UNIVERSITI TEKNIKAL MALAYSIA MELAKA

IMPROVING MECHANICAL PROPERTIES OF FUSED DEPOSITION MODELING PRINTED PART WITH OPTIMIZED PARAMETER

This report is submitted in with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Manufacturing Engineering Technology (Product Design) with Honours.

by

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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of the Bachelor's Degree in Manufacturing Engineering Technology (Product Design) with Honours. The member of the supervisory is as follow:

……

(MADAM NURULAIN BINTI MAIDIN)

(Project Supervisor)

ABSTRAK

Pemodelan pemendapan yang bersandar (FDM) adalah teknologi prototaip cepat pesat (RP) yang berkembang pesat kerana keupayaannya untuk membina bahagian berfungsi yang mempunyai bentuk geometri yang kompleks dalam waktu membina yang munasabah. Ketepatan dimensi, kekasaran permukaan, kekuatan mekanik dan di atas semua fungsi bahagian yang dibina bergantung kepada banyak pembolehubah proses dan tetapannya. Selain itu, prototaip Rapid adalah teknologi yang dapat menghasilkan objek 3D secara langsung dari fail CAD, yang bertentangan dengan proses pemesinan konvensional. Secara amnya, pemesinan konvensional telah membuang lapisan bahan mentah dengan lapisan tetapi prototaip cepat menambah lapisan bahan mentah oleh lapisan. Projek ini membincangkan bagaimana meningkatkan sifat mekanik pemendapan pemendapan yang bercampur dengan bahagian yang dicetak dengan parameter yang dioptimumkan. Oleh itu, untuk analisis tentang sifat-sifat mekanikal perlu merancang tulang anjing mengikut saiz yang telah ditetapkan dengan menggunakan perisian model reka bentuk komputer (CAD) yang dibantu komputer dan mengeksport ke stereolitografi (STL) fi le. Dalam projek ini, dua puluh tujuh sampel tetapan tulang anjing akan digunakan dalam fabrikasi prototaip. Kemudian, sampel tulang anjing akan digunakan untuk analisis sifat-sifat mekanik seperti kekuatan tegangan dan kekasaran permukaan. Selepas itu, perlu analisis sifat-sifat mekanik sampel dari segi kekuatan tegangan dan kekasaran permukaan. Untuk menguji kekuatan tegangan sampel adalah perlu menggunakan mesin UTM, dan ujian kekasaran permukaan dengan menggunakan alat kekasaran permukaan. Kemudian, projek ini akan meningkatkan sifat-sifat mekanik pemendapan pemendapan yang dicetak dengan parameter yang dioptimumkan dengan menggunakan kaedah Taguchi. Kekuatan tertentu projek ini adalah dengan parameter yang dioptimumkan dengan menggunakan kaedah Taguchi untuk meningkatkan sifat mekanik pemodelan pemendapan yang bercampur.

ABSTRACT

Fused Deposition Modeling (FDM) is a fast growing Rapid Prototyping (RP) technology due to its ability to build functional parts having complex geometrical shapes in reasonable build time. The dimensional accuracy, surface roughness, mechanical strength and above all functionality of built parts are dependent on many process variables and their settings. Besides that, Rapid prototyping is technologies that able to generate a 3D object directly from the CAD file, which was opposite with the conventional machining processes. Generally, conventional machining was removing the raw materials layer by layer but rapid prototyping is adding the raw material layer by layer. This project discuss how to improving mechanical properties of fused deposition modeling printed part with optimized parameter. Therefore, to analysis about mechanical properties need to design the dog bone according to predetermined size using 3D computer aided design (CAD) model software and exporting it into Stereolithography (STL) file. In this project, twenty-seven sample of dog bone setting will be used in fabricating the prototype. Then, the sample of dog bone will be used for analysis the mechanical properties such as tensile strength and surface roughness. After that, need to analysis the mechanical properties of the sample in terms of tensile strength and surface roughness. To test the tensile strength of sample are need using the UTM machine, and for surface roughness test by using surface roughness apparatus. Then, this project will be improving the mechanical properties of fused deposition modeling printed part with optimized parameter by using Taguchi method. The particular strength of this project is with optimized parameter by using Taguchi method to improving the mechanical properties of fused deposition modeling.

DEDICATION

To my beloved parents

MOHD ALI BIN PAGON

AZIZAH BINTI SAED

Special dedicated to my supervisor

PUAN NURUL AIN BINTI MAIDIN

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LIST OF ABBREVIATIONS, SYMBOLS, AND NOMENCLATURE

FDM	-	Fused Deposition Modeling
RP	-	Rapid Prototyping
CAD	-	Computer Aided Design
3D	-	Three Dimensional
STL	-	Stereolithography File
SLS	-	Selective Laser Sintering
S/N	-	Signal to Noise
DOE	-	Design of Experiment
UTM	-	Universal Testing Machine
ASTM	-	Standard Test Methods
BVI	-	Bulk Volume Irreducible
BET	-	Brunauer–Emmett–Teller
ABS	-	Acrylonitrile Butadiene Styrene
Ra	-	Roughness Average
UTS	-	Ultimate Tensile Strength

CHAPTER 1
INTRODUCTION

This chapter describes the background of the project and briefly explains the problem statement in this research and objectives of the study. This chapter also includes the scope of study for analysis the mechanical properties of fused deposition modeling (FDM). Besides that, this chapter will be also discussing for improving the mechanical properties of Fused Deposition Modeling (FDM).

1.1 Background of the Project

Today, FDM is a fast growing Rapid Prototyping (RP) process that integrates Computer-Aided Design (CAD), polymer science, computer numerical control, and extrusion technologies to produce three-dimensional (3D) solid objects directly from a CAD data without the use of tooling with minimum human intervention M Alhubail et al (2013). FDM process parameters play a significant role in the performance of the fabricated parts, especially in regards to mechanical properties. This project is about to investigate mechanical properties of Fused Deposition Modeling (FDM) with an optimized parameter. The mechanical properties and surface finish of functional parts are an important consideration in rapid prototyping, and the selection of proper parameters is essential to improve manufacturing solutions. Then, this project is to analysis about mechanical properties with the design of dog bone according to the predetermined size. After that, print the dog bone using the 3D-printer machine. Besides that, this project needs to analysis the

mechanical properties of Fused Deposition Modeling (FDM) such as the tensile strength and surface roughness. However, the result obtained for tensile strength and surface roughness are not a good result. So, need to find a suitable method to improve the mechanical properties in terms of tensile strength and surface roughness. Therefore, in Fused Deposition Modeling (FDM) are also have some type of 3d printer which is high end and an open-source. For this project, a machine used to produce the prototypes is 3d printer machine known as Up plus 2 which an open-source fused deposition modeling 3d printer. Besides that, it is small, reasonably priced 3D printer that offers an out-of-the-box printing solution.

1.2 Problem Statement

Nowadays, 3D printing via Fused Deposition Modeling (FDM) has developed to the probably most common rapid prototyping technology due to its ease of use and a broad range of available materials. However, the fluctuations of temperature during production will affect the mechanical properties such as tensile strength and surface roughness. Therefore, the main problem of this project is how to improve the mechanical properties of Fused Deposition Modeling (FDM) printed part by using the optimized parameter setting.

1.3 Objectives

The objective of this project is to improving mechanical properties of fused deposition modeling printed part with an optimized parameter. The objectives of these projects are:

1. To study and test mechanical properties (tensile strength and surface roughness) of the Fused Deposition Modeling (FDM) printed part.
2. To propose the best value for mechanical properties (tensile strength and surface roughness) of the Fused Deposition Modeling (FDM) printed part by using Taguchi method.
3. To optimize the parameter setting of ABS fused deposition modeling printed part for surface roughness and tensile strength.

1.4 Scope of Study

The scope of this project is specifically to analyze the mechanical properties of Fused Deposition Modeling (FDM). Firstly, need to design the dog bone according to predetermined size using 3D Computer Aided Design (CAD) model software and exporting it into Stereolithography (STL) file. Then STL file is imported into the Fused Deposition Modeling (FDM) pre-processing software and print the product using 3D - printer machine. To produce the prototypes need to using 3d printer machine which an open-source fused deposition modeling 3d printer. In this project, a sample of dog bone setting will be used in fabricating the prototype. Then, the sample of dog bone will be used for analysis the mechanical properties such as tensile strength and surface roughness. After that, analysis the mechanical properties of the product in terms which tensile strength and surface roughness using the surface roughness apparatus and UTM machine. Then, this project will be improving the mechanical properties of fused deposition modeling printed part by using optimized parameters such as the resolution (mm), infill density and quality, then improve the mechanical properties with Taguchi method.

CHAPTER 2
LITERATURE REVIEW

This chapter describes the material and process in this project. Then, explains about type of machine used in this project. Besides that, it also describes about mechanical properties of Fused Deposition Modeling (FDM) such as tensile strength and surface roughness from the previous journal and according the website. After that, the optimized parameter that used to improving the mechanical properties from the previous journal was also explained in this chapter.

2.1 Rapid Prototyping Process

Rapid Prototyping (RP) can be defined as a group of techniques used to quickly fabricate a fabricate prototype or assembly using three-dimensional Computer Aided Design (CAD) data. Rapid Prototyping is fast and low cost manufacturing a small series of component directly from the component geometry parameterization stored in a 3-dimensional CAD model Kotlinski (2014).

In addition to providing 3-D visualization for digitally rendered items, rapid prototyping can be used to test the efficiency of a part or product design before it is manufactured in larger quantities. Testing may have more to do with the shape or size of a design, rather than its strength or durability, because the prototype may not be made of the same material as the final product. Rapid Prototyping has also been referred to as solid free-form manufacturing; computer automated manufacturing, and layered manufacturing. In addition, Rapid Prototyping models can be used for testing.

2.2 3D Printing

3D printing is a processes and equipment used in the synthesis of a three-dimensional object. 3D printing is also known as additive manufacturing. Therefore, the numerous available 3D printing processes tend to be additive in nature with a few key differences. The main areas in which these processes differ are the technologies used in the process and the materials. Then, 3D printing signals the beginning of a third industrial revolution succeeding the production line assembly that dominated manufacturing starting in the late 19th century. Some methods use melting or softening material to produce the layers. Selective Laser Sintering (SLS) and Fused Deposition Modeling (FDM) are the most common technologies using this way of 3D printing.

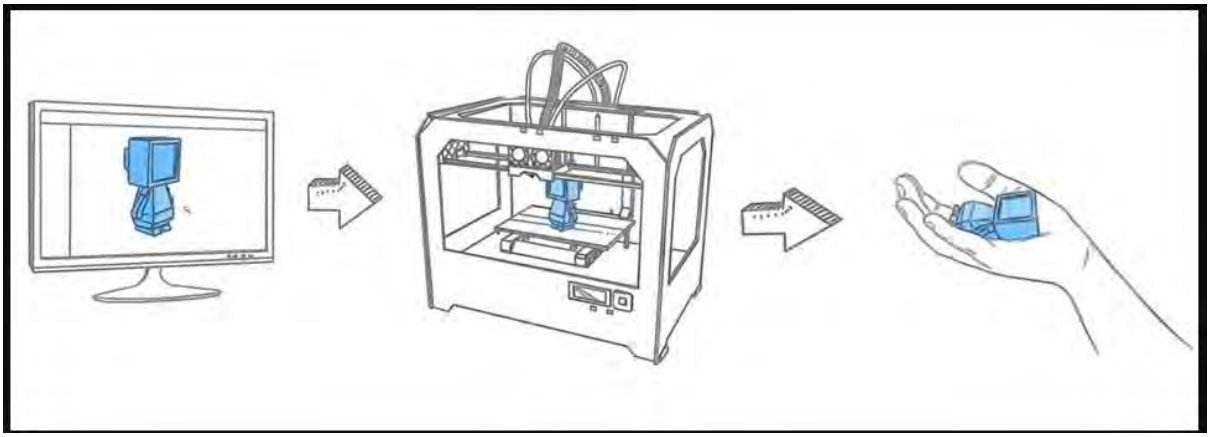

Figure 2.1: Process of 3D Printing
(Source :< http://doodlesplash.co.uk/3d-printing/what-is-3d-printing--news> 19 APRIL.2107)

2.2.1 UP Plus 2 Machine

The UP Plus 2 is an original standard bearer in great 3D printing at an affordable price, the UP Plus 2 has been employed for prototyping and final product creation in a wide array of industries including aerospace, medical, dental, science, architecture, industrial and mechanical engineering, scale model creation and more. Besides that, the UP Plus 2 have need groundbreaking and time-saving feature and was the first 3D printer in its class with an automatic platform calibration system. A probe's sensor checks nine different points on the build surface for irregularities. Furthermore, the UP Plus 2 also have there is variation from one point to another and then has compensation settings is automatically entered into UP Studio. Not only does the Plus 2 automatically calibrate platform level, it also automatically calibrates nozzle height.

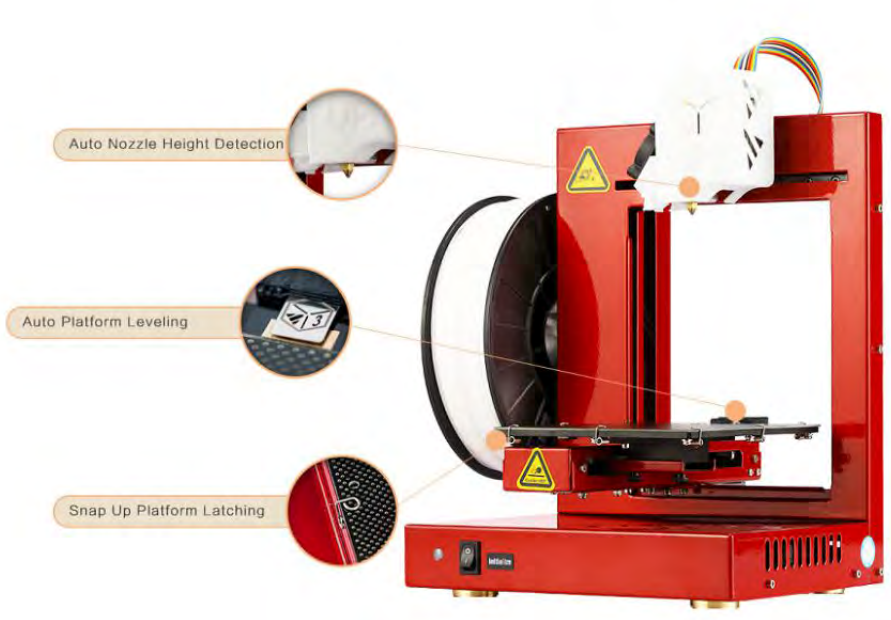

Figure 2.2: UP Plus 2 Machines
(Source :< https://3dprintingsystems.co.za/wp-content/uploads/3d_printer_UP_plus_2.png> 7 September 2107)

Table 2.1: Printer Physical Characteristics('UP Plus 2 3D Printer User Manual UP Plus 2 3D Printer User Manual', 2013)

Printing Material	ABS or PLA
Material Colour	White
Layer Thickness	0.15mm-0.40mm
Print Speed	(fine)10 – (fast) 100cm^3/h
Print Bed Size	140mm x 140mm x 135mm
Printer Weight	5KG (11 1b)
Printer Size	245mm x 260mm x 350mm
Extrusion Temperature	ABS: 260c – 270c PLA:200c
Platfrom Temperature	ABS: 100c PLA: 50c

Table 2.2: Printer Specification ('UP Plus 2 3D Printer User Manual UP Plus 2 3D Printer User Manual', 2013)

Power Requirements	100 – 240VAC, 50-60Hz. 200W Input: 19VDC 9.5amp Output (optional feeder) 12VDC lamp
Model Support	Smart auto-generated and easy to breaks away support material
Input Format	STL
Workstation compatibility	Windows XP/ Vista/7 & Mac

Table 2.3: Printer Environment Specification ('UP Plus 2 3D Printer User Manual UP Plus 2 3D Printer User Manual', 2013)

Ambient temperature	15°C – 30°C
Relative humidity	20% - 50%

2.3 Fused Deposition Modeling

Fused Deposition Modeling (FDM) is an additive manufacturing technology commonly used for modeling, prototyping, and production applications. It is one of the techniques used for 3D printing. The technology was developed by S. Scott Crump in the late 1980s and was commercialized in 1990 (Rayegani and Onwubolu, 2014). FDM begins with a software process which processes an STL file (Stereolithography file format), mathematically slicing and orienting the model for the build process. If required, support structures may be generated. The machine may dispense multiple materials to achieve different goals: For example, one may use one material to build up the model and use another as a soluble support structure or one could use multiple colors of the same type of thermoplastic on the same model.

The implementation of Fused Deposition Modeling Printed Part technique is shown in figure 2.3 as below. A fused deposition modeling machine melts a plastic filament and extrudes it through a nozzle. The melted material is laid down on the build platform, where it cools and solidifies. By laying down layer on layer the part is built. Fused deposition modeling requires support structures which anchors the parts on the build platform and supports overhanging structures. Through the use of a second nozzle, the support structure can be built in a different material. Several parts can be produced at the same time as long as they are all anchored on the platform.

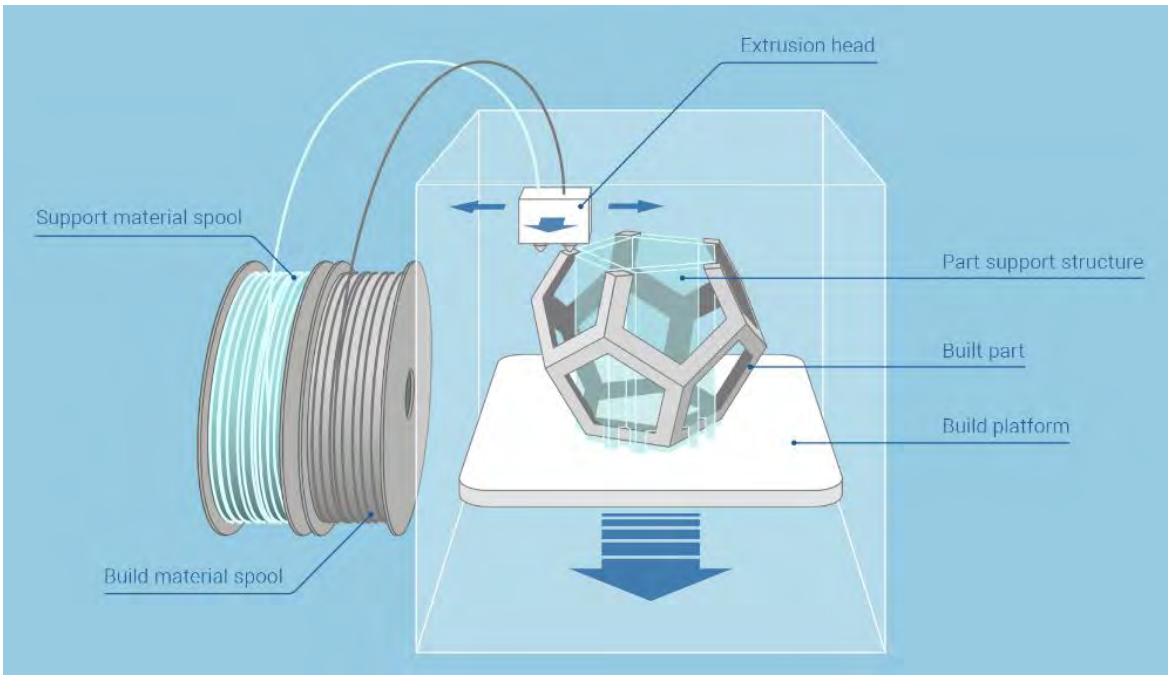

Figure 2.3: Fused Deposition Modeling Printed Part
(Source: < https://www.additively.com/en/learn-about/fused-deposition-modeling> 20 APRIL 2017)

2.4 Optimized Parameter

Fused Deposition Modeling (FDM) is a fast-growing Rapid Prototyping (RP) technology due to its ability to build functional parts having complex geometrical shapes in reasonable build time (Rayegani and Onwubolu, 2014). The dimensional accuracy, surface roughness, mechanical strength, and above all functionality of built parts are dependent on many process variables and their settings. Optimized parameters have been found to achieve good strength simultaneously for the response (Panda, 2009). The mathematical model of the response of the tensile strength with respect to the process parameters and it has been found that the functionality of the additive manufacturing part produced is improved by optimizing the process parameters. The results obtained are very promising. Hence, the technique is used to suggest a theoretical combination of parameter settings to achieve good result simultaneously for all responses. This project will be improving the mechanical properties of fused deposition modeling printed part by using optimized parameters such as the resolution (mm), infill density and quality.