UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF FDM PARAMETERS WITH TAGUCHI METHOD FOR PRODUCTION OF FLEXIBLE ABS PART

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

HO KAM YUEN

B051210023

910216065499

FACULTY OF MANUFACTURING ENGINEERING

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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:

………………………………

(DR. SHAJAHAN BIN MAIDIN)

DECLARATION

I hereby, declared this report entitled "Optimization of FDM Parameters with Taguchi Method for Production of Flexible ABS Part" is the results of my own research except as cited in the references.

Signature	:	…………………………
Author's Name	:	Ho Kam Yuen
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ABSTRAK

Kaedah Taguchi adalah alat yang berkesan diperkenalkan bagi mengoptimumkan kualiti produk atau proses. Produk yang dihasilkan dengan bahan ABS oleh teknologi Fused Deposition Modelling (FDM) mengatakan prestasi produk berbeza dengan perubahan parameter proses mesin seperti ketebalan lapisan, sudut raster, jurang udara raster, dan beberapa yang lain. Prestasi produk yang dihasilkan menguna mesin FDM desktop diukur dalam aspek membuang jarak objek dengan produk. Dalam usaha untuk mencapai prestasi optimum bagi produk yang dihasilkan, kaedah Taguchi telah dilaksanakan kerana ia adalah satu kaedah yang mudah tetapi berkuasa untuk reka bentuk uji kaji menggunakan kaedah orthogonal array. Dalam projek ini, orthogonal array L_9 (3^3) telah digunakan dan 9 keping sampel telah ditentukan untuk 3 parameter iaitu: ketebalan lapisan, corak infill dan kepadatan infill dengan 3 tahap bagi setiap parameter. Sampel telah direka menggunakan SolidWorks dan mesin FDM desktop FlashForge Dreamer telah digunakan untuk membina 9 sampel tersebut. Sampel kemudiannya diuji ke atas prestasinya dalam membaling objek dengan sudut anjakan berbeza 10º, 15º dan 20º. Keputusan telah diperolehi dan data dianalisis. Data menunjukkan bahawa sampel dengan gabungan parameter ketebalan 0.2mm lapisan, corak isian heksagon dan 60% ketumpatan infill masing-masing mencapai purata jarak membaling terpanjang 52cm, 92cm dan 126.67cm bagi sudut anjakan 10º, 15º dan 20º. Oleh itu, keputusan ini menunjukkan bahawa ciri-ciri produk yang dihasilkan dengan menggunakan mesin FDM berbeza dengan kombinasi yang berbeza parameter proses dan Kaedah Taguchi menyediakan penyelesaian menentukan kombinasi yang optimum dengan jumlah minimum eksperimen.

ABSTRACT

Taguchi Method is an effective tool introduced for the optimization of the product or process quality. The ABS product produced by Fused Deposition Modeling (FDM) has it performance varies with the changes of the process parameters of the machine such as layer thickness, raster angle, air gaps and some others. The performance of the part produced via a desktop FDM machine was measured with the aspect of throwing distance of an object by the part. In order to achieve the optimum performance of the produced part, the Taguchi method was employed because it is a simplified yet powerful method for experimental design using the orthogonal array method. In this project, an orthogonal array of L_9 (3^3) was used and 9 pieces of samples were determined for 3 parameters namely: layer thickness, infill pattern and infill density with 3 levels each. The sample was designed using SolidWorks and FlashForge Dreamer a desktop FDM machine was used to fabricate the 9 samples. The samples were then tested on its performance in throwing objects with different displacement angles of 10º, 15º and 20º. The results were obtained and data was analyzed. The data shows that the samples with parameters combination of 0.2mm layer thickness, hexagon infill pattern and 60% infill density achieved the longest average throwing distance of 52cm, 92cm and 126.67cm for displacement angles of 10º, 15º and 20º respectively. Thus, this result shows that the properties of a product produced using FDM machine varies with different combination of process parameters and the Taguchi Method provides the solution of determining the optimum combination with minimum number of experiment.

DEDICATION

I would like to dedicate this work to my

Beloved parents

Dearest siblings

Honorable supervisor and lecturers

Supportive friends and mates

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I would like to use this opportunity to express my gratitude to everyone who supported me throughout the completion of the report for Final Year Project. I am thankful for their guidance, criticism and also advice during the project.

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CHAPTER 1

INTRODUCTION

This chapter introduces the project and briefly describe the aims, objectives and also the scopes. This chapter will also give an overview on the implementation of the project.

1.1 Introduction

Ever since the first commercial rapid prototype (RP) machine in 1986 which known as Stereolithography, RP machines have been commercialized widely with many more advance system developed in all around the world. Rapid prototyping which also known as additive manufacturing (AM) is clearly a key technology in shortens the time of product development for faster built of physical prototypes, tooling and models. Generally AM is more flexible and fast in adapting the rapid changes of the product design compared to conventional method such as casting, moulding and machining.

Fused deposition modeling (FDM) is one of the AM system uses plastic materials such as Acrylonitrile butadiene styrene (ABS) to produce prototypes or even functional products. The molten plastic material is ejected by nozzle layered to form the desired part which basically in solid form or shell form. The parameters which normally take count in producing good parts are the layer thickness, air gaps and raster angle. The parameters are studied and optimized or well paired in order to ensure good quality of the output. In recent years, Taguchi's techniques have been widely used in the optimization for both process design and product design, based on comprehensive experimental investigation. It is a suitable method is determining and optimizing the parameters of the FDM machine by pairing and testing the parameters (variables) which gives optimum output.

1.2 Problem Statement

It is important to determine the right parameters of the FDM machine in order to produce a part which can fulfil the desire specifications. There are basically few parameters which are important and will influence the specifications of the produced part, and these parameters are the layer thickness, air gaps and also the raster angle. The combinations of different setting of the parameters will definitely produce parts with different specifications, thus the study of the suitable combination of parameters is necessary for optimum output produced.

1.3 Aims

The aim of this project is to optimize the FDM machine parameters for flexible ABS part using the Taguchi method approach.

1.4 Objectives

The objectives of the project are:

i. To study and understand the parameter of FDM influencing the performance of the flexible ABS part,
ii. To use Taguchi method approach for design of experiment improving the FDM parameters,
iii. To determine optimum FDM process parameters combination which results in longest throwing distance with the ABS part.

1.5 Scope

The study covers the AM system which is the Fused deposition modeling (FDM). The parameters of the FDM machine, FlashForge Dreamer which will serve as the focus of the study are the layer thickness, infill pattern and infill density. The parameters optimized in order to achieve good performance in terms of throwing distance. The material used in producing the part is ABS type material.

CHAPTER 2

LITERATURE REVIEW

This chapter discuss about the related knowledge of the project which cover the introduction of the additive manufacturing, fused deposition modeling and Taguchi method.

2.1 Additive Manufacturing (AM)

Additive manufacturing, often been referred as 3D printing is a technology or process that convert digital model into parts and components. This technology firstly introduced as rapid prototype (RP) machine since the 1980s which is the Stereolithography (Lee, Abdullah & Khan, 2005).

Rapid prototyping is referred as group of techniques that creates functional model or components of a part or assembly layer by layer with input of 3D CAD data (Yagnik, D., 2014) which later known as additive manufacturing. AM techniques are classified and grouped based on each of the fundamental metal decomposition and its working principle which shown in Figure 2.1.

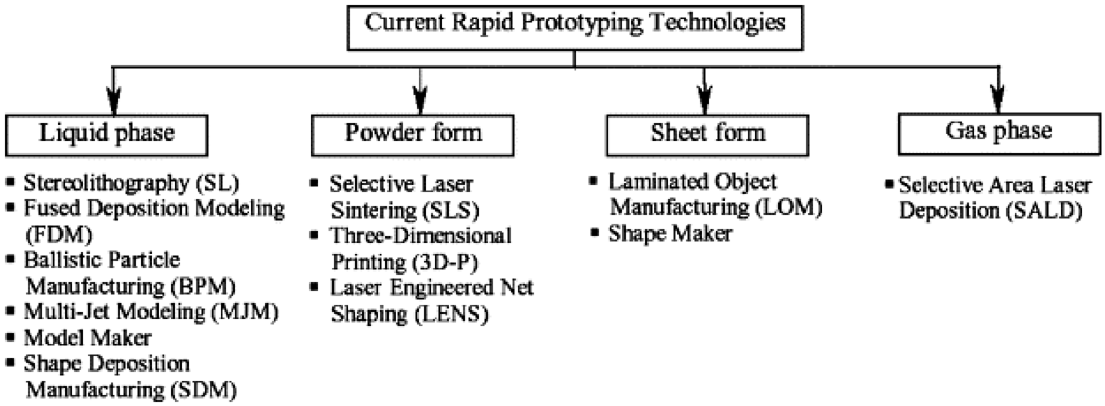

Figure 2.1: Categories of RP technologies (Yagnik,D., 2014)

Ever since the Stereolithography is introduced, the idea has been studied and many new processes are invented, patented and commercialized, which some has been fall out and disappeared (Levy, Schindel, & Kruth, 2003). Table 2.1 shows the overview of the development of the rapid prototype process and defined as additive manufacturing later.

Table 2.1: AM technologies, Acronym and development years (Levy, Schindel, & Kruth, 2003)

Name	Acronym	Year
Stereolithography	SLA	1986 – 1988
Solid Ground Curing (* = year of disappearance)	SGC	1986 – 1988 1999*
Laminated Object Manufacturing	LOM	1985 - 1991
Fused Deposition Modeling	FDM	1988 – 1991
Selective Laser Sintering	SLS	1987 - 1992
3D Printing	3DP	1985 - 1997

AM creates object and part layer by layer, after a layer of particles are bound by heat or chemical agent, another layer is added and repeated the binding process. Since the part or object is created layer by layer, this technology bring benefits to the design process by providing more freedom in part complexity which couldn't be produced by conventional method such as milling and casting (Adam, G.A., & Zimmer, D., 2014).

2.1.1 Advantages and Limitations of AM

AM gives definite competitive advantages in the aspect of geometrical freedom and material flexibility (Levy, Schindel, & Kruth, 2003). AM techniques provides advantages (Jauhar, S. K., & Asthankar, K. M., 2012) in:

i. Automated fabrication process
ii. Fabrication of intricate and small parts
iii. Reduced in fabrication lead time
iv. No tooling involvement
v. Elimination of process planning
vi. Product customization
vii. No scrap/waste

AM provides advantages in material saving because it considered as a "clean" build process as it requires only the exact amount of material for the design itself. Other than that, AM has shorter production lead time compared to the conventional processes. The building time for a conventional machine is mostly depending to the complexity of the part design itself, the build time is directly proportional to the amount of features consist on that design, the more feature it have, the longer the built steps and result in longer built time. While AM gives a distinct advantages at this aspect as the build process of a part with AM machine will be one, which is layering the material regardless the features of the part. Apart of that, AM requires no tooling for the part production process and this lead to a cost reduction in the aspect of tooling and also manpower due to the automated process of AM.

Despite of the advantages brought by AM, there are also some limitations behind it. AM can now access a wide range of materials according to each of the processes, yet the part produced using AM need to be refined in order to achieve the similar strength or chemical characteristics of the part made by traditional manufacturing process using same material. Besides, with the introduction of AM, the product design process has been shifted in a different approach to design for layer manufacturing. The CAD software/systems will be a limitations to design the model in order to have full advantages provided by AM technologies since the current CAD software is developed based on the traditional manufacturing processes. Accuracy of the part always a concern in AM technology. The part produced using AM will have layered and rather rough surface finishing which requires the assistance of post-production of finishing processes. Productivity would be an issue for AM when comparing with the conventional processes. AM processes might have rather low productivity compared to traditional processes but in consideration of other factors such as the overall lead time, product complexity and more, AM would have provide a better alternative, yet the production rate of the AM techniques still a limitation that need to be addressed (Levy, Schindel, & Kruth, 2003).

2.1.2 Applications of AM

AM grew rapidly and its applications has expanded from prototyping to possible end-use parts/products. There are some history of AM applications and its estimated future developments.

Table 2.2: AM application timeline

(Royal Academy of Engineering (Great Britian), 2013)

1988 – 1994	Rapid prototyping
1994	Rapid casting
1995	Rapid tooling
2001	AM for automotive
2004	Aerospace (polymers)
2005	Medical (polymer jigs and guides)

2009	Medical implants (metals)
2011	Aerospace (metals)
2013 – 2016	Nano-manufacturing
2013 – 2017	Architecture
2013 – 2018	Biomedical implant
2013 – 2022	In situ bio-manufacturing
2013 – 2032	Full body organs

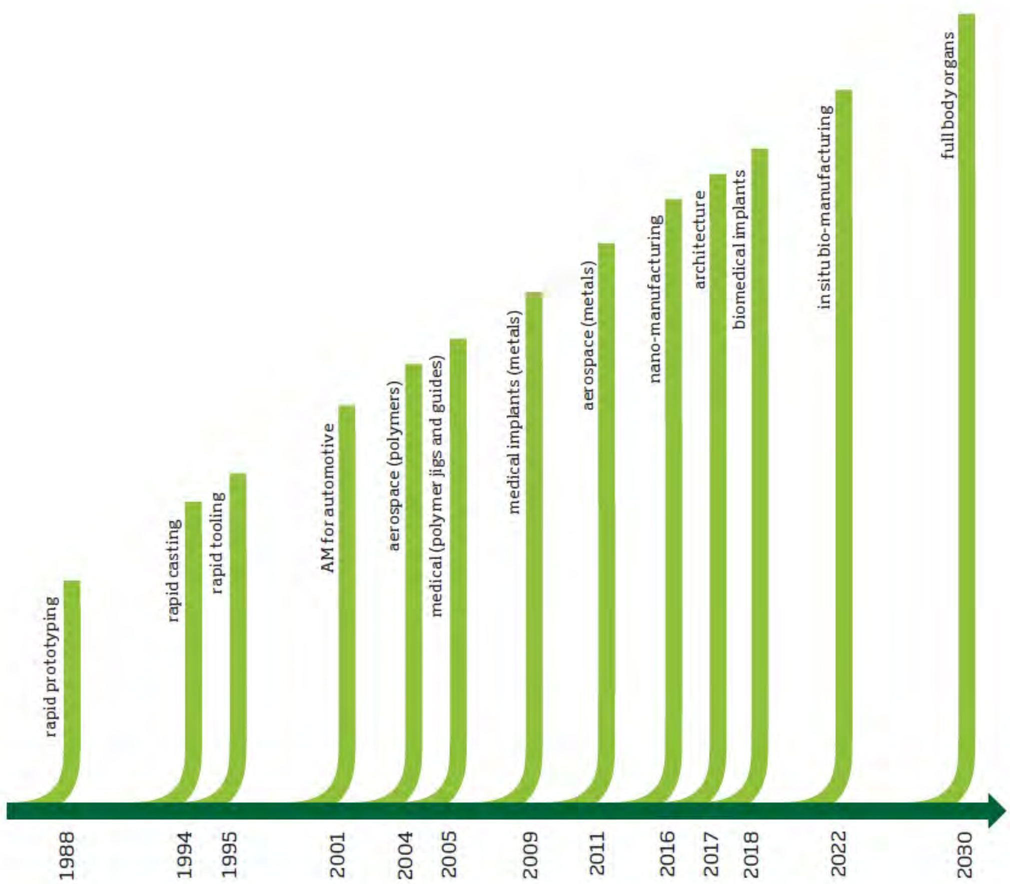

Figure 2.2: AM application timeline

(Royal Academy of Engineering (Great Britian), 2013)

AM developed from producing prototypes to building end-use product and bring significant changes to sectors like medical, aerospace/automotive and recently the architecture sector.

2.1.2.1 Medical Applications

With the unique characteristics of AM which is the great geometrical freedom promotes the expansion of its application to medical field due to the body structure varies among patients. (Su et al, 2012) The application of AM in medical field helps in fabricating parts for implant surgery such as scaffold.

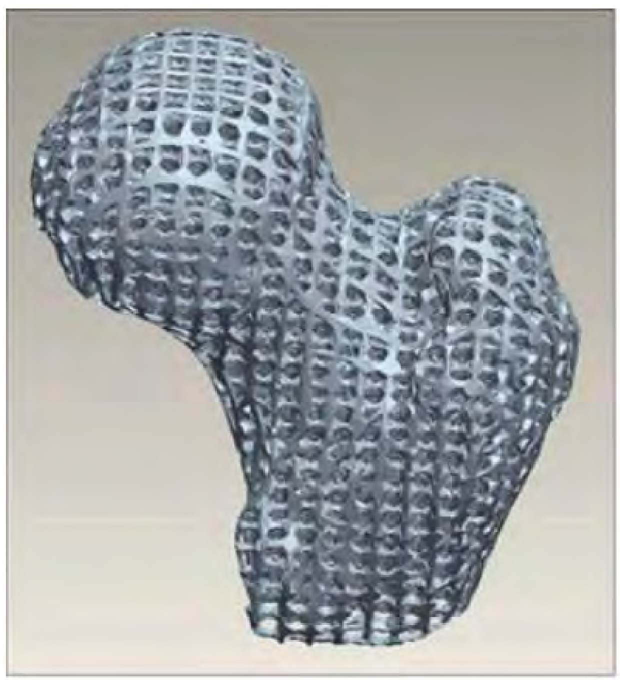

Figure 2.3: Example of a scaffold model (Su et al, 2012)

Fabrication of scaffold using conventional processes hard due to the porous structure, thus AM is brought into attention as the scaffold could be fabricated with the regenerating of the CAD model which could be done using the CT scanner and leave everything to the