INVESTIGATION OF THE EFFECT OF RASTER ANGLE AND LAYER THICKNESS ON MECHANICAL PROPERTIES OF FUSED DEPOSITION MODELING (FDM) PARTS

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

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DECLARATION

I hereby, declared this report entitled "Investigation of The Effect of Raster Angle And Layer Thickness On Mechanical Properties of Fused Deposition Modeling (FDM) Parts" is the results of my own research except 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 of Manufacturing Engineering (Manufacturing Design) (Hons.). The members of the supervisory committee are as follow:

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(Dr. Zulkeflee Bin Abdullah)

ABSTRAK

3D Printing adalah teknologi yang berkembang pesat dan digunakan secare meluas di seluruh dunia. Pemendapan Modeling Bercantum (FDM) adalah salah satu teknologi pembuatan bahan tambahan yang paling popular dan banyak digunakan dalam penghasilan dan prototaip. Walau bagaimanapun, kualiti bahagian yang dihasilkan dengan mengunakan FDM amat dipengaruhi oleh pelbagai parameter yang digunakan dalam proses. Parameter yang paling ketara adalah ketebalan lapisan dan sudut raster. Dalam usaha untuk memastikan kualiti produk atau bahagian, kajian terhadap sifat mekanikal bahagian pembuatan dengan FDM adalah amat penting. Oleh itu, tujuan projek ini adalah untuk mengkaji kesan sudut raster dan ketebalan lapisan kepada sifat-sifat mekanikal bahagian FDM. Matlamat-matlamat untuk kajian ini adalah untuk menjalankan ujian tegangan dan ujian lenturan kepada specimen yang dicetak dengan 3D printer pada tahap sudut raster dan ketebalan lapisan yang berbeza, mengkaji kesan sudut raster dan ketebalan lapisan terhadap sifat-sifat mekanikal FDM specimen ujian serta mencadangkan parameter yang optimum untuk specimen. Beberapa ketebalan lapisan dan sudut raster telah diperkenalkan iaitu 0.2mm, 0.3mm, 0.4mm dan 30°/60°, 45°/-45° dan 0°/90°. Specimen ujian yang diperbuat dengan ketebalan lapisan dan raster sudut yang berbeza telah direka degan mengunakan FolgerTech 3D printer dengan fail STL yang wujud dalam perisian SolidWork. Bahan ABS dan PLA telah digunakan untuk membuat specimen ujian. Ujian mekanikal dijalankan untuk menentukan sifat-sifat mekanikal ialah kekuatan tegangan dan kekuatan lenturan. ASTM D638 dan ASTM D790 standard telah diikuti dalam ujian tegangan dan ujian lenturan masing-masing. Analysis of variance (ANOVA) digunakan untuk menetukan pengaruh parameter-parameter proses FDM. Keputusan telah menunjukkan ketebalan lapisan dan sudut raster adalah kesan ketara terhadap kekuatann specimen ujian. Akhir sekali, satu set parameter yang optimum telah dicadangkan untuk meningkatkan kualiti dan kekuatan bahagian yang dicetak.

ABSTRACT

Additive manufacturing is a fast-growing technology and widely used in worldwide. Fused Deposition Modeling (FDM) is one of the additive manufacturing technologies which is most popular and widely use for production application and prototyping. However, the quality of FDM produced parts is significantly affected by various parameters used in this process. The most significant parameters are layer thickness and raster angle. In order to ensure the quality of the product or part, it is essential to study the mechanical properties of the part the manufactured by FDM. Hence, the purpose of this project is to investigate the effect of raster angle and layer thickness on mechanical properties of the Fused Deposition Modeling (FDM) part. The objectives of this study are to conduct tensile test and flexural test for different level of raster angle and layer thickness on 3D printed test specimen, study the effect of raster angle and layer thickness on the mechanical properties of FDM test specimens as well as identify the optimum layer thickness and the raster angle parameter for the test specimen. Various layer thickness and raster angle are introduced which are 0.2mm, 0.3mm, 0.4mm and 30°/60°, 45°/-45° and 0°/90°. Test specimens with different layer thickness and raster angle are fabricated by using FolgerTech 3D printer with the STL file which created through SolidWork software. ABS and PLA material are used to manufacture the test specimen. Mechanical test is carried out to determine the mechanical properties such as tensile strength and flexural strength. ASTM D638 and ASTM D790 standard were followed to carry out tensile and flexural test, respectively. Analysis of Variance (ANOVA) is used to determine the influence of the variable FDM process parameter layer thickness and raster angle. The results revealed that the layer thickness and raster angle significantly affect the strength of the test specimen. Lastly, the optimized set of parameter are suggested to improve the quality and the strength of the printed part.

DEDICATION

I would like to dedicate this work to my

Beloved parents

Honorable supervisor and lecturers

Supportive friends

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I would like to thank my supervisor Dr. Zulkeflee bin Abdullah for guiding and advising me for every single part on this project. I believe that I could not accomplish this final year project successfully without his help and guidance. Besides, I also would like to thank to family members and friends for giving me encouragement as well as support me along the progress of this Final Year Project. I also thank for their advice during carry out this project.

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LIST OF ABBREVIATIONS

AM	-	Additive Manufacturing
ASTM	-	American Society for Testing and Materials
3D	-	Three Dimensional
CAD	-	Computer –Aided Design
FDM	-	Fused Deposition Modeling
DOE	-	Design of Experiment
ANOVA	-	Analysis of Variance
ABS	-	Acrylonitrile-Butadiene-Styrene
PLA	-	Polylatic Acid
UTM	-	Universal Testing Machine
FKP	-	Fakulti Kejuruteraan Pembuatan
PSM	-	Project Sarjana Muda
FFF	-	Fused Filament Fabrication
SLS	-	Selective Laser Sintering
SLA	-	Stereolithgraphy
UV	-	Ultraviolet
STL	-	StereoLithography
UTS	-	Ultimate Tensile Strength
PEEK	-	polyether-ether-ketone

LIST OF SYMBOLS

mm	-	Millimeter
°	-	Degree
MPa	-	Mega Pascal
%	-	Percentage

CHAPTER 1

INTRODUCTION

In this chapter, an introduction of Additive Manufacturing (AM) technology-3D printing, which includes the parameters, application as well as the performance of printed parts are discussed. Next, the inspiration of using AM systems to replace the conventional method is discussed in the background of this study. Furthermore, the problem statement, objective and scope are also discussed.

1.1 Background

There are more than 20 years Additive manufacturing (AM) technology has been developed and researched. AM system involves different new manufacturing technologies, which allocate such as metal and polymer materials to be utilized to make new objects through layer-wise material melding. Based on ASTM F42 Technical Committee, additive manufacturing is defined as " process of joining materials to make objects from three-dimensional (3D) model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies" (Guo & Leu, 2013). The process is basically different from conventional method like drilling, milling, and turning, which are used to remove the materials. AM term describe additive manufacturing processes in the widest way that included model, designs, apparatuses, and ideas parts, furthermore useful part with required properties for direct manufacturing applications and resource.

Three-dimensional parts are produced by using AM technologies, usually layer by layer method which built directly from 3D CAD data. AM technology offer geometrical freedom parts without uncommon installations as required in the material removal process. Geometrical freedoms offered by AM are include design complexity, parts consolidation, parts customisation and multiple assemble. Therefore, AM drastically reduce the lead time, production cost, and can build parts that subtractive manufacturing processes cannot make it (Guo & Leu, 2013). AM technology has been utilized to carry model parts with required material properties for assessment and testing, and additionally to fabricate little or standard amounts of end-utilize items.

Fused Deposition Modeling (FDM) is one of the current 3D printing technologies. FDM is one of the broadly used technologies that rapidly created three-dimensional (3D) solid object with complex geometries (Bagsik et al., 2010). In this process, the nozzle is heated to melt the material, and then deposited in the part layer by layer. Besides, Wu et al., (2015) explained the benefit of FDM are include simple material change easily, without supervision operation, low costs, minimized size and low working temperature. In spite of the fact that FDM is fundamentally utilized for prototyping, with gradual improvement in process and material factors, the scope of application of the process further increase and being considered for the direct requires particular end-utilize parts. Keeping in mind the end goal to be utilized as a part for serial production, the parts must have the required mechanical properties. Enhancing the mechanical performance of the product regularly comes to the loss of printing speed, affordability and quality.

However, in FDM process, the mechanical properties, surface finish and geometric accuracy obtained are often influenced by number of process parameters, for example road width, raster angle, build orientation, air gap and layer-thickness. As highlighted by Anitha et al. (2001), the quality of a product is noticeable by several parameters. Therefore, proper selection of process parameters has to be done in order to create a product with high quality that may fulfil customer requirement. The raster angles and layer thickness was observed to be the most significant parameters. The raster angle and layer thickness available on the FDM machine will change the final product's mechanical properties such as tensile and flexural. Other than that, raster angle and layer thickness also will affect some other properties such as cost, part quality and building time as well. Therefore, the process parameters need to set to prevent failure or low quality. To optimize the process parameters, design of experiment (DOE) approach is utilized to list out possible combinations of parameters and experiment is carry out with available combinations of parameters. With the tensile and flexural testing results, the optimized parameters can be found by using the design of experiment method.

1.2 Problem Statement

AM has exposed excellent potential, especially in term of process duration and cost of product development. However, when presented with an FDM system, many process parameters are involved when manufacture the part. The mechanical performance includes surface roughness, build time and material usage, which eventually determines customer satisfaction or dissatisfaction are the major influence of the process parameters. The mechanical properties such as tensile strength, development of residual stress and impact strengths play an vital role in tooling applications (Chockalingam, Jawahar, & Chandrasekhar, 2006). However, the raster angle and layer thickness plays an important character in influencing the mechanical characteristic of parts produced compared to others parameters. When the parameters are set at different levels, the mechanical performance will change. This is because of changing at microstructure of the product or part. Thus, to enhance the quality of the part, the process parameters raster angle and layer thickness should be optimized.

In this study, optimization of the parameters is focused and the effect of the mechanical properties. The optimized parameters can be used to study the effect of mechanical performance on the printed part and identified the optimum process parameter of FDM printing. This is because the determination of optimum process parameters is very important that can help to enhance the strength of the parts. Thus, to maximize the strength, the effect of layer thickness and raster angle on mechanical properties of FDM parts should be determined.

1.3 Objective

The objectives of the study are:

i. To conduct tensile test and flexural test for different level of raster angle and layer thickness on the 3D printed.

ii. To study the influence of raster angle and layer thickness on the mechanical properties of FDM test specimens.

iii. To identify the optimum raster angle and the layer thickness parameter for the test specimen.

1.4 Scope of Study

In this study mainly focused on the process parameter raster angle and layer thickness. This project will use AM to produce the sample specimen. The specimens are fabricated by using Fused Deposition Modeling (FDM) machine which is the FolgerTech 3D printer. All test specimen parts are built using Acrylonitrile-Butadiene-Styrene (ABS) and Polylatic Acid (PLA) materials. Furthermore, flexural test and tensile test are carried out to collect the data, such as elongation at break, ultimate tensile strength and bend test. The universal testing machine (UTM) available in the laboratory FKP is used to carry out all two tests which are tensile tested and flexural test. The sample specimens will be also discussed and analysis. In addition, Design of Experiment (DOE) method is utilized to list out all the possible parameter combinations and the CAD software used in this study is SolidWork. The experiment result will analysis by using Analysis of Variance (ANOVA) method.

1.5 Activity Planning

Activity planning of this study is outlined in the Gantt Charts as in Appendix A. The Gantt Charts are prepared for both FYP 1 and FYP 2.

CHAPTER 2

LITERATURE REVIEW

In this chapter, it focuses on the review of the literature from the journal, article, books and other resources. The main idea of this chapter is to acquire an understanding of the additive manufacturing as well as the impact of process parameters on the mechanical properties.

2.1 Definitions of AM

Based on American Society for Testing and Materials (ASTM) 52900:2015 standard, the definition of Additive Manufacturing is a process of joining the filaments or materials from 3D CAD data to create an object, layer upon layer, as different with subtractive manufacturing and formative manufacturing methodologies (ASTM, 2012). It was initially called "3D Printing" and is still regularly called additive manufacturing (Gebhardt, 2012). Besides that, it also identified as rapid prototyping, additive fabrication, layer manufacturing, additive processes, rapid manufacturing and solid freedom fabrication (Guo & Leu, 2013).

The manufacturer utilizes computer-aided design (CAD) system to make a 3D model that gets cut into thin cross-sectional layers, and then to print a 3D object. In the printing process, the 3D printer starts at the base of the design and creates progressive layers of materials until the object is printed completely. Figure 2.1 shows the process chain of AM.

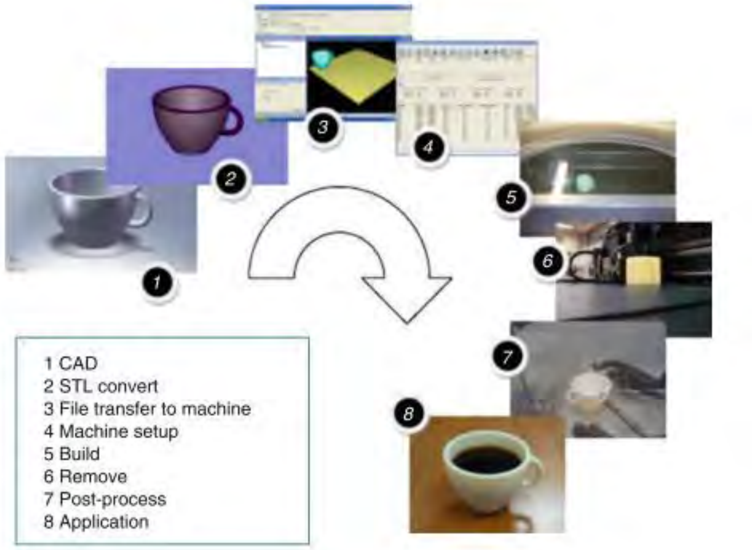

Figure 2.1: Additive Manufacturing (AM) process chain (Gibson, Rosen, & Stucker, 2010).

The first 3D printer was developed in 1985 and its use becomes more widespread. This technology is broadly used in various fields, for example, aerospace, medical implants, industry and electrical. Furthermore, diverse 3D printers use distinctive materials to fabricate layers. Some machine use fluid polymer or gel, sheet material, powder or others, which has a tendency to be more costly.

AM technology has offer greatest benefit, especially in term of time, cost and quality compare to subtractive manufacturing. Besides that, it also capable to create a wide range of shape that could be very complicated to machine.

2.2 Classification of AM and AM system

AM processes may be divided broadly into four categories. AM technologies can be classified by numerous ways. AM are categorized according to baseline technology, whether the process uses laser, extrusion technology, printer technology and others. Variation between AM technologies can be arranged whether the build materials are handled as ink-jet deposited photopolymer or vat of liquid photopolymer, a powder, liquid material and solid sheet. Figure 2.2 shows the classification of AM with a flow chart.