UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION OF DESIGN RULE FOR FDM SYSTEM IN ADDITIVE MANUFACTURING: A CASE STUDY OF A BLENDER JAR

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

by

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ABSTRAK

Teknologi tambahan baru (AM) digunakan untuk membuat plastik dan bahagian logam lapisan demi lapisan. Walaupun AM menyediakan banyak potensi dan manfaat seperti membuat bahagian-bahagian yang sangat kompleks, teknologi ini masih jarang ditubuhkan untuk tujuan pengeluaran produk yang berfungsi. Salah satu faktor yang mempengaruhi had penubuhannya adalah kekurangan peraturan reka bentuk untuk AM. Malah sebilangan besar kajian kes dapat diketahui bahawa reka bentuk AM kekurangan. Dalam usaha untuk menyokong reka bentuk yang sesuai untuk AM, konkrit dan reka bentuk bebas diperlukan. Keberkesanan kaedah reka bentuk yang tidak terkenal. Projek ini akan mengkaji keberkesanan kaedah-kaedah reka bentuk untuk sistem FDM. Untuk mengkaji keberkesanan kaedah-kaedah reka bentuk, kaedah-kaedah reka bentuk akan digunakan pada balang pengisar yang sedia ada. Analisis unsur terhingga (FEA) akan dianalisis pada kedua-dua reka bentuk yang sedia ada dan reka bentuk baru untuk membuat perbandingan. Terdapat banyak kelebihan menggunakan kaedah-kaedah reka bentuk. Walau bagaimanapun, didapati bahawa terdapat juga keburukan dengan menggunakan kaedah-kaedah reka bentuk. Kelebihannya ialah ia memberi tekanan Von Mises yang tinggi dimana ia adalah baik kerana ia dapat mengatasi beban yang lebih banyak untuk bahan untuk mula bengkok. Selain itu perubahan dari bentuk asal adalah lebih kecil disebabkan oleh sesaran yang lebih kecil daripada reka bentuk lama. Kelemahannya adalah ia mempunyai faktor keselamatan yang lebih kecil daripada reka bentuk lama kerana tekanan Von Mises yang tinggi. Reka bentuk baru itu juga mengambil masa yang lebih pendek dan menggunakan bilangan bahan yang lebih kecil untuk membuat prototaip daripada reka bentuk lama. Dengan membandingkan reka bentuk yang sedia ada dan reka bentuk baru, kaedah reka bentuk yang sesuai untuk digunakan untuk membuat prototaip FDM akan diketahui. Walau bagaimanapun, disebabkan banyak halangan semasa melakukan projek, analisis yang sesuai telah dicadangkan untuk penambahbaikan kajian di masa depan.

ABSTRACT

Additive manufacturing (AM) technologies is used to create plastic and metal parts layer by layer. Although AM provides lots of potential and benefit such as manufacturability of highly complex parts, the technology is still rarely industrial established for end-used part production purposes. One limiting factor that affects its establishment is the insufficient availability of design rules for AM. Indeed, large numbers of case studies are known that exemplarily present AM design freedoms. In order to support a suitable design for AM, concrete and function independent design rules are required. The effectiveness of the design rule is not well known. This project will study the effectiveness of the design rules for FDM system. To study the effectiveness of the design rules, the design rules will be applied to an existing design of a blender jar. The finite element analysis (FEA) will be analyzed on both existing design and redesign to make a comparison. There are advantages of using design rules. However, it is found that there are also disadvantages by using design rules. The advantages are it gives high Von Mises Stress which it is good because it can overcome more load to start yield. Besides that the deformation is smaller due to its smaller displacement than old design. The disadvantage is it has smaller factor of safety than the old design due to its high Von Mises Stress. The new design also takes a shorter time and using smaller material length to build the prototype than the old design. By comparing the existing design and redesign, the design rules that suitable to used to make a FDM's prototype will be known. However, due to many flaws found during the development, proper analyses have been suggested for future study improvements.

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TABLE OF CONTENT

Abstrak	i
Abstract	ii
Acknowledgement	iii
Table of Content	iv
List of Tables	viii
List of Figures	x
List of abbreviations, symbols and nomenclature	xi
CHAPTER 1: INTRODUCTION	**1**
1.1 Introduction	1
1.2 Problem Statement	2
1.3 Aims	2
1.4 Objectives	2
1.5 Scope	3
1.6 Project Planning Gantt Chart	4
CHAPTER 2: LITERATURE REVIEW	**6**
2.1 Additive Manufacturing (AM)	6
2.1.1 Definition of AM	6
2.1.2 Basic Steps of AM	7
2.1.3 The Generic AM Process	7
2.1.4 Types of AM	10

2.1.4.1 Fused Deposition Modelling 10
2.1.4.2 Stereolithography (SLA) 11
2.1.4.3 Selective Laser Sintering 13
2.1.4.4 EBM 13
2.1.5 Advantages/Disadvantages of AM 14
2.1.6 Applications of AM 15
2.1.6.1 Lightweight Machines. 15
2.1.6.2 Architectural Modeling. 15
2.1.6.3 Medical Applications 16
2.1.6.4 Improving the Manufacturing of Fuel Cells 17
2.1.6.5 Additive Manufacturing in Art 18
2.1.6.6 Additive Manufacturing for Hobbyist 18
2.2 FDM System 18
2.2.1 FDM History 18
2.2.2 Build materials 19
2.2.3 FDM Working Principle 19
2.2.4 Advantages of FDM 20
2.3 Design Rules of FDM 20
2.3.1 Method for the development of design rules 20
2.3.2 Definition of standard elements 21
2.3.3 Basic Elements 21
2.3.4 Element Transitions 21
2.3.4.1 Design rules of element transition 22
2.3.5 Aggregated Structures 27
2.3.5.1 Design rules of aggregated structures 27

CHAPTER 3: METHODOLOGY **30**

3.1 Introduction 30
3.2 Design rule used for FDM system 30
3.2.1 Thickness and Edge in Element Transition 30
3.2.2 Starting Position and Material Accumulation in Aggregated Structures 31
3.3 Project Planning 34
3.3.1 Flowchart 35
3.3.2 Gantt Chart 36
3.3 Identify Existing Design 39
3.5 Remodelling of Existing Design 39
3.6 Modelling using SolidWork software 39
3.7 Finite Element Analysis (FEA) using SolidWork software. 40
3.8 Prototype 40

CHAPTER 4: RESULT AND DISCUSSION **41**

4.1 3D CAD Modelling using SolidWork software. 41
4.2 Differences of 3D CAD Modelling of Each Design Rules. 43
4.2.1 Material Accumulation 43
4.2.2 Island’s starting position 43
4.2.3 Outer Edge Shape 44
4.2.4 Thickness 45
4.3 Controlled Variable 45
4.3.1 Force Applied 45

4.3.2 Material Used 46
4.4 Finite Element Analysis (FEA) for Edge and Thickness Design Rules 47
4.4.1 Direction Of Fixture And Force Applied 47
4.4.2 Von Mises stress 48
4.4.3 Displacement 48
4.4.4 Deformation Shape 49
4.4.5 Factor of Safety (FOS) 50
4.5 Finite Element Analysis (FEA) for island's starting position 51
4.5.1 Direction Of Fixture And Force Applied 51
4.5.2 Von Mises Stress 52
4.5.3 Displacement 52
4.5.4 Deformation shape 53
4.5.5 Factor of safety (FOS) 54
4.6 Building Time And Material Length For Material Accumulation 55

CHAPTER 5: CONCLUSION 57

5.1 Conclusion 57
5.2 Recommendation 58

REFERENCES 59

List of Tables

Table 1.1	Gantt Chart PSM 1	4
Table 1.2	Gantt Chart PSM 2	5
Table 2.1	Historical development of RP and with any related technologies.	7
Table 2.2	Design Rules of Element Transition	23
Table 2.3	Design Rules of Aggregated Structures	28
Table 3.1	Design rules of element transition	32
Table 3.2	Design rules of aggregated structures.	33
Table 3.3	Gantt Chart of PSM I	37
Table 3.4	Gantt Chart of PSM II	38
Table 4.1	3D CAD Modelling of Old Design and New Design	42
Table 4.2	Force applied in FEA.	46
Table 4.3	Material used and its properties.	47
Table 4.4	Direction of fixture.	47
Table 4.5	Direction of force applied.	48
Table 4.6	FEA of Von Mises Stress	48
Table 4.7	FEA of displacement.	49
Table 4.8	FEA of deformation shape.	49
Table 4.9	FEA result of FOS.	50
Table 4.10	Direction of fixture.	51
Table 4.11	Direction Of Force Applied.	51
Table 4.12	FEA Result Of Von Mises Stress	52

Table 4.13	FEA Result Of Displacement.	53
Table 4.14	FEA Result Of Deformation Shape.	53
Table 4.15	FEA result of FOS.	54
Table 4.16	Building time and material length.	55

List of Figures

Figure 2.1	Generic process of CAD to part	8
Figure 2.2	Fused Deposition Modelling.	11
Figure 2.3	Stereolithography.	12
Figure 2.4	FDM Technology	19
Figure 3.1	Overall Flowchart	35
Figure 3.2	Example of blender jar design.	39
Figure 4.1	The differences of height of the body of blender jar.	43
Figure 4.2	The differences in island’s position	43
Figure 4.3	Shape of edge of blender jar.	44
Figure 4.4	Thickness of base and body of the blender jar.	45

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

µm	-	micrometer
kV	-	kilovolt
3D	-	3 Dimensional
ABS	-	Acrylonitrile Butadiene Styrene
AM	-	Additive Manufacturing
CAD	-	Computer Aided Design
DIY	-	Do it yourself
EBM	-	Electron Beam Melting
FEA	-	Finite Element Analysis
FDM	-	Fused Deposition Modelling
FOS	-	Factor of Safety
LOM	-	Laminated Object Manufacturing
MPa	-	Mega Pascal
PA	-	Polyamide
PC	-	Polycarbonate
PEMFCs	-	polymer electrolyte membrane fuel cells
PPSF	-	Polyphenylsulfone
RP	-	Rapid Prototyping
SLA	-	Stereolithography

SLS	-	Selective Laser Sintering
STL	-	Stereolitography file
UV	-	Ultraviolet

CHAPTER 1

INTRODUCTION

This chapter introduces the project as well as briefly describe the aims, objectives and its scope. This chapter will also provide an overview of the project's implementation.

1.1 Introduction

Additive manufacturing (AM) technologies refers to a process by which digital 3D design data is used to create plastic and metal parts layer by layer by depositing material (Kaifui and Aldo, 2012). The technology first developed with Stereolithography in the 1980s. Since then, AM was used for prototype production purposes only. Recently, with the increasing development of important technological and material enable AM applicability for the creation of end-used parts (Guido and Detmar, 2013). Thus, AM more and more turns to a production capable technology.

The strengths of AM lie in those areas where conventional machines reach its limitations. Using AM in terms of direct manufacturing to manufacture functional parts new advantages can be gained due to the layer by layer manufacturing. Thereby the extension of design freedoms is one of AM most remarkable potential. It describes a professional production technique permit the manufacturability of highly complex parts which cannot be produced with conventional technologies of material removal like milling or casting. Instead of milling a work piece from solid block, for example, AM builds components layer by layer using materials which are available in fine powder form. A range of different metals, plastics and composite materials may be used. The technology is of interest where a new approach to design and manufacturing is required so as to come up with solutions. It allows a design driven manufacturing process where design determines production and not the other way around. What is more, AM enables for highly complex parts which can still be extremely light and stable (Kaifui and Aldo, 2012). It produce a high degree of design freedom, the optimisation and integration of functional features, the manufacture of small batch sizes at reasonable unit costs and a high degree of product customisation even in serial production.

1.2 Problem Statement

Although AM provides lots of potential and benefit such as manufacturability of highly complex parts, the technology is still rarely industrial established for end-used part production purposes. One limiting factor that affects its establishment is the insufficient availability of design rules for AM. Indeed, large numbers of case studies are known that exemplarily present AM design freedoms. In order to support a suitable design for AM, concrete and function independent design rules are required. The effectiveness of the design rules is not well known. This project will study the effectiveness of the design rules for FDM system.

1.3 Aims

The aim of this project is to investigate the design rule for FDM system.

1.4 Objectives

1. To produce CAD model of a blender jar.
2. To apply the design rule for FDM system to the CAD model of the blender jar.
3. To study the effectiveness of the design rule for FDM system.

1.5 Scope

Scope of this study apply the design rules for FDM system of AM process developed by Adam, G. a. O., & Zimmer, D. (2014). From the design rules of FDM system, the design rules that will be chosen to apply on the blender jar is the thickness, edge, material accumulation and island's starting position because the design rules are suitable to be apply to the blender jar due to blender jar features. The design rules of FDM system will be applied to the blender jar because blender jar is a consumer product and suitable to be produce using FDM machine.

1.6 Project Planning Gantt Chart

Table 1.1: Gantt Chart of PSM I

No	**Task**	**Week**													
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Discuss the the title with supervisor														
2	Study about additive manufacturing and design rules.														
3	Draft chapter 1														
4	Submit chapter 1 to the supervisor														
5	Draft chapter 2														
6	Submit chapter 2 to the supervisor														
7	Draft chapter 3														
8	Submit chapter 3 to the supervisor														
9	Poster presentation														
10	Submit report PSM 1														

Table 1.2: Gantt Chart of PSM II

No	Task	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Draw a 3D CAD modelling of existing design														
2	Redesign by applying design rules														
3	Conduct finite element analysis (FEA)														
4	Draft chapter 4														
5	Submit draft chapter 4														
6	Conclusion and recommendation														
7	Draft chapter 5														
8	Submit chapter 5 to the supervisor														
9	PSM II presentation														
10	Submit draft report PSM II to panel and supervisor														

CHAPTER 2

LITERATURE REVIEW

This chapter will provide an initial understanding regarding the definition of AM, basic steps in AM system, and the techniques known to the public. This chapter also will provide information on the benefits of AM along with the limitations of AM and also the design rules for AM.

2.1 Additive Manufacturing(AM)

2.1.1 Definition of AM

AM is a technique which produces a product starting layer by layer based on the information from CAD data (Vlasea et al., 2011). Before the term AM was created popular, the technique of layer by layer (RP) which is used to fabricate the prototypes to be tested (Pandey, 2012). Table 2.1 shows the historical growth of RP along with any other related technologies.

Table 2.1: Historical development of RP and with any related technologies(Chua and Leong, 2000)

Inception Year	Technology
1770	Mechanization
1946	First computer
1952	First Numerical Control (NC) machine tool
1960	First commercial laser
1961	First commercial robot
1963	First interactive graphics system (early version of CAD)
1988	First commercial RP system

2.1.2 Basic Steps in AM

In RP, according to Aarnio (2010) there basic step that needs in order to be used dependent on the criteria mentioned by Chua previously. Although there are several RP techniques was indeed mentioned, each employs the same basic technique .The steps are making 3D CAD model, convert to STL format, and slice each file into thin layers, constructing the model one layer a top another as well as cleaning and completing the model.

2.1.3 The Generic AM Process

According Gibson, Rosen and Stucker (2010), AM involves several of steps that move from virtual CAD description towards physical resultant part. Different products will involve AM in different ways and to different degrees. Small, relatively easy products may just create usage of AM for visualization models, while larger, more complex products with greater engineering information could involve AM during numerous phases and iterations throughout the development process. Furthermore, beginning stages of the product development process may just require rough parts, with AM being used because of the speed at which they can be created.

At later phases of the process, parts may need careful cleaning and postprocessing (including sanding, surface preparation and painting) before they are used, with AM being helpful here due to the complexity of form that can be produced without having to think about tooling. Later on, we will study thoroughly the different stages regarding the AM process, but to summarize, most AM processes involve, to some degree at least, the following eight steps as illustrated in Figure 2.1.

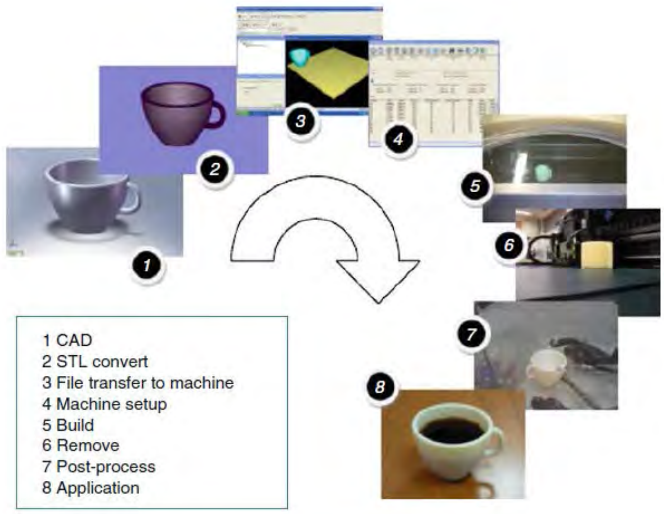

Figure 2.1: Generic process of CAD to part (Gibson, Rosen and Stucker, 2010)

Step 1: CAD

All AM parts must start from a software model that fully describes the external geometry. This can involve the use of almost any professional CAD solid modelling software, but the output must be a 3D solid or surface representation. Reverse engineering equipment (e.g., laser scanning) can also be used to create this representation.

Step 2: Conversion to STL

Nearly every AM machine accepts the STL file format, which has become a defacto standard, and nearly every CAD system can output such a file format. This file describes the external closed surfaces of the original CAD model and forms the basis for calculation of the slices.

Step 3: Transfer to AM Machine and STL File Manipulation

The STL file describing the part must be transferred to the AM machine. Here, there may be some general manipulation of the file so that it is the correct size, position, and orientation for building.

Step 4: Machine Setup

The AM machine must be properly set up prior to the build process. Such settings would relate to the build parameters like the material constraints, energy source, layer thickness, timings, etc.

Step 5: Build

Building the part is mainly an automated process and the machines can largely carryon without supervision. Only superficial monitoring of the machine needs to take place at this time to ensure no errors have taken place like running out of material, power or software glitches, etc.

Step 6: Removal

Once the AM machine has completed the build, the parts must be removed. This may require interaction with the machine, which may have safety interlocks to ensure for example that the operating temperatures are sufficiently low or that there are no actively moving parts.

Step 7: Postprocessing

Once removed from the machine, parts may require an amount of additional cleaning up before they are ready for use. Parts may be weak at this stage or they may have supporting features that must be removed. This therefore often requires time and careful, experienced manual manipulation.

Step 8: Application

Parts may now be ready to be used. However, they may also require additional treatment before they are acceptable for use. For example, they may require priming and painting to give an acceptable surface texture and finish. Treatments may be laborious and lengthy if the finishing requirements are very demanding.

2.1.4 Types of AM

2.1.4.1 Fused Deposition Modelling

According to KaufuiV.Wong and Aldo Hernandez (2012) Fused Deposition Modelling (FDM) is actually an additive manufacturing process at which the thin filament of plastic feeds the machine in which a print head melts it and also extrude it where the typical thickness is usually of 0.25 mm. Materials found in this particular process are polycarbonate (PC), polyphenylsulfone (PPSF), PC-ABS blends, acrylonitrile butadiene styrene (ABS), and also PC-ISO, which is a medical level PC. The primary benefits of this process are that no chemical post-processing recommended, no resins to cure, less expensive machine, and materials resulting in a more cost effective procedure .The drawbacks are that the resolution on *z* axis is low compared to different additive manufacturing process (0.25 mm), so in cases where a soft surface is required a finishing process is actually needed and it is a slow procedure sometimes taking times in order to build big complicated components. In order to consume time many models allow two modes; a fully dense mode and a sparse mode that consume time but obviously decreasing the mechanical characteristics. Figure 2.2 shown the schematic diagram of Fused Deposition Modelling Process