995; Reeves and Cobb, 1997; Mahesh *et al*., 2004). According to Boschetto and Bottini (2014), parts fabricate by RP have an accuracy and surface roughness poorer than those made by machining process. Moreover, there are also some of research works related to the topic of surfaces finish have been presented, but most of them only focused on the problem of the part for process optimization (Ahn *et al*., 2009). In recent years, researchers have explored a few ways to improve the mechanical properties and part quality using different experimental design techniques and concepts (Mohamed et al., 2015). By using the Taguchi technique and analysis of variance (ANOVA), it analyzes the parameters of layer thickness, road width and speed deposition to get the effect of critical parameters for getting great surface roughness. At the end, layer thickness is the most effected parameter for surface roughness (Anitha *et al*., 2001). Therefore, an experiment will be done for specimen "trapezium" made from ABS in fused deposition modelling (FDM) in order to study the optimization of parameter to improve the surface finish by using design of experiment (DoE) for Taguchi method.

1.3 Objectives

Based on the difficulty turn up when doing this project which is to study the process optimization to improve surface finish in FDM, there are several objectives that exist:

i. To evaluate the relevant parameters used to achieve the excellent surface finish in FDM

ii. To investigate the effect of parameter on surface finish in Fused Deposition Modeling (FDM)

1.4 Scope

In this scope part will be focused on the Fused Deposition Modeling where it is one of Rapid Prototyping (RP) technologies today. FDM is the solid-based RP process where it is universal used in creating design and product development processes. It is also using ABS material which is in this project used ABS 3D print with diameter coil 1.75mm. It comes in vary colour but it is not important to use any colours because it does not affected the surface finish of the prototype.

The varying parameter will be observe which are top infill, speed of deposition and fill density in order to get desired surface finish of prototype. In this project, the fixed parameter will be based on the previous researched which are temperature, layer thickness and part angle. The software used in this experiment formerly known as Repetier-Host software.

There is a platform use for printing in FDM machine and the temperature of FDM machine will heat until it reached 50 ˚C then it will continue with the nozzle of FDM machine where it will heat up to 220 ˚C so that it can melt the filament before it can be used to start the printing process. Besides, the size of filament will be use is 1.75mm and the surrounding temperature must be around 30˚C. Then, for the analysis, the data will be analyzed by using Design of Experiment (DoE) in term of Taguchi method.

1.5 Important of Study

There are several benefits that can be obtained when this project is completed. As we all know Fused Deposition Modeling (FDM) is commonly used in industry for rapid prototyping part by using Acrylonitrile Butadiene Styrene (ABS) because ABS can melt in suitable temperature in order to get a great surface finish. In addition, many problems can solve especially in rework problems and which dimensional and temperature can be use in future in order to get good quality surface finish product. Thus, we can reduce or avoid rework when doing any ABS part by using FDM.

1.6 Organization Thesis

In chapter 1, a few parts will be discussed which are the objectives, problem statements of this project, the machine and process used to fabricate the prototype are identified. Next, the scope will focus on the area of study for project. Then, for chapter 2 which is the literature review is describe by searching some journals from previous research for their supports in discussion and methods used for project. Besides, literature review will be done by searching any reliable resources from books, internets or journals.

Lastly, for chapter 3 which is methodology mentions the procedure used for the project. It also includes the software, the type of material used and the parameter chosen for the project. For chapter 4, the analysis will be analyzed by using DoE using Minitab version 17 in term of Taguchi method and ANOVA.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

In this chapter 2 which is literature review, it will focused on the previous research about the fused deposition modeling (FDM), Rapid Prototyping (RP) and others discussion that have been done before by the other researchers regarding to the parameter that will improve the surface finish of prototype. Furthermore, this chapter objective also to gain more understanding about the FDM, RP, the material used which is ABS, measurement tools used and software involve in fabricate the prototype with proof of research or study in related subject.

2.2 Rapid Prototyping (RP)

In this modern era, Rapid prototyping (RP) has grown and become one of the most used in additive manufacturing industry. By using rapid prototyping method, a lot of complex shaped can be fabricate by adding and alternately modifying materials in layer (Boschetto & Bottini, 2014). Furthermore, Singh (2013) stated that these "three dimensional printers" enable designer to rapidly make real models of their pattern, as opposed to only two-dimensional pictures. Next, Boschetto & Veniali (2010) claimed that by comparing to the classical techniques for example CNC milling, it permit to form parts specifically from computer information without geometry restriction in toolless, automated and also patternless approaches.

Besides, Boejang *et al*. (2013) found that in the presence of RP methods, the time of fabrication of one part can be done faster compared to the traditional methods. Thus, the new product can be put into the market in a short time with less rework. Furthermore, RP methods can be done by several machining such as Stereolithography (SL), Laser Sintering (LS), Fused Deposition Modeling (FDM) and 3D Printing (ZCorp), Laminated Object Manufacturing (LOM) and lastly, Digital Light Processing (DLP).

Moreover, Ahn et al. (2009) stated that rapid prototyping (RP) is a manufacturing innovation technology that fabricates 3D physical models by using a layered manufacturing (LM) procedure that stacks and bonds thin layers in one direction. Then, RP technology is used to produce prototype from thermoplastic material such ABS material. Moreover, Boejang *et al*., (2013) claims that most of the RP techniques always used in industry such as jewellery, medical and mobile phone.

2.2.1 RP Procedure from CAD Drawing to Prototype

Based on Figure 2.1, we can see the flow of procedure of Rapid prototyping from CAD drawing into prototype. First of all, Boejang *et al*. (2010) stated that a model or any part is created by using surface or solid modellers CAD system and then it will converted into standard triangulation language (STL) format and STL format is de-facto to all Rapid prototyping system. Next, the third stage of this process is a pre-processing program provide the STL file to be assembled. A few projects are accessible, and most enable the user to change the size, area and orientation of the model (Singh, 2013).

Then , the STL file will be transfer into a software that suitable and can be connected to the Rapid prototyping machine. Boejang *et al*. (2010) said that the process continues with Rapid prototyping system start to manufacture the model layer by layer until the last layer is form. The layer manufacturing (LM) has made the fabrication of model that has complex 3D design become easy and simple to be manufacture. The last step is post-processing for prototype which including the support removal,part washing,de-waxing or infiltration,post curing, sanding and painting and some other process that depends on the end-used of the prototype and type of Rapid prototyping machines used in manufacture the prototype.

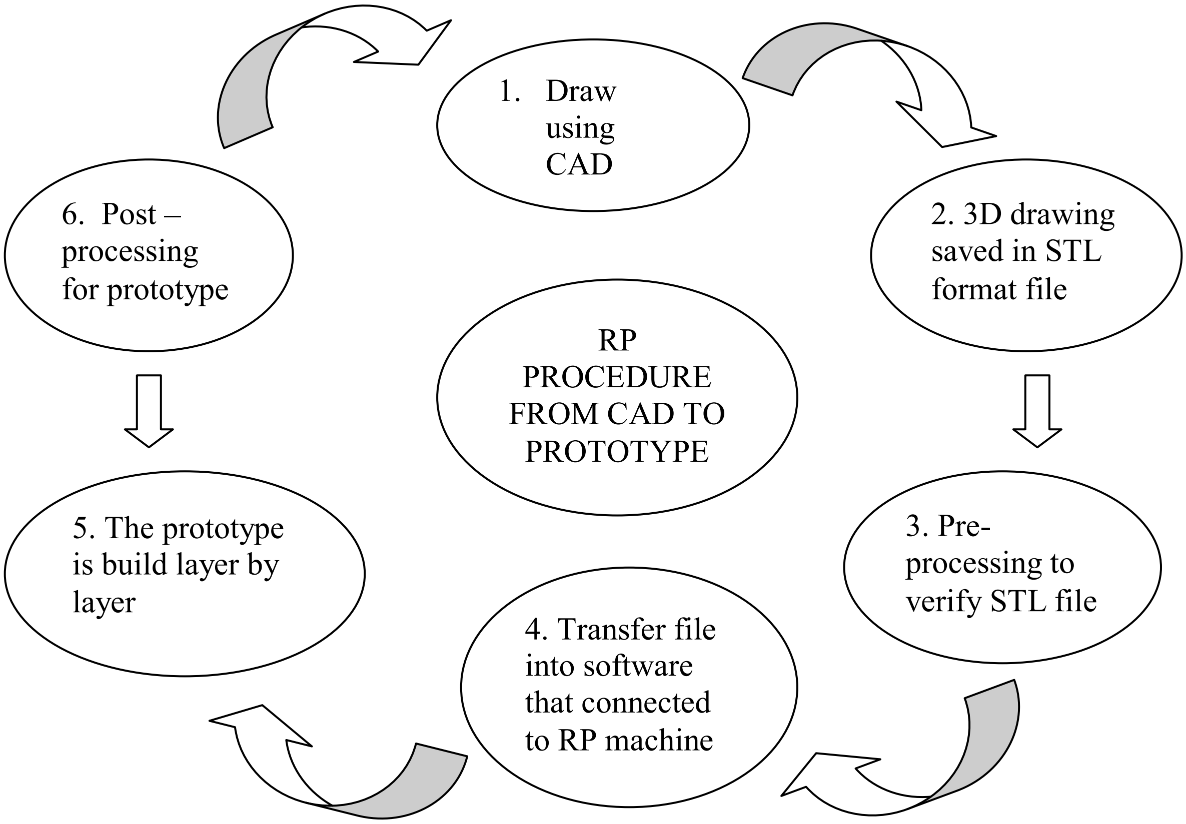

Figure 2.1 Procedure of CAD drawing into prototype (Boejang *et al*., 2010)

2.2.2 Advantages of RP

There are few advantages of RP that can be obtained and these are the reasons why RP usually used in additive manufacturing industry.

- Enhance the Product Quality

  Before entering the market, any products that have problems or small damages can be drawback or eliminated earlier so that the consumer will get the best product from the production. Thus, enhancement of product quality can be achieved when the manufactures have a plenty times to and space to making an analysis of product that already been produced (Boejang *et al*.,2013).