POST PROCESSING TECHNIQUES OF 3D PRINTED PART AND ITS EFFECTS ON MECHANICAL PROPERTIES

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The thesis is submitted in fulfillment of the requirements for the Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

DECLARATION OF ORIGINAL WORK

I hereby declare that this thesis entitled "Post Processing Techniques of 3D Printed Part and Its Effects on Mechanical Properties" is the result of my own, except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

SIGNATURE : ____________________

NAME : LEONG KOK SENG

DATE : 16th MAY 2018

SUPERVISOR'S APPROVAL

' I, hereby declared that I had read through this thesis and in my opinion that this thesis is adequate in terms of scope and quality which fulfill the requirements for the award of Bachelor of Mechanical Engineering.'

SIGNATURE : ____________________

NAME OF SUPERVISOR : IR. DR. MOHD RIZAL BIN ALKAHARI

DATE : ____________________

DEDICATION

I would like to dedicate the appreciation to my parents, Leong Soon Chee and Ching Chooi Fong who supported me from spiritually and financially, my supervisor, Ir. Dr. Mohd Rizal bin Alkahari and my course mates that assisted me through the journey of research.

ABSTRACT

Fused Deposition Modeling (FDM) is one of the additive manufacturing technology, where printing material is deposited layer by layer onto the surface to form a complex product. FDM technique is widely used in producing prototypes. However, FDM technique has poor surface finishing and staircase effect compared to other additive manufacturing techniques. The purpose of this study was to develop a new post-treatment technique, known as Blow Cold vapor smoothing treatment. Later analysis on the effectiveness of this newly developed post-treatment technique and evaluate the tensile strength of the printed part. The specimens were printed using open source low-cost 3D printer with acrylonitrile-butadiene-styrene (ABS) printing material. Acetone solvent was used in this Blow Cold vapor smoothing treatment. A comparison in term of surface roughness value and tensile strength was made between the treated and untreated specimens. It was found that the surface roughness value on the treated specimen was reduced dramatically. However, this post-treatment technique weaken the material structure of the outer layer on the specimen, which had a slight effect on the tensile strength of the specimen.

ABSTRAK

Fused Deposition Modeling (FDM) atau dikenali sebagai proses pembuatan pertambahan adalah proses untuk membuat objek berbentuk 3 dimensi dari model digital dengan menggunakan teknik membuat objek daripada sejumlah bahan plastik dicetak berlapis-lapis di bawah kawalan komputer sehingga membentuk objek yang diinginkan. Walau bagaimanapun, produk hasil daripada teknik FDM mempunyai kemukaan yang lebih kasar dan kesan staircase berbanding dengan teknik yang lain. Kajian ini bertujuan untuk menghasilkan satu proses baru untuk melicinkan permukaan spesimen selepas cetakan. Seterusnya, menganalisiskan keberkesanan teknik ini dan menilaikan kekuatan spesimen selepas menggunakan teknik rawatan ini. Teknik rawatan ini dikenali sebagai teknik Blow Cold vapor smoothing. Spesimen dicetak dengan menggunakan 3D printer yang kos rendah dan perisian sumber terbuka. Sumber bahan plastik cetakan yang digunakan adalah plastik acrylonitrile-butadiene-styrene (ABS). Pelarut kimia yang digunakan dalam teknik rawatan Blow Cold vapor smoothing adalah aseton. Perbandingan dibuat dari segi kekasaran permukaan dan kekuatan spesimen antara spesimen sebelum dan selepas rawatan. Hasil perbandingan menunjuk bahawa kekasaran permukaan selepas rawatan menurun secara dramatik, tetapi teknik rawatan ini akan melemahkan struktur bahan pada lapisan spesimen yang paling luar. Oleh sebab itu, kekuatan spesimen akan mengurang sedikit.

ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere acknowledgment to my supervisor Ir. Dr. Mohd Rizal bin Alkahari from Faculty of Mechanical Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this thesis. His timely advice, meticulous scrutiny, and scholarly advice had helped me to a very great extent to accomplish this thesis.

I would also like to express my gratitude to Professor Dr. Ghazali bin Omar, the person in charge for Advanced Materials Characterization Laboratory (AMCHAL) Faculty of Mechanical Engineering, Mr. Azrul Syafiq bin Mazlan, the technician from Tribology laboratory Faculty of Mechanical Engineering, Madam Adybah Atyqa Shahrina binti Aimee Shah, technician from Chemical laboratory Faculty of Mechanical Engineering, and Mr. Mohd Yuszrin bin Md Yacob, technician from Final Year Project (PSM) laboratory for their kind assistant and efforts in all the labs and analysis works. Special thanks profusely to UTeM for the financial support throughout this study.

I am extremely thankful to my mentor, Siti Nur Humaira binti Mazlan for her overwhelming guidance throughout this study. I also do not forget to thank all my peers, friends, family and all who, directly or indirectly have lent their helping hand throughout this study.

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LIST OF ABBREVIATIONS

3D	3 Dimensional
FDM	Fused Deposition Modeling
MEK	Methyl Ethyl Ketone
RTV	Room-Temperature-Vulcanizing
UTeM	Universiti Teknikal Malaysia Melaka
UV	Ultraviolet

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Rapid Prototyping is defined as a collective method used to quickly design and create a scaled size model or part using three-dimension computer-aided design (CAD) software data. With the help of Rapid Prototyping technology, prototypes are able to produce quicker and in a more effective way. Rapid Prototyping technology is a time-saving technique to fabricate complexly shaped prototype by using additive manufacturing method. 3D printing is also known as additive manufacturing. Additive manufacturing is a process of designing a solid prototype using computer-aided design software, converting the designed solid into Standard Triangulation Language (STL) format and fabricating the designed solid using 3D printer. Stereolithography (SLA) method is an early and most widely used technology developed by 3D Systems of Valencia, CA, USA in 1986 (Gibson and Bártolo, 2011).

There are a few different methods of 3D printing, but Fused Deposition Modeling (FDM) is most widely used process (Palermo, 2013). FDM technique was developed and patented by Scott Crump and Lisa Crump, co-founder of Stratasys, Ltd. in 1988 (Anonymous, 2013). The FDM processes are filament first being extruded by the filament extruder, then, the filament is heated to the semi-molten temperature, and the semi-molten filament is flowing out through the automatic controlled nozzle depositing material layer by layer onto the surface (Conner et al., 2014). The printing materials which are most widely used include Polylactic acid (PLA) and Acrylonitrile butadiene styrene (ABS). However, the disadvantage of using FDM additive method is high surface roughness compare with other methods (Krolczyk, Raos, and Legutko, 2014).

Two most important criteria of a product in many engineering industries are surface roughness and surface topography (Poljacek et al., 2008). Surface roughness treatment can be classified into two methods; Pre-processing method and Post-processing method. In pre-processing method, optimum printing parameters such as layer thickness, raster angle, infill density, infill pattern, nozzle temperature are determined to maximize the mechanical properties of the project. However, "staircase" effect still can be found on the surface and greatly influence the surface roughness. Post-processing methods such as sanding, chemical treatment, painting are needed to reduce the staircase effect and improve the surface roughness.

In this study, a new post-processing method, namely Blow Cold vapor smoothing treatment was proposed. Previous researches had done using post-processing hot acetone vapor bath method was proved to be very effective in improving the surface roughness. However, this process was dangerous due to acetone is highly flammable. This new post-processing method was practically safe which does not involve heating the acetone.

1.2 PROBLEM STATEMENT

3D printing technology is an emerging technology and widely used in producing prototyping. Many researches and studies have been done to enhance the functionality and improve the mechanical properties of the 3D printed project. FDM technique is one of the widely used 3D printing technology. However, FDM technique has higher surface roughness value compare to other techniques. One of the key factors that influences the surface roughness of the FDM printed part was temperature (Chaidas et al., 2016). As the temperature increases, the filament material was tended to liquefy to a more liquid stage and hence, softening the printed surface (Bharath, Dharma, and Henderson, 2000). This will result in lowering its flexural modulus. As the new layer is printed, the previous layer will tend to curve downward and results in preferential flow and reduce surface finish (Comb, Priedeman, and Turley, 1994). Therefore, optimum temperature needs to be determined using Taguchi method. Besides that, a new post-processing method needs to be researched in order to further improve the surface roughness of the part produced by FDM technique.

1.3 OBJECTIVES

The objectives of this study are as follows:

i) To analyze effectiveness of post treatment process.

ii) To evaluate the mechanical properties of the treated 3D printed part.

iii) To study the optimum parameter in post process method.

1.4 SCOPES OF PROJECT

The scopes of this project are:

i) Fabrication was made using low cost 3D printer (Open source system / entry level printer).

ii) Acetone was used as chemical agent.

iii) The project used thermoplastic material such as ABS material.

CHAPTER 2

LITERATURE REVIEW

2.1 Rapid Prototyping

"Prototyping" is defined as the product development in term of shape, dimension and functionality of a designed part before investment in large-scale manufacturing process (Pham and Gault, 1998). In term of marketing, prototype is the physical model which able to present the design concept, idea, functionality of a product to the customers and modifications can be made to meet customers' requirements (Yan and Gu, 1996). In term of engineering, prototype able to help engineers to transform the CAD data into physical model, which helps to visualize exactly the actual product (Yan and Gu, 1996). This is useful for engineers to anticipate the problem while designing the complex part.

Campbell et al. (2012) defined rapid prototyping as "a wide range of technologies that fabricate prototypes, layer by layer in a quick and automated manner during the early stages of product development". One of the advantages in rapid prototyping is able to produce the physical model with range of automated technologies and validate the product rapidly with minimum cost. Therefore, design changes can be happened in the earlier stages of product development and reduce the amendment's cost at the later stages (Gurr and Mülhaupt, 2012). Figure 2.1 below shows the flowchart of product development cycle. Studies proved that rapid prototyping able to reduce product development cost by up to 70% and time to market by 90% (Pham and Gault, 1998).

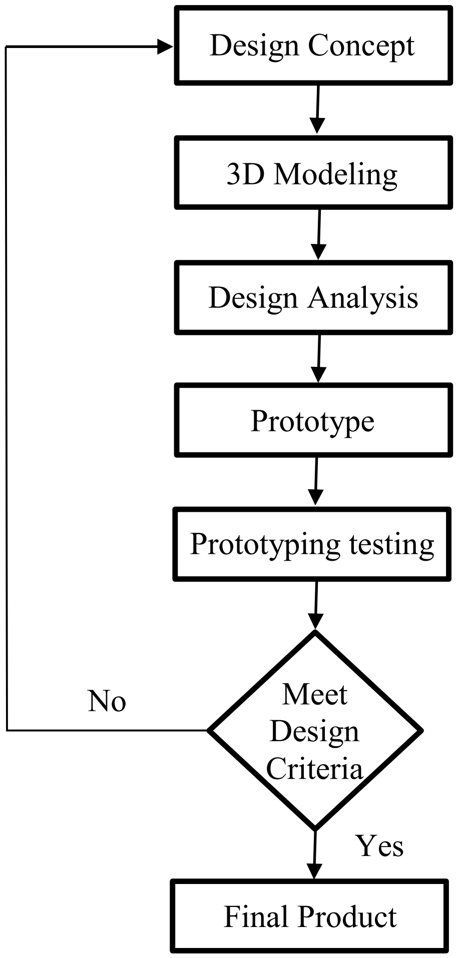

Figure 2.1: Product Development Cycle (Wong and Hernandez, 2012).

Gurr (2012) explained rapid prototyping synonymously demoted as “solid freeform fabrication (SFF) or layered manufacturing (LM), represents layer by layer fabrication of 3-dimensional (3D) prototypes”. All the preprocessing procedures are almost same throughout all the rapid prototyping process. The 3D modeling data of the prototype is created by computer-aided design (CAD) software or 3D scanning, and sliced into layers to obtain information needed for producing the 3D product. Rapid prototyping technologies can be divided into additive manufacturing and subtractive manufacturing.

2.1.1 Additive Manufacturing (AM)

Additive manufacturing is defined as "the process of joining materials to make object from three dimensional (3D) model data, usually layer upon layer as opposed to subtractive manufacturing methodologies" (Guo and Leu, 2013). Additive manufacturing also known as additive fabrication, direct digital manufacturing and layer manufacturing. Figure 2.2 below illustrates one of the additive manufacturing process – Fused Deposition Modeling (FDM). Additive manufacturing is the first computer automated methods that able to produce physical model layer by layer according to 3D modeling in computer-aided design (CAD) using various kind of materials, such as metal, ceramic, plastic, and composite material (Huang et al., 2015).

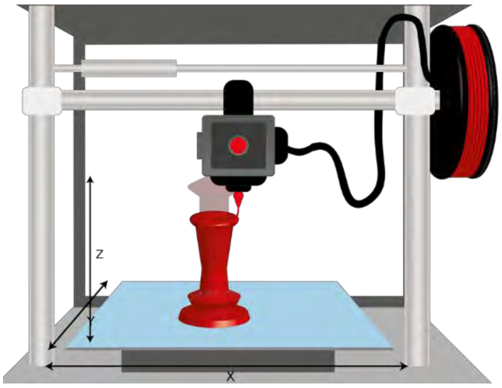

Figure 2.2: Fused Deposition Modeling Process (Raghavan, K., 2016).

One of the advantages of additive manufacturing is the ability to fabricate complex model rapidly without the use of additional fixtures and cutting tools (Huang et al., 2013). Unlike subtractive manufacturing process, additive manufacturing able to construct complex geometries as shown in Figure 2.3 and consolidate all the separate parts into a single model. However, the curved surface or overhang geometry required additional support material while fabricating. The support material which is able to remove easily after the fabrication process. Besides that, design optimization and testing can be performed at the same time in order to test product's functionality and marketability, hence, reducing the need for natural resource during the process.

Figure 2.3: Complex Air Duct System Used in Aerospace Industry Fabricate by Additive Manufacturing Process.

Furthermore, the flexibility of additive manufacturing allows manufacturers to optimize the product development lead time and further reduce the manufacturing cost with less human interaction (Gardan, 2015). According to Babu & Goodridge (2015) showed that additive manufacturing able to improve sustainability through the efficient use of the material. Figure 2.4 below illustrates the comparison waste of material between additive manufacturing and subtractive manufacturing. Unlike subtractive manufacturing using material removal techniques such as machining, punching and stamping to fabricate the product, additive manufacturing fabricates the product by depositing material layer by layer repeatedly until the final shape is formed.

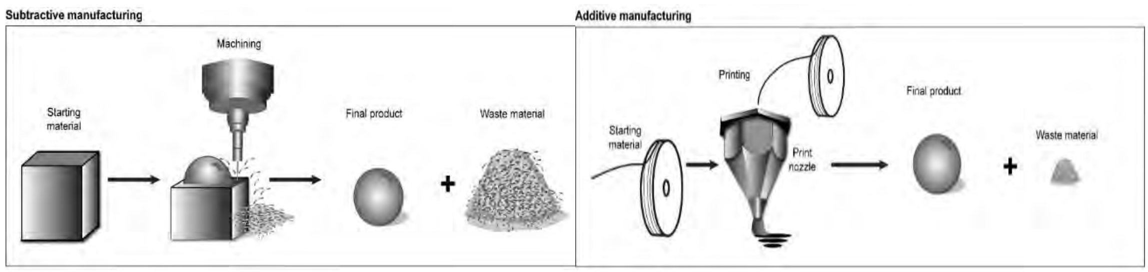

Figure 2.4: Conceptual Comparison between Subtractive and Additive Manufacturing.