STUDY ON THE PROPERTIES OF PARTS MANUFACTURED USING FUSED DEPOSITION MODELING (FDM)

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Design and Innovation)"

Signature: …………………………

Supervisor: …………………………

Date: …………………………

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This thesis is submitted as
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DECLARATION

"I declare this thesis is on my own work except for summary and quotes that I have mentioned its sources"

Signature:	………………………..
Name of Author:	Anwar Naimi Bin Arsat
Date:	………………………...

For my beloved mum, Pn. Salmah Bt Mohamed and my caring dad,
Mr. Arsat bin Samsudin.

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ABSTRACT

The aim of this research is to determine the quality of parts manufactured by Fused Deposition Modeling (FDM) method. FDM is one of the rapid prototyping techniques which use additive fabrication approach. The FDM machine used in this experiment are Mini Kossel 3D printer and Cube Pro 3D printer. The process parameters studied are print density, print pattern, shell option, raster angle, layer thickness and pattern spacing. The experiment focused more on pattern spacing because both FDM machine has the availability to modify the parameter. The quality of the parts produced was accessed in term of surface roughness, tensile strength and porosity. The surface roughness, tensile strength and porosity data were obtained by using Roughness Tester TR200, Instron Floor Mounted machine and Inverted Microscope respectively. The result shows as the pattern spacing process parameter are increased, the tensile strength tends to decreases. The pattern spacing also affects the value of porosity and roughness of test specimens.

ABSTRAK

Tujuan penyelidikan ini adalah untuk mengenal pasti kualiti komponen yang dihasilkan dengan menggunakan kaedah model pengendapan terlakur (FDM). FDM ialah salah satu teknik yang digunakan dalam pembangunan prototaip dengan menggunakan pendekatan fabrikasi tambahan. Mesin FDM yang digunakan dalam eksperimen ini adalah mesin pencetak 3D Mini Kossel dan mesin pencetak Cube Pro. Proses parameter adalah kepadatan cetakan, corak cetakan , pilihan luaran, sudut raster, ketebalan lapisan dan jarak corak. Eksperimen memberi tumpuan lebih kepada jarak corak kerana kedua-dua mesin FDM mempunyai ketersediaan untuk mengubah suai parameter ini. Kualiti bahagian-bahagian yang dihasilkan telah dicapai dari segi kekasaran permukaan, kekuatan tegangan dan keliangan. Kekasaran permukaan, kekuatan tegangan dan data keliangan masing-masing diperolehi dengan menggunakan Roughness Tester TR200, mesin Instron Floor Mounted dan Inverted Microscope. Keputusan menunjukkan kenaikan parameter jarak corak akan menurunkan kekuatan tegangan. Jarak corak juga mempengaruhi nilai keliangan dan kekasaran spesimen ujian.

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ABS	=	Acrylonitrile-Butadiene-Styrene
ASTM	=	American Society for Testing and Materials
CAD	=	Computer Aided Design
FDM	=	Fused Deposition Modeling
FEA	=	Finite Element Analysis
PLA	=	Polylactic-Acid
RP	=	Rapid Prototyping
STL	=	Stereo-Lithography
3D	=	Three-Dimensional

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Many process involved in the design, test, manufacture, and market of the product have been squeezed, both in term of time and material resources (Wheelwright, 1992). Additive manufacturing technique has the advantages of manufacturing parts via an additive process without needing a forming tool. FDM is second most widely used rapid prototyping (RP) technology, after Stereo-lithography (uses laser). FDM is a RP process in which a part is fabricated by stacking layer after layer. The filament are heated and extruded from the tip of nozzle and harden in the room temperature. Several materials are available for the process including Acrylonitrile-Butadiene-Styrene (ABS) and Polylactic-Acid (PLA). The question is how far the quality of material produces by the FDM machine in order to be used as a part for serial production. In this project, by study the parts manufactured by FDM, all the process parameters is being optimized.

1.2 PROBLEM STATEMENT

In fused deposition modeling the part's mechanical properties depend mainly on process parameters such as the material depositing orientation, the filament flow rate, the raster's separation, raster angle, pattern spacing and the extrusion temperatures. This final year project investigates the plastic material used in FDM manufactured parts and to determine the quality of parts where the process parameter is being optimized.

1.3 OBJECTIVES

The objectives of this project are:

1. To investigate the mechanical properties of parts manufactured using FDM.
2. To study the influence of processing parameters on mechanical properties.
3. To improve the existing FDM machine and compare its influence on parts properties

1.4 SCOPE OF PROJECT

For this project, there are three scopes in order to achieve the project objectives:

1. The project study the effects of pattern spacing on mechanical properties
2. The project utilizes both Mini Kossel and Cube Pro 3D printer mechanical properties.
3. ABS material is used in the study.

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CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A literature review is an evaluative report of information found in the literature that related in the field of study. The purpose of a literature review is to identify or establish the area of studies in the selecting topic. In this chapter, the literature review involve in development of the project such as sample preparation, process parameters, design of experiment are studied. All the information gathered from literature review is from the website, journals and books. This is important to be review so that the existing FDM machine can be improved, meet the specification needs and well function according to the problem statement.

2.2 FUSED DEPOSITION MODELING

Rapid prototyping (RP) technologies have continuously evolved over time. There are many RP technologies existed. FDM is one of the technologies used to produce prototype from plastic material. Acrylonitrile butadiene styrene (ABS) is an example of plastic filament used to make the prototype by laying path of the molten state of the filament onto a print bed layer by layer from the base to the top (Raut *et al*., 2014). Figure 2.1 show the process of FDM.

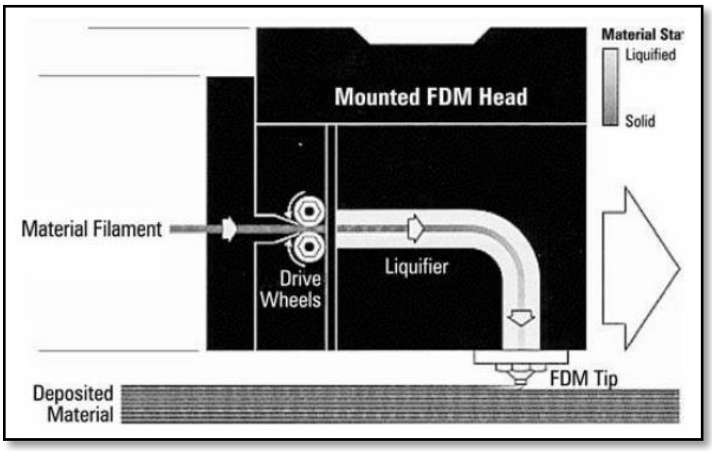

Figure 2.1: Fused deposition modeling process (Ahn S. H. *et al*., 2002)

The physical procedure of manufacture, an ABS filament is nourished through a heated component and turns to be semi-liquid. The filament is then nourished through the tip of the nozzle and stack onto the mostly built part. Since the filament is in semi- liquid state, the newly deposited material stack with adjacent material that already been extruded (Ahn S. H. *et al*., 2002). The FDM head then moves around according to the programming code based on the original CAD file geometry and the Z axis control the height of the part and it takes several hours depend on the complexity of the part that want to be printed. The uses of adhesion at the print bed also is very important to ensure the part is not moving while be printed because it affecting the quality of the printed part.

2.3 ACRYLONITRILE-BUTADIENE-STYRENE (ABS)

ABS are thermoplastic resins composed of three kinds of monomers-acrylonitrile, butadiene, and styrene. They were created with the harmony of hardness and softness by improving the brittleness, which is the disadvantage of polystyrenes, through addition of a rubber component while maintaining hardness and fluidity, which are the advantages of polystyrenes. Figure 2.2 show the ABS polymer and its functionality.

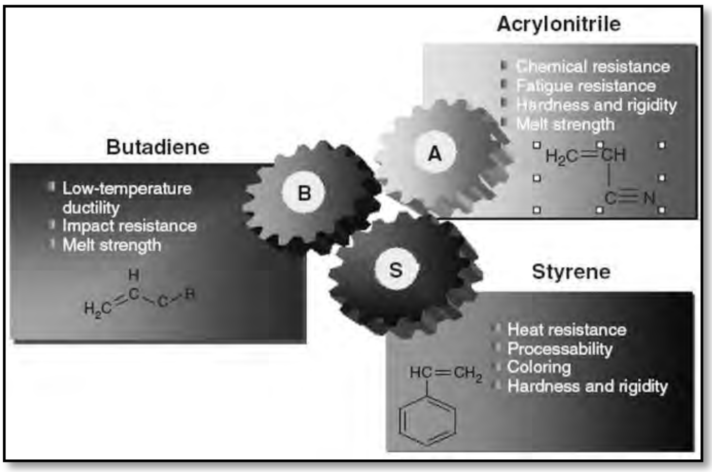

Figure 2.2: ABS polymer and its functionality (Charles A. H., 2002)

As is well known, ABS are one type of excellent desirable properties, including impact resistance, ability to process, gloss property, good mechanical properties, and high heat distortion temperature. Therefore, ABS has been used in very broad fields of application and particularly in many aspects of daily life. At present, the amount of ABS filament used has gradually increased in rapid prototyping technology.

2.4 EXPERIMENTAL DESIGN PROCESS

There are eight steps to complete an experimental design process. Each step must be follow in order to obtain the good conclusion of the experiment. The experimental design begins by determining the goal for the experiment. This is to set the objective of the experiment what leads to desired result. The goal must be straightforward and clear so that an experiment strategy can be developed. If the experiment is ended in success or failure, there is a plan of action need to be taken.

After the goal has been set, a measure of success must be defined. The feature of the process or the product must be metric and refer to an intrinsic. The critical part of meeting the goal set is by the responses of a large number of responded.

After step one and two is completed, we must make a rough estimation in order to verify the feasibility involve. By using the power of calculation, information that are gather can be determine whether any is reasonable with the number of trials. If there is larger amount of noise present in the process, the amount of trial required to see a change in the desired parameter.

The next step is to make a precise estimation of the designing the experiment. In order to conduct the experiment, the design of the experiment must be constructed. To obtain the response variable the control variable must be identified first hand.

After all the design experiment is complete with the variable involve, the experiment are conducted. The experiment is a task in resource management in order to obtain the data. The experiment must be complete as efficiently as possible in order to achieve an accurate data.

When the experiment is completed, the necessary data must be collect for analyze purpose. The excellent method is to analyze the data as a whole. The advantages of analyzing a set of data so that it can show the contrast result between two point of data If there is an optional, the best is to collect the most critical and important data in order.

The result must be verified so that it can be predicted and can be compared. The ability to predict is given by a response surface. The behavior of the process at any point within the design window can be predicted with the help of statistical limits. Several keys specifications can be simultaneously optimize by combining the prediction from several responses.

Lastly after all steps are completed, the result produce must take action. Compare the result whether it is related with the goal set in the first step. Determine whether the experiment is a success or a failure. The experiment result of the experiment must be documentation for future use as a reference.

2.5 PROCESS PARAMETERS

There are several process parameters such as part build orientation and tool path parameters like layer thickness, pattern spacing, raster angle, raster width and air gap.In FDM, one of the critical factor is to select the buildup orientation of the model since it affects the different areas of the model like main material, support material, built up time, total cost per part and most important the mechanical properties of the part (Raut *et al*., 2014). The investigation done by (Jaimin *et al*., 2014) about the effect of three important parameters like layer thickness, orientation angle and raster width on tensile strength and flexural strength of FDM fabricate test specimens. They have found that the layer thickness and orientation angle is highly significant to response characteristic whereas raster width have a little effect on it as shown in Figure 2.3.