UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION OF THE EFFECT OF BUILD ORIENTATION ON MECHANICAL PROPERTIES OF FUSED DEPOSITION MODELING PART

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

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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 member of the supervisory is as follow:

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(DR. SHAJAHAN BIN MAIDIN)

ABSTRAK

Tujuan projek ini adalah untuk mengenalpasti kesan orientasi pembinaan kepada sifat-sifat mekanikal bahagian FDM. Orientasi pembinaan yang digunakan di projek ini adalah rata, mendatar dan menegak. Specimen ujian telah direka dengan menggunakan UP 3D Printer dengan fail STL yang diwujudkan pada perisian SolidWorks. Dua bahan iaitu PLA dan ABS digunakan untuk mereka specimen ujian. Ujian yang digunakan untuk menentukan sifat-sifat mekanikal ialah ujian tegangan dan ujian mampatan. Sifat-sifat yang dianalisis adalah kekuatan tegangan, modulus keanjalan dan daya maksimum yang boleh ditahan oleh spesimen ujian. Spesimen ujian dengan orientasi mendatar mempunyai kekuatan tegangan yang tinggi, modulus keanjalan dan daya maksimum berbanding dengan orientasi yang lain, iaitu 45.5 MPa, 8.53 MPa dan 5.01 kN masing-masing bagi bahan PLA. Untuk bahan ABS, Kekuatan tegangan, modulus keanjalan dan daya maksimum untuk orientasi mendatar 35 MPa, 7.03 MPa dan 4.99 kN masing-masing. Sebaliknya, orientasi menegak mempunyai kekuatan tegangan, modulus keanjalan dan daya maksimum yang paling rendah, iaitu, 37.1 MPa, 7.7 MPa dan 3.73 kN masing-masing untuk bahan PLA. Manakala bagi bahan ABS, kekuatan tegangan, modulus keanjalan dan daya maksimum ialah 21.8MPa, 6.57 MPa dan 3.71 kN masing-masing.. Selain itu, perbandingan antara bahan menunjukkan bahawa bahan PLA mempunyai kekuatan yang lebih baik dalam semua aspek berbanding bahan ABS. Selain itu, permukaan patah juga dianalisis oleh mikroskop stereo untuk mendapatkan corak patah. Spesimen menegak mempunyai permukaan licin pada permukaan patah manakala orientasi mendatar dan rata mempunyai permukaan patah yang tidak sekata.

ABSTRACT

The aim of this project is to determine the effect of built orientation on the mechanical properties of the FDM part. The built orientation that consider in this project is flat, horizontal and vertical orientation. Test specimen are fabricated using UP 3D printer with the STL file created on SolidWorks software. Two material which are PLA and ABS are used to fabricate the test specimens. Test to be carry out to determine the mechanical properties are tensile test and compression test. The properties to be analyze are tensile strength, modulus of elasticity and maximum force that can withstand by the test specimen. Test specimen with horizontal orientation has the highest tensile strength, modulus of elasticity and maximum force compare to other orientation which are 45.5 MPa, 8.53 MPa and 5.01 kN respectively for PLA material. For ABS material, the tensile strength, modulus of elasticity and maximum force for horizontal orientation are 35 MPa, 7.03 MPa and 4.99 kN respectively. In contrast, vertical orientation has the lowest tensile strength, modulus of elasticity and maximum force which are 37.1 MPa, 7.7 MPa and 3.73 kN respectively for PLA material. While for ABS material, the tensile strength, modulus of elasticity and maximum force are 21.8MPa, 6.57 MPa and 3.71 kN respectively. Besides, comparison between material shows that PLA material has better strength in all aspect compared to ABS material. Besides, the surface of fracture also being analyzed by stereo microscope to detain out the pattern of the fracture. Vertical specimen has the smooth surface of fracture while horizontal and flat orientation has uneven surface of fracture.

DEDICATION

I would like to dedicate this work to my

Beloved parents

Honorable supervisor and lecturers

Supportive friends and mates

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I would like to express my gratitude to everyone that support and guide me throughout the completion of my Final Year Project. I also thankful for their advice during carry out this project.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ABS	-	Acrylonitrile Butadiene Styrene
AM	-	Additive Manufacturing
ASTM	-	American Society for Testing and Materials
CAD	-	Computer Aided Design
2D	-	2 Dimension
3D	-	3 Dimension
EL	-	Elongation
FDM	-	Fused Deposition Modelling
FKP	-	Fakulti Kejuruteraan Pembuatan
FTMK	-	Fakulti Teknologi Maklumat dan Komunikasi
PLA	-	Polylactic acid
PSM	-	Project Sarjana Muda
SLA	-	Stereolithography
SLS	-	Selective Laser Sintering
SOP	-	Standard Operating Procedure
UTeM	-	Universiti Teknikal Malaysia Malaka
UTS	-	Ultimate Tensile Strength
UTM	-	Universal Testing Machine

CHAPTER 1

INTRODUCTION

This chapter introduces the project and briefly discuss the problem statement, objectives and also the scopes.

1.1 Introduction

Additive manufacturing (AM) is an advance manufacturing used to fabricate parts layer by layer. Domino-Espin *et al*. (2015) wrote that the ability of creating complex three-dimensional (3D) parts from AM technology results in production of complex part with lower cycle time and cost compared to the traditional manufacturing process. Omar *et al*. (2015) explained that AM technology is widely used in many fields in engineering and industry nowadays due to the increasing in competition of products. Designer and product engineer able to produce a product in shorter time to fulfil the customer requirements and as well as achieve competitive edge.

Fused deposition modelling (FDM) is an extrusion-based additive manufacturing process. It has the same working principle with other rapid prototyping system which is layer by layer principle. It is one of the most used additive manufacturing processes to produce prototypes and end use parts due to its capabilities of producing parts neatly and safely in office friendly environment.

Proper selection of process parameters has to be done in order to produce high quality product to meet the customer requirement and satisfactions. The process parameter includes built orientation, layer thickness, raster width and more. The mechanical properties of a part vary with the process parameters.

In this project, process parameter of built orientation will be emphasized. Build orientation refers to the way in which the part is oriented in the machine build platform with respect to X, Y, Z axes. The built orientation of the FDM parts is important as it will affect the mechanical properties of the parts. Other than that, built orientation will affect some other characteristics such as part building time, amount of supports required, part quality and cost as well.

1.2 Problem statement

The quality of a part is important as it determines the lifetime of the products. Omar *et al*. (2015) stated that in order to gain satisfaction of the customer, the process condition for AM must be established for each application. Determination of optimum process condition is important to ensure the quality of product. A prototype part built that does not consider the effect of built orientation may result in mechanical failure. A same part will deform differently with the difference of the built orientation of the part. Thus, to enhance the quality of the part, the process parameter such as build orientation should be optimized. There are few build orientations such as flat, horizontal and vertical oriented. Bagsik *et al*. (2011) concluded that different builds orientation will give different results on the strength which is also the mechanical properties of the part.

Thus, to maximize the strength, the effect of proper builds orientation on mechanical properties of Fused Deposition Modelling (FDM) part should be determined.

1.3 Objective

i. To produce the CAD drawing of test specimens and to build it with different built orientations by using the FDM machine.

ii. To test the test-specimen with different mechanical tests such as tensile test and compression test.

iii. To investigate the effect of the build orientation on mechanical properties of FDM test specimen.

1.4 Scope

There are many process parameters that affect the part quality in FDM parts. In this project, the process parameter is limited to build orientation of FDM. Besides, acrylonitrile-butadiene-styrene (ABS) and Polylactic Acid (PLA) are the materials used to produce the test specimen. Besides, the mechanical properties of FDM produced parts considered in this study are tensile strength, modulus of elasticity and maximum force that can withstand by the compression test piece. To get these mechanical properties, Universal Testing Machine (UTM) which located in material engineering lab, FKP block B is used to perform all two tests which are tensile test and compression test. In addition, microscopic inspection on the fracture surface of the test specimen is performed by using stereo microscope that located in the metrology lab in FKP block B.

The CAD software used in this research is SolidWork. The parameter for the production of the test specimen is as shown in Table 1.1.

Table 1.1: Parameters with its description

Parameters	Description
Build orientation	Flat, horizontal, vertical
Layer thickness (mm)	0.15
Raster angle (^{0})	45
Air gap	Level 1

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss some of the related knowledge on the additive manufacturing as well as its effect of parameters to the mechanical properties. Some mechanical properties also discussed in this chapter.

2.1. Definition of additive manufacturing

American Society for Testing and Materials (ASTM) defines Additive Manufacturing (AM) as a joining process of material, layer by layer, to make objects from 3D model data. Besides, Gibson *et al*. (2010) states that AM used widely in industry to describe the process of rapidly creating a system or part representation before its release into the market.

Anil *et al*. (2014) define AM process is unlike subtractive or forming process such as milling and grinding which the shape of the part is formed by material removal or plastic deformation. AM belongs to generative (or additive) production processes where the part is formed by deposition of layers contoured in a (x-y) plane. The third dimension, which is Z direction, is resulting from stacking of layers on top of each other but not as a continuous Z coordinate. Thus, the prototype is very exact on x-y plane and may have stepped effect in z-direction.

2.2 Additive Manufacturing System

2.2.1 Selective Laser Sintering (SLS)

Castoro (2013) defines selective laser sintering (SLS) as a process used to create 3D object from a plastic, metal or ceramic powder. As other AM system, the part is built layer by layer from the bottom and able to produce complex part. Usually the part is produced from digital CAD data. The main components of the SLS machine are roller, powder container, part bed and laser.

In SLS process, the laser traces the cross section of a part on a thin layer of powder, sintering the top layer of powder to the one below it. After the layer is finished, powder swept across the built area to form a new layer. This operation is done by the roller in the SLS machine where the roller moves across the powder container and sweeps thin layer of powder across part bed. The process is continuing until the part has completely sintered. Figure 2.1 shows the SLS system and the component in the process.