EFFECT OF SLICING PARAMETERS ON VOID FORMATION IN FUSED DEPOSITION MODELLING (FDM) PART

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**A report submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering**

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

KESAN PARAMETER PEMOTONGAN TERHADAP PEMBENTUKAN LIANG DALAM KOMPONEN PEMODELAN PEMENDAPAN BERLAKUR

AHMAD AL-NABIL SHAMSUDIN

Laporan ini dikemukakan sebagai memenuhi sebahagian daripada syarat pengaugerahan Ijazah Sarjana Muda Kejuruteraan Mekanikal

Fakulti Kejuruteraan Mekanikal

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this project report entitled "Effect of Slicing Parameters on Void Formation in Fused Deposition Modelling (FDM) Part" is the result of my own work except as cited in the references.

Signature :	…………………………..
Name :	Ahmad al-Nabil Shamsudin
Date :	10/2/2021

PENGAKUAN

Saya akui laporan ini yang bertajuk “Kesan Parameter Pemotongan Terhadap Pembentukan Liang Dalam Komponen Pemodelan Pemendapan Berlakur” adalah hasil kerja saya sendiri kecuali yang dipetik daripada sumber rujukan.

Tandatangan : ………………………….

Nama : Ahmad al-Nabil Shamsudin

Tarikh : 10/2/2021

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature : ………………………….

Supervisor's Name : ………………………….

Date : ………………………….

PENGESAHAN

Saya akui bahawa telah membaca laporan ini dan pada pandangan saya laporan ini adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan Ijazah Sarjana Muda Kejuruteraan Mekanikal.

Tandatangan : ………………………….

Nama Penyelia : ………………………….

Tarikh : ………………………….

DEDICATION

To my beloved parents.

DEDIKASI

Buat ibu bapaku yang tercinta.

ABSTRACT

Void formation is a structural defect which is formed during the process of 3D printing. Void affects the structural integrity of a 3D printed part which would lead to reduced durability and functionality. This minor defect could affect other important manufacturing aspects such as cost, time and energy, which also determine the efficiency of overall manufacturing processes. Therefore, this project was carried out to conduct an experiment on the effect of slicing parameters towards void formation and to study the effect of different model shapes on the intensity of void formation. Experimental work is a part where the printed parts were developed and tested using Pressurized Gas Release (PGR) method. Infill density, infill pattern and raster angle were manipulated to obtain the difference of void formation. From the experiment, gas bubbles were seen to form the least on 3D printed parts with 100% infill density, grid infill pattern and 45° raster angle. Similar findings were seen when compared between cuboid, cylinder and prism shape. This project concluded that 100% infill density, grid infill pattern and 45° raster angle result in the least void formation and difference in shape gave minimal effect on void formation on 3D printed parts.

ABSTRAK

Pembentukan liang adalah kecacatan struktur yang terbentuk semasa proses pencetakan 3D. Pembentukan liang mempengaruhi integriti struktur bahagian bercetak 3D yang akan menyebabkan pengurangan dari segi ketahanan dan fungsi. Kecacatan kecil ini boleh mempengaruhi aspek pembuatan penting seperti kos, masa dan tenaga, yang juga menentukan kecekapan keseluruhan proses pembuatan. Oleh itu, projek ini dijalankan untuk melakukan eksperimen mengenai pengaruh parameter pemotongan terhadap pembentukan liang dan untuk mengkaji pengaruh bentuk model yang berbeza terhadap kekerapan pembentukan liang. Kerja eksperimental adalah bahagian di mana bahagian 3D dicetak dan diuji menggunakan kaedah Pressurized Gas Release (PGR). Ketumpatan pengisian, corak pengisian dan sudut raster dimanipulasi untuk mendapatkan perbezaan pembentukan liang. Dari eksperimen tersebut, gelembung gas dilihat paling sedikit pada bahagian bercetak 3D dengan kepadatan pengisian 100%, corak grid dan sudut raster 45 °. Penemuan serupa dilihat jika dibandingkan antara bentuk kuboid, silinder dan prisma. Projek ini menyimpulkan bahawa ketumpatan pengisian 100%, corak grid dan sudut raster 45 ° mengakibatkan pembentukan liang paling sedikit dan perbezaan bentuk mempengaruhi secara minimal kepada pembentukan liang pada bahagian bercetak 3D.

ACKNOWLEDGEMENT

First and foremost, I would like to express my utmost gratitude and sincere acknowledgement to my supervisor, Dr. Mohd Nizam bin Sudin from the Faculty of Mechanical Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his supervision, guidance and assistance throughout the whole project.

I would also like to express my appreciation to the representative of the Projek Sarjana Muda Committee, Dr. Fadhli bin Syahrial for his guidance and assistance regarding documents and requirements provided by faculty in order to pass the project successfully.

Furthermore, I would like to thank my fellow classmates for their willingness to provide assistance to go through this semester together, and to share idea and thoughts regarding this project and any topics related to it.

Lastly, special thanks to my beloved parents, siblings and in-laws for their utmost support and motivation in completing this degree. Final appreciation to those who have involved in the completion of this project.

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LIST OF ABBREVIATIONS

3D	-	3-Dimensional
ABS	-	Acrylonitrile Butadiene Styrene
AM	-	Additive Manufacturing
ANSI	-	American National Standards Institute
CAD	-	Computer-Aided Design
FDM	-	Fused Deposition Modelling
FEA	-	Finite Element Analysis
ISO	-	International Organization of Standardization
PGR	-	Pressurized Gas Release
PLA	-	Polylactic Acid
SEM	-	Scanning Electron Microscope
SLS	-	Selective Laser Sintering

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CHAPTER 1

INTRODUCTION

1.1 Background

Back then where designs were simple and boxy, value of aesthetics were constrained due to limited manufacturing technology, thus effecting overall efficiency of a product. As the world advanced through Technology Era, manufacturing technology began to expand upon discovery of new methods which would break the boundaries of limited technology. Arcs and curves began to incorporate with lines and edges to revolutionize design language, thus maximizing potential of a product.

One of the new methods in manufacturing technology that is being used up to this day is known as additive manufacturing (AM) whereby the purpose of AM is to efficiently manufacture intricately-designed parts in terms of cost and production time (Mohan et al., 2017). AM is widely utilized for industrial usage with variety of AM processes such as fused deposition modelling (FDM), selective laser sintering (SLS), ink jet modelling and many others. Each of these process shares the same concept of manufacturing but differs in terms of application; material usage, layer construction and cost (Mohan et al., 2017).

FDM is one of the AM processes at which material filament is extruded layer-by-layer on to a flat heat bed to form a 3D part. Material filament made of thermoplastics such as polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS) which comes in form of wire shape is fed into extruder of a 3D printer. The extruder consists of heating element to melt the material filament before being extruded on to a flat heat bed. In most 3D printer, the extruder moves in two axis namely; x-axis and z-axis while y-axis is varied based on movement of the heat bed. The movement of the extruder is controlled by programming code generated from 3D model designed in CAD software.

Every FDM process begins at creating desired product in form of 3D model using a CAD software which is then exported to a slicing software. Slicing software is described as preparation of a 3D CAD file (e.g: STL file) for 3D printing purpose (Šljivic et al, 2019). In other words, slicing software converts a 3D CAD file into programming code specifically to be read and executed by 3D printers. The programming code is known as G-Code. G-Code consists of sets of instructions which hold values of extruder coordinates and several slicing parameter such as raster angle, raster pattern, heat bed temperature, extruder temperature, layer thickness, infill pattern and infill density (Baumann et al, 2017).

Slicing parameters play major role in determining the quality of printed 3D parts (Gordeev et al, 2018). Quality such as mechanical properties can affect the performance of the printed 3D parts which is crucial for real world application. Therefore, studies have been carried by many researchers on various slicing parameter in order to obtain optimum values for certain parameters to ensure the best performance of printed 3D parts.

1.2 Problem Statement

Prototype modelling is an important process to replicate functions of an actual model. Therefore, having similar mechanical properties to the actual model is crucial to ensure the replication is as exact as possible in order to achieve best possible result for real-world testing or simulation.

FDM method have been used in prototype development which provide good replication of an actual model. However, the developed prototypes could not achieve the best replication due to structural strength which deviate from the actual model at such huge margin due to reduction of mechanical properties.

Mechanical properties of a prototype is partially affected by structural flaw formed during prototype development process known as void. Void is described as pores or air bubble developed in solid walls of a prototype at which their presence are much unwanted. Intensity of void formation varies according to several parameters which can be controlled by slicing software during pre-processing stage.

1.3 Objectives

The objectives of this project are as follows:

1. To investigate the effect of slicing parameters towards void formation.
2. To study the effect of different model shapes on the intensity of void formation.

1.4 Scopes of Project

The scopes of this project are:

1. Slicing parameters involved in this project are only infill density, infill pattern and raster angle which would be adjusted using Ultimaker Cura slicing software.
2. Material used for this project experimentation will be PLA filament.
3. 3D models for this project experimentation will be in the shape of cuboid, prism and cylinder with maximum length, width and height of 7 cm, 4 cm and 4 cm, respectively, excluding air hole.
4. Experimental result of this project is purely observation via naked eye only without any usage of scanning electron microscope (SEM) for microstructural observation.

1.5 General Methodology

The actions needed to be carried out to achieve the objectives in this project are listed below:

1. Literature review

   Journals, articles, or any materials regarding the project will be reviewed and used as reference.

2. 3D modelling

   Creating 3D model with the shape of cylinder, cuboid and prism using Autodesk Fusion 360. Custom air hole will be incorporated into designs for experimental purpose.

3. Slicing process

   Slicing, or can be described as preparing 3D model for printing purpose. Slicing will be done using Ultimaker Cura slicing software. Slicing parameters will be adjusted in this software.

4. 3D printing

   Printing 3D model using printer provided by faculty in Prototype Lab using PLA filament.

5. Printed part testing

   Printed part will be tested using Pressurized Gas Release (PGR) method to form air bubble from the walls of the printed part.

6. Analysis

   Analysis will be presented based on observation on how the intensity of air bubble varied from different model shapes and slicing parameters.

7. Report writing

   A report on this study will be written at the end of the project.

The methodology of this study is summarized in the flow chart as shown in Figure 1.1

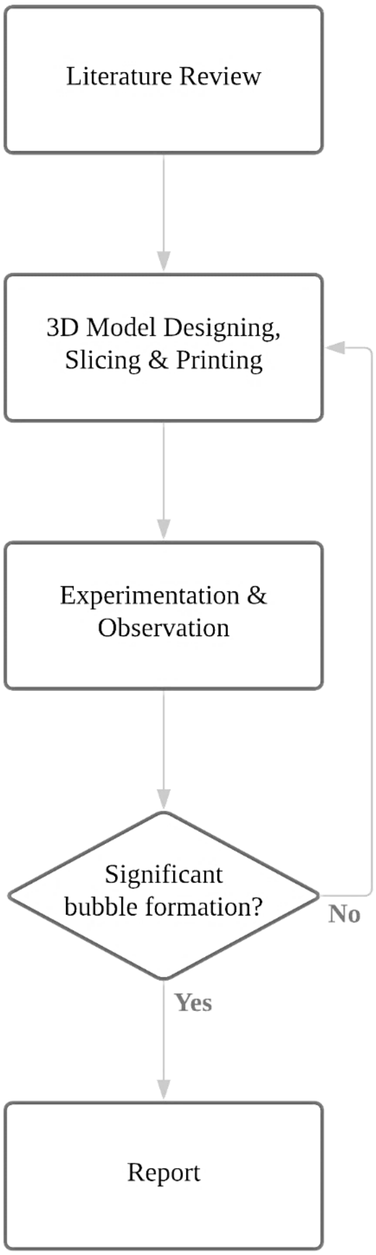


Figure 1.1: Flow Chart of the Methodology

CHAPTER 2

LITERATURE REVIEW

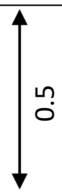
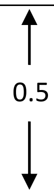
2.1 3D Computer-Aided Design (CAD) Software

In design process, computer-aided design (CAD) can be described as the very basic of generated design with presumptions of performing nearly accurate compared to real world along with the application of engineering knowledge which would then shift from manual drafting to generative design. There are variation of generated design which is used for many purpose such as computer-aided design (design), finite element analysis (analysis), computer-aided simulation, design optimization and others.

CAD can be defined as “a process that uses a computer system to assist in the creation, modification, and display of a design” (Mohammed et al., 2008). CAD software is capable of executing other functions, not only generating designs, provided that user acquires certain skills to vary and utilise the function of a CAD software. Functions such as simulation and testing are incorporated in modern CAD software, which helps users to reduce time to perform simulation instead of having to use other software to perform the same task.

Utilising a CAD software requires basic knowledge of standards in design. Standards are a set of published requirements or specifications that is commonly used in technical task to ensure the usability and safety. Common standards that can be seen is International Organization of Standardization (ISO) standards and American National Standards Institute (ANSI) standards. There are other standards at which every one of them differs based on needs in respective location affected. Therefore, acquiring the basic knowledge of standards is a need in order to utilise CAD software. Table 2.1 below shows a few example of differences between ISO and ANSI standards.

Table 2.1: Example differences between ISO and ANSI standards

Standards	ISO	ANSI
Dimension style		
Symbol	R, Ø, 3X	RAD, DIAM, 3 PLACES

CAD software is known for its flexibility whereby any designed 3D models can be simulated to various conditions by changing the variables such as appearance and material. This allows user to visualize the 3D parts in different forms. The flexibility is not limited to only appearances of 3D models. Nowadays, newer CAD software offers feature which allows user to apply different material along with their material properties such as density, tensile strength and elasticity modulus. The material properties will be utilised during simulation which would visualize defects in real world such as deflection and deformation. Figure 2.1, 2.2 and 2.3 show various materials that are available in Autodesk Fusion 360.

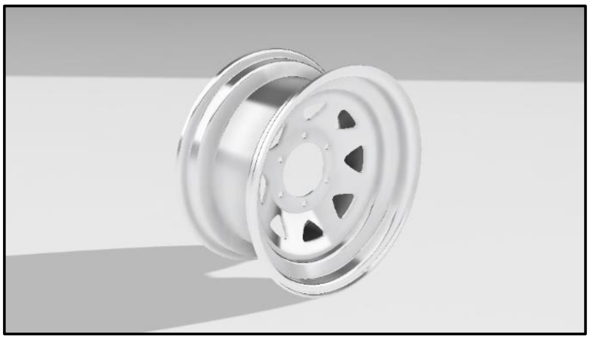


Figure 2.1: Aluminium wheels (Source: Autodesk Fusion 360)