MECHANICAL PROPERTIES OF COMPONENTS FABRICATED VIA LOW COST ADDITIVE MANUFACTURING

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DECLARATION

I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledge.

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Date : ……..

SUPERVISOR DECLARATION

I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for award of the degree of Bachelor of Mechanical Engineering (Design and Innovation)

Signature : ……

Name : Ir. Dr. Mohd Rizal Bin Alkahari

Date : ……

DEDICATION

My beloved mother and father

My dearest siblings

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ABSTRACT

The aim of this research is to study about the mechanical properties of acrylonitrile butadiene stryrene (ABS) which is widely used in 3D printing. The technique being used in this research is fused deposition modelling (FDM). It is widely known that the product made by open source 3D printer facing some problems related to the strength of the product. The current open source 3D printer can be improved in order to produce good quality of product. Based on the study, it is found that by applying pressure on the printed product, may enhance the quality of the product. Thus, the mechanical properties of ABS can be improved after applying the pressure on the ABS while printing the part. The roller is designed and installed to the nozzle of the printer. The design of the roller is selected through several stages including morphological chart and conceptual design. In order to determine the strength of the samples, there are several experiments are tested to determine the strength of the existing printed part as well by applying pressure using Kossel open source 3D printer. The parameters used to produce the samples are layer thickness, fill density and speed of printing. Fourteen samples are prepared for every types of printing method which is for printing the samples with normal Kossel 3D printer and printing the samples with applied pressure (roller) using Kossel 3D printer as well. The standard of dog bone sample used to print is ASTM D638. Next, tensile test, surface roughness test and porosity test were made. It was found that, the quality and strength of the product can be improved after applying pressure on the printed part while printing process.

ABSTRAK

Tujuan kajian ini adalah untuk mengkaji tentang sifat-sifat mekanikal acrylonitrile butadiene stryrene (ABS) yang digunakan secara meluas dalam bidang pencetakan 3D. Teknik yang digunakan dalam kajian ini adalah model pemendapan terlakur (FDM). Ia diketahui secara meluas produk yang dibuat oleh pencetak 3D sumber terbuka menghadapi beberapa masalah yang berkaitan dengan kekuatan produk. Pencetak 3D Kossel yang sedia ada boleh diubahsuai untuk menghasilkan kualiti produk yang baik . Berdasarkan jurnal-jurnal dan artikel-artikel yang ditemui daripada penyelidik tertentu, didapati bahawa dengan mengenakan tekanan ke atas produk yang dicetak, ia boleh meningkatkan kualiti produk tersebut. Oleh itu, sifat-sifat mekanikal ABS boleh dipertingkatkan selepas dikenakan tekanan ke atasnya semasa proses mencetak dijalankan. Penggolek direkabentuk dan dimasang pada bilah penyejuk pencetak. Rekabentuk penggolek dipilih melalui beberapa peringkat termasuk carta morfologi dan rekabentuk konseptual. Parameter yang digunakan untuk menghasilkan sampel adalah ketebalan lapisan, isi ketumpatan dan kelajuan pencetakan. Empat belas sampel disediakan untuk setiap jenis kaedah percetakan iaitu mencetak sampel normal dengan pencetak 3D Kossel dan mencetak sampel yang dikenakan tekanan (roller) dengan menggunakan pencetak 3D Kossel juga. Standard sampel tulang anjing yang digunakan untuk mencetak sampel adalah ASTM D638. Seterusnya, ujian tegangan, ujian kekasaran permukaan dan ujian keliangan dijalankan. Ia telah mendapati bahawa, kualiti dan kekuatan produk boleh boleh diperbaiki selepas mengenakan tekanan pada setiap lapisan sampel yang dicetak semasa proses pencetakan.

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LIST OF ABBREVIATIONS

ABS	Acrylonitrile Butadiene Styrene
CAD	Computer Aided Design
CATIA	Computer Aided Three-dimensional Interactice Application
FDM	Fused Deposition Modelling
PC	Personal Computer
RP	Rapid Prototyping
SLA	Strero Lithography
SLS	Selective Laser Sintering
STL	Stereo Lithography File
LOM	Laminated Object Manufacturing
USB	Universal Series Bus
UTeM	Universiti Teknikal Malaysia Melaka
3D	Three Dimensions

CHAPTER 1

INTRODUCTION

1.1 Project Background

Three-dimensional printing technology has been well known use and requires a large number of quantities in industry needed nowadays. Most of the regular or conceptual two-dimensional printer still remains the plane print, where the paper is printed with the text, graphics to be printed. However, since the technologies growth rapidly by times, the invention of 3D printer become a popular technology requires in engineering fields and human needs. The technologies of 3D printer began to be applied to design, digital product mould, industrial design, paint, and other fields. Meanwhile, there is still requires an enhancement on 3D printer due to stability, accuracy, and balance.

Additive manufacturing or well know as three dimensional (3D) printing technologies have been growth widely in engineering field. Nowadays, this technology has a various methods and types in order to print 3D parts or object layer by layer completely. stereolithography (SLA) is the one of the types of additive manufacturing which produces high-resolution parts. On the other hand, it is proved that SLA method in terms of producing 3D product is not long lasting. Hence, the other type of 3D printer is fused filament fabrication (FFF) or fused deposition modelling (FDM) has been commonly used to build parts depositing successive filament beads of polymer. A similar technique is uses including continuous fiber reinforced materials together with a resin are deposited in a ‘green state’. Then followed by the process where the parts is placed under vacuum condition and heated in

order to remove entrapped air voids. The air voids may trap and presented in the deposited materials; thus, the part will fully cured through this process.

Due to unstable and inaccuracy system development of 3D printer, a study of 3D printer properties as well as it mechanical characteristics, have been identified by certain researcher. Thus, this project is lead to enhance and identified the mechanical characteristic of components fabricated via low cost additive manufacturing.

1.2 Working Principle

3D printer built a part which support structure is create by fused deposition modelling (FDM) which is using thermoplastic blended material to form the model. The material containing a polyphenysulfone (PPSF) polymer and a polycarbonate (PC) polymer, which is good chemical resistance, thermal stability, and resist build-up through the nozzle of 3D modelling apparatus. The support structure is removed from a completed model while the material is hot to ease the process of removing. The depositing layers of solidifiable modelling material is extrude through the nozzle head and pointing to the printing table to form a layer of part. The molten extruded material is deposited layer-by-layer from nozzle head to the base. This technique use Thermoplastics as a material that suitable for deposition modelling process.

1.3 Problem Statement

Unstable and inaccuracy of 3D printer will cause problems on outcomes or the products. There are certain mechanical characteristics need to be improvised due to this problem that can cause a defect on parts of product. Meanwhile, to develop a low cost additive manufacturing system, need to be more precise on mechanical characteristics as well as it quality itself. Regarding to the low cost additive manufacturing, it may affect the quality of the object. Thus the strength, bonding, and complexity of the process also influence in order to produce a good part of 3D model. The existence 3D printer produces a model with a porosity structure and the structure need to be improved in order to enhance the strengthen of

the ‘dog bone’ model. Thus, a few inventions and brainstorming an ideas process should be taken in this project.

1.4 Objective

In order to improvise and enhancement of 3D printing development, there are a few objectives related to this project. This project consists of skills to generate an idea to improvise the system of 3D printer in terms of low cost additive manufacturing. However, the objectives of this project are listed as below. The objective of this project is:

a) to study the mechanical properties of material used to produce the product made by 3D printer itself. It also included the tensile stress, tensile strain, maximum load and modulus of the material.
b) to design a suitable roller to improvise the mechanical structure of the sample.
c) to enhance the strength of the model on porous structure through various processes while the experiment is carried out. Thus the mechanical properties of the material used, ABS also improved.

1.5 Scope

The scope of this research including:

a) to improve the mechanical properties as well as the quality of the samples.
b) to produce a normal samples and samples with applied pressure made by Kossel 3D printer.
c) the experiment will be conducted for both types of samples for tensile test, surface roughness test, and also porosity test.

1.6 General Methodology

The actions that required in order to achieve the objectives in this project are listed below.

1. Literature review
   Commonly review on articles, journals, or any materials which related to the project.

2. Inspection
   The structure of the 'dog bone' model will be inspected and a few tests including tensile test will be run to investigate and examine the porosity against the 'dog bone' model.

3. Measurement
   The measurement will be based on the 'dog bone' model size. Meanwhile the actual product of 3D printer will be tested after the test is run onto the 'dog bone' model. The criteria of the strength and porous structure of the 'dog bone' model should be considered.

4. Simulation
   Simulation of the 'dog bone' model will be visualized and simulated through various software including CATIA, G-Code simulator and others to convert the file into '.STL' file form to proceed the process into the making of the model.

5. Report writing
   A report on this study is written during the project is carried out.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Additive manufacturing or commonly known as three dimensional printing where the process happened from designing the product from digital file to the real prototype or solid object. The process involve in the making of 3D printed object by using additive processes which specifically the successive layers are laying down and gradually made until the object is created. In order to print a 3D object, the manufacturer uses 3D computer-aided design (CAD) software to create a digital model. As a time grow rapidly in a term of technology, 3D printing methods become more accessible either in small or mid-sized businesses as well as home users. The cost of 3D printing gradually decreases due to the growth of new technology of 3D printing in industries uses. 3D printers are able to produce and create a small components such as toys or small mechanical components. It also tested as prototypes for experiment and analysis purposes.

In 1985, Michael Feygen was the first developer of 3D printer and this invention create various names including rapid prototyping, stereolighography (SLA), fused filaments fabrication (FFF), and also additive manufacturing. The materials used in the making of the product are based on the requirement and needs and some of it are use liquid polymer or gel; others use resin where the cost of material is slightly higher. The object is created by layers and these layers produced a thin sliced horizontal cross-section from the base of an object until the object is done layered to the top.

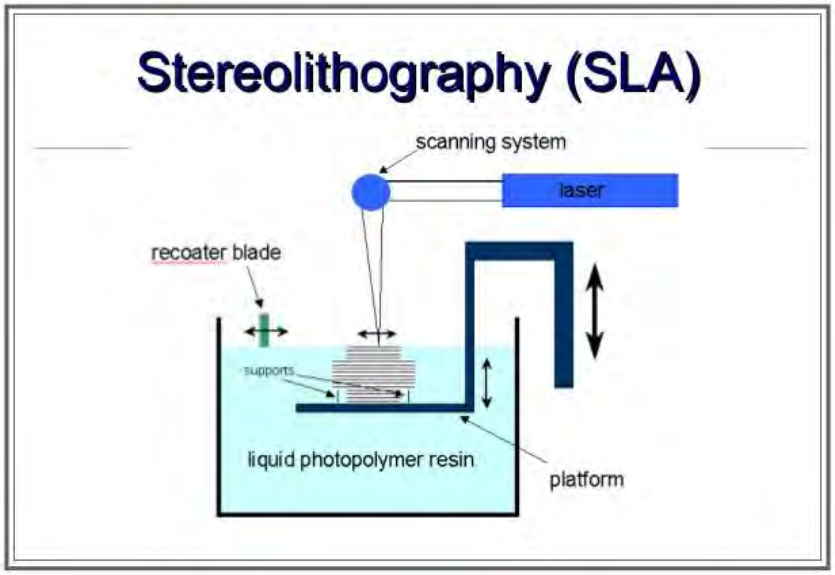

Figure 2.1: Stereolithography (SLA) diagram

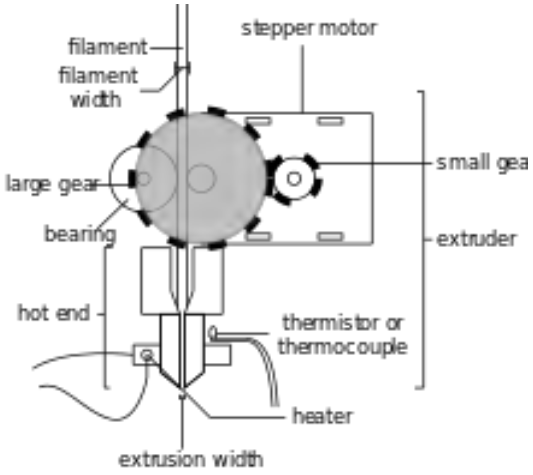

Figure 2.2: Fused filaments fabrication (FFF) diagram

2.2 Fused Deposition Modeling (FDM) Process

The 3D printer works when the virtual design is done by CAD programme to create an actual object through 3D printer. This software may develop a 3D modelling application. There is various ways to create a 3D modelling object. In industrial, the software used may cost thousands a year per license. But as a beginner or for a study purposes, it is advisable to subscribe free open source software, like Blender, for instance. When the 3D model is made, the next process is to prepare it in order to make it 3D printable. Certain technologies are

involved in order to complete the process of 3D printing for instance a 3D scanner. 3D scanner can imitate an actual object in 3D digital copy.

Some of 3D printer not use the same technology and there are various way to print including additive, where the object are build layer by layer until the final object is complete. In order to produce the layers of an object, there are two methods either in melting of softening material to form the object. Generally, selective laser sintering (SLS) and fused deposition modelling (FDM) are commonly used in this technology of 3D printing.

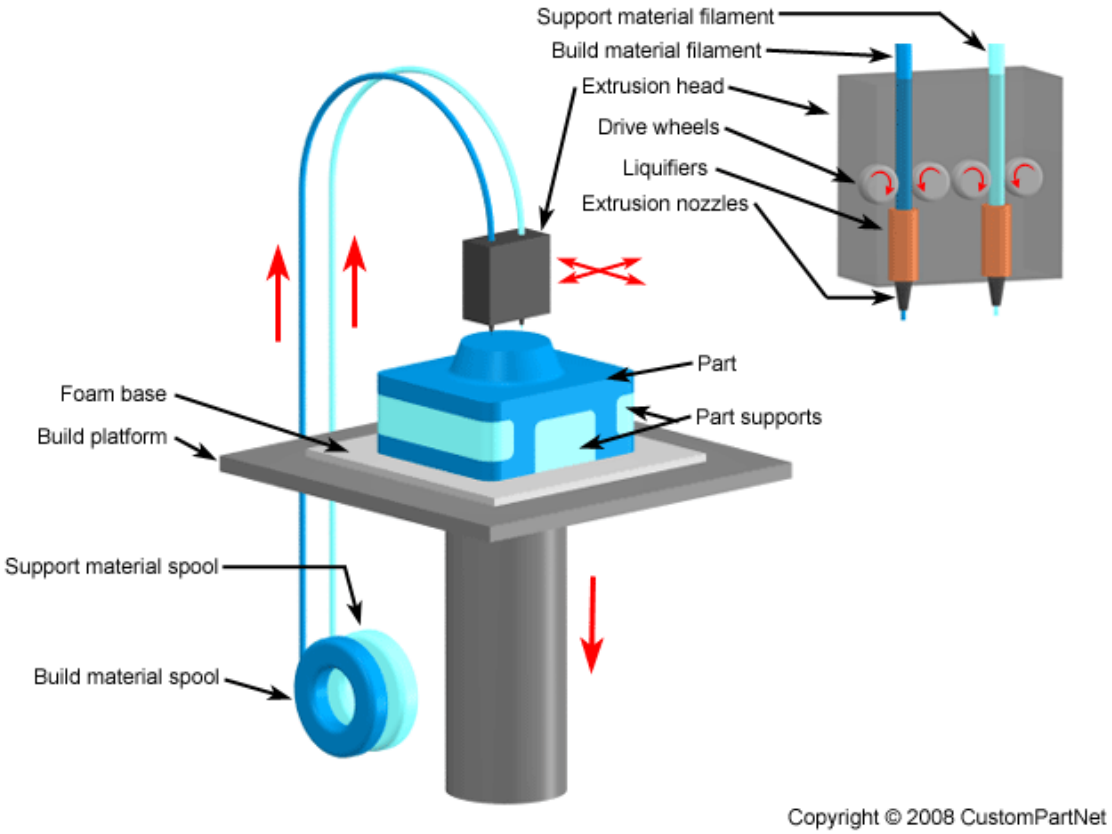

Figure 2.3: Fused Deposition Modelling (FDM) diagram

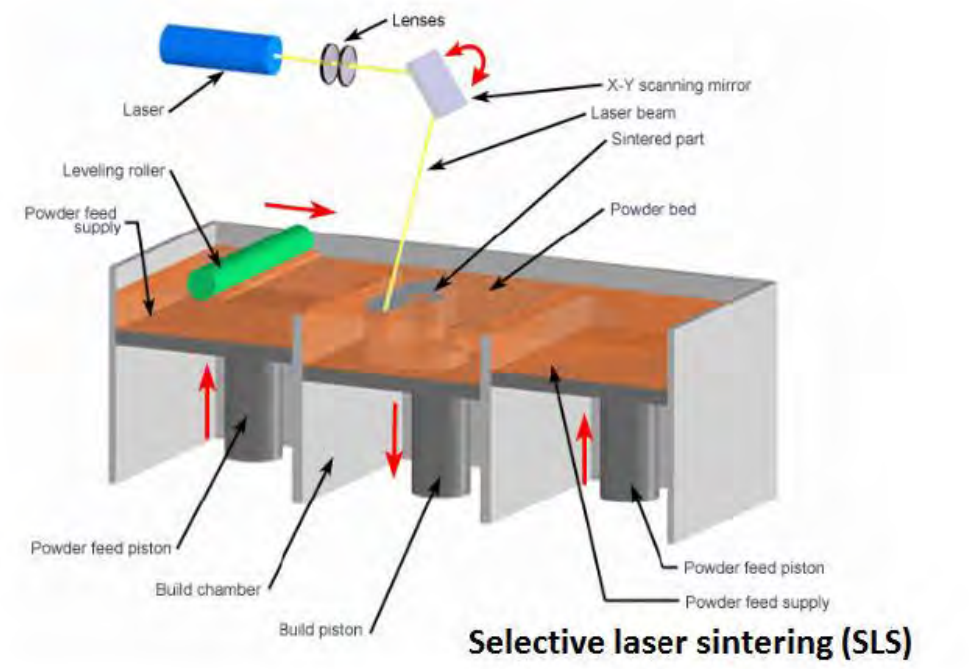

Figure 2.4: Selective Laser Sintering (SLS) diagram

2.3 The Advantages and Disadvantages of 3D Printing

The growth of 3D printing technology rise gradually since the product of 3D printer has been widely used for industry purposes, packaging, manufacturing and also for health care. Since this technique became popular, there must be a benefits and limitations of the 3D printing technologies towards human needs. So, here are just the main benefits of 3D printing. Basically, the traditional methods exposed an expert person to handle the tooling and machining works, while 3D printer has less tooling processes. Since the cost traditional way like injection moulding, are expensive, 3D printing is the best solution to replace the production cost as well as reduce the process of tooling and the labour cost to run the machine. Thus, the cost of production is much lower and affordable compare to the traditional ways. Then, the time management should be plan in certain project or task give. Thus, 3D printing requires a short and quick production without wasting time to waits until the product is done. In manufacturing industries, large quantities of production use the same mould and design to produce one shape at a time. Thus, the product only can produce the same shape and once the design change; the manufacturer should produce another mould. Meanwhile, a 3D printer itself may produce any shape and design base on desired design. In this way, people are freedom to customize the design base on the requirement. A 3D printer also produces better quality products. A 3D printing is so powerful that can create almost

any shape, design from any materials such as metals, glass, paper and also even food. Moreover, 3D printing technology is better, cheaper, flexible, and faster.

However, this machine also has their own limitations and lacks due to production needs. The biggest issues related to the industries are the labour worker will having problems due to fewer workers in factory especially for the big companies. Manufacturing jobs will decrease with this new technology in industries. Recently, the usage of plastics, resins, certain metals and ceramics, is having a problem due to limited sources as a big consumer of 3D printer materials. Thus, the new development of studies for future materials of 3D printer material is still ongoing such as circuit boards. Since 3d printer becoming more common, the copyrighted product will become easier to duplicate and it is nearly impossible to detect the authentic of the product. Plus, it also can create dangerous items, even weapon such as knives, guns or any tiny parts. With the benefits of 3D printing technologies, people are easily to create the parts that have a same level with industrial does. However, the disadvantages of this technology need to be known to be understood and should be avoid for our future generation.

2.4 Acrylonitrile-Butadiene-Styrene (ABS)

Acrylonitrile-butadiene-styrene, ABS is known as thermoplastic resins with a combination of three kinds of monomers which consisting of acrylonitrile, butadiene, and styrene. Meanwhile, the group of these combinations make ABS as a good combination of hardness and softness by enhance its brittleness properties. Thus, by adding up the rubber components into these materials, it may enhance the hardness and fluidity of the polystyrenes. In addition, ABS also well known as a good type of excellent desirable properties, including fatigue resistance, chemical resistance, hardness, easy to handle, and also good mechanical properties. Therefore, it is not surprising if ABS products are widely used and also can be found in daily life. Nowadays, the number of ABS usage has gradually increased especially in rapid prototyping technology.