J. Appl. Environ. Biol. Sci., 6(7S)1-6, 2016

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Experimental Investigation on Mechanical Properties of FDM using Different Post-Process

Zulkarnain Abdul Latiff[1], Nik Shahril Afiq Mokhtar[2], Fazidah Saad[2]

[1]Manufacturing Section, UniversitiKuala Lumpur Malaysian Spanish Institute, Kulim Hi-Tech Park, Kulim, Kedah, Malaysia
[2]Mechanical Section, UniversitiKuala Lumpur Malaysian Spanish Institute, Kulim Hi-Tech Park, Kulim, Kedah, Malaysia

Received: March 31, 2016
Accepted: May20, 2016

ABSTRACT

In this paper, the purpose of this investigation is to determine the optimal post-process to obtain the best result in term of good tensile strength, hardness and compressive on parts that produced by Rapid Prototyping (RP) process. The experiments were conducted at different post-process by using Fiberglass, ASG Joint Compound, Painting with Putty Filler and Adhesive Epoxy. Using the standard specimen of American Standard for testing Material-ASTM 638-96, it has found that in term of tensile strength, the post-process with fiber glass was the optimal post-process. While in term of compression test show that paint with putty filler were optimum post-process. According to calculations of Brinell Hardness numbers with a hardness test show that fiber glass was the optimal post-process. These optimum post-process will help user of rapid prototyping especially using Fused Deposition Modeling (FDM) technique to have the best strength, hardness and compressive needed in term of economical and manufacturing perspective compare with currently usage that used gypsum and cellulose.

KEYWORDS: Rapid Prototyping (RP), Post-Process, Fused Deposition Modeling (FDM), ABS, Experimental Test.

INTRODUCTION

Additive manufacturing technologies under various designations have been in existence for about three decades now. However, it is only after the expiration of Fused Deposition Modeling (FDM) patent rights in 2009 that the surge of consumer-grade FDM printer became available on the market and low-cost 3D printers are now available to a much wider number of researchers, professionals and enthusiasts.

This research will introduced about technology known as Rapid Prototyping (RP) and Post-Process methods to improved mechanical properties. RP process belongs to the generative (or additive) production processes unlike subtractive or forming process such as lathing, milling, grinding or coining in which form is shaped by material removal or plastic deformation [1]. This process may increase manufacturer cost and spend a lot of time. Similarly, expiration of patent right for other popular additive manufacturing technologies such as Stereolythography and Selective Laser Sintering (SLS) shall further revolutionize the way in which modern society utilizes additive manufacturing. RP has changed the method of product design and manufacturing. With the help of RP technologies a physical model can be created within a couple of hours from any complex CAD model.

3D printing is one of the most widespread technologies in the industry. Because of the porous structure and bad mechanical properties, treatment always means infiltration of the models, in case of gypsum and cellulose epoxy resin is mostly used. Within this mind, the result will determined by experimentation with tensile strength, hardness test and compression test of the specimen test by a fellow of the American Society for Testing and Materials (ASTM).

LITERATURE REVIEW

Fused Deposition Modeling (FDM)

A study was conducted by [2] examined mechanical properties of Fused Deposition Modeling parts manufactured with ULTEM*9085 for different orientation, and the tool path generation of manufactured parts based on the mechanical property data is analyzed. The FDM techniques has particular to fill one part layer. The most used tool path is raster fill. Firstly, the perimeter of the layer is formed by the contour tool path. Then, the interior is filled with a back and forth pattern and an angle of 45° x-axis as shown in Figure 1 represents an alternating layer are filled with raster angle direction at 90° to one another. This study was using material

Corresponding Author: Zulkarnain Abdul Latiff, Manufacturing Section, Universiti Kuala Lumpur MalaysianSpanish Institute, Kulim Hi-Tech Park, Kulim, Kedah, Malaysia, E-mail: zulkarnain@unikl.edu.my

Polytherimide (PEI) with the trade name ULTEM*9085 is an amorphous and transparent polymer. They conclude that the tensile test shows different strength and strain characteristic that depends on the given structure and as the result of build direction. Figure 2 shows the Parameter of Tool Path that can be defined in FDM.

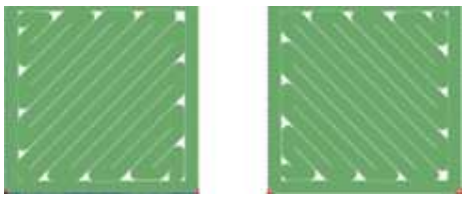

Figure 1: Raster fill with raster direction 90°

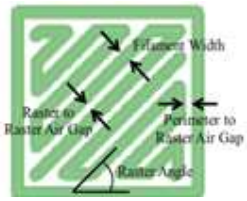

Figure 2: Parameter of tool path

As defined by [3], it examined the ways to improve tensile testing mechanical properties of FDM-manufactured parts. It adjusts FDM processing parameter and analyzing stress concentration features between adjacent roads of material influence of four FDM process parameter which are raster angle, contour width, raster width and raster to raster air gap as illustrate in Figure 3.

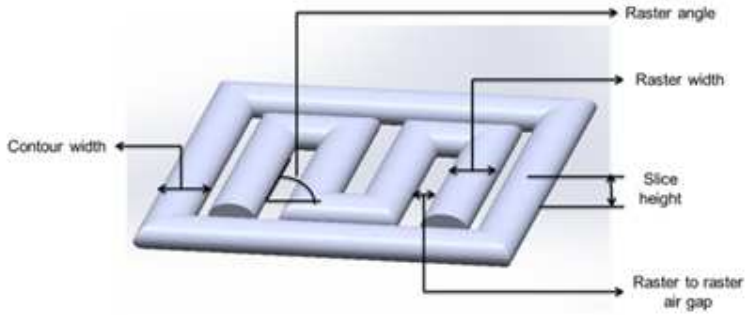

Figure3: Fused deposition modeling build parameter

Further study by [4]investigated the dependence of the mechanical properties of FDM parts on raster orientation and their ability to maintain integrity under service loading. They examined the effect of fiber orientation on a variety of important mechanical properties such as compressive, flexural and fatigue strength and compared their properties to those of an injection model of ABS parts as shown in Figure 4.

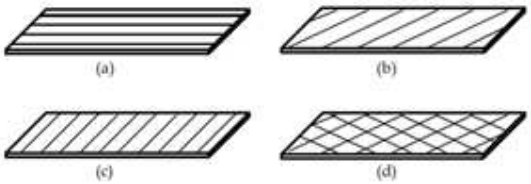

Figure4: Four different raster orientations investigated

METHODOLOGY

In this section, the method will be conducted in experimental and investigate on mechanical properties of FDM by using different post-process. The procedures of this project are described to obtain an objective, including the equipment's and apparatus uses. An experimental design technique is a useful tool in improving the parts by analyzing the data that will obtain from the post-process.

SolidWorks Software

SolidWorks CAD software is a mechanical design automation application that lets the designer quickly sketch out of ideas, experiment with the feature and dimension and produce model and detailed drawing.

Insight™ Software for Fortus 200mc

Stratasys Fortus Insight™ software will prepare CAD program and also it can prepare SolidWorks program and the output of the program for 3D manufacturing on a Fortus machine is STL file. STL file will read by Insight™ software. To be manufactured, FDM will automatically slicing and generating support structure and

material extrusion path. With Insight™ software, the user can manually edit parameter that determines the look, strength and precision of parts as well as speed and material use of the material FDM process. In this study, the parameter that be used is the default setting.

Selection Material for Post Process

Figure 5: Two components of adhesive epoxy

Figure 6: ASG joint compound

Figure 7: Paint for coating with putty filler

Figure 8: Fiber glass

Figure above shows that the selected material for the post-process of this research. Each material were covered or coating on the surface specimen or RP parts. Adhesive epoxy is a mixture two different materials will mix together and become epoxy adhesive, sealants, coating, potting/encapsulation compound and impregnation resin. Before spread the epoxy, make sure the surface of the specimen is dry. Mix well two component adhesive epoxy with ratio 1:1. Then, spread the adhesive on the surface specimen until it dry well. Repeat procedure for 3 layers epoxy as in Figure 9.

The ASG joint compound is a kind of compound specially formulated for quality finishing of drywell joint. It is an ideal material for covering embedded fasteners, corner beads and skim coating gypsum panel where necessary. To use this material, make sure the specimen is dry. Spread the ASG joint on the surface equally. Then use sand paper to make sure surface finishing is smooth. Repeat this procedure until 3 layers as shown in Figure 10. Fiber glass is a really made of glass, similar to a window or the drinking glass in the kitchen. To apply this material, spread the surface with resin.Then, patch the fiber glass on the resin until drywell. Repeat procedure with 2 layers of fiber glass because this fiber glass is thick as in Figure 11. Putty filler is a material which acts like cement for the car. When it is dry it, the surface changed to hard. Spread the putty filler on the specimen surface and let it drywell. Use sand paper with grit 80, then use another sand paper with grit 120 to obtain a smooth surface. Repeat this procedure until 3 layers. After that, spread the specimen with putty filler with paint. Then, let it dry well as illustrate in Figure 12.

Figure 9: Adhesive epoxy

Figure 10: ASG joint compound

Figure 11: Fiber glass

Figure 12: Paint withputty filler

FINDINGS AND DISCUSSION

This section represents the result and discussion of experimental investigations on mechanical properties of FDM using different post-process by using rapid prototyping FDM 200mc machine. The main purpose of this study is to know which post-process will give the best result on mechanical properties. The red spot with arrows show that the applied force by indenter hit on the surface to determine hardness number as in Figure13. Applied force applies to the surface is 100kg/f with 30s for one complete indentation cycle per second on the specimen. Figure 14 shows that the tensile specimen break after rupture and elongation process with time taken 10s to pull the specimen until it breaks apart. While Figure 15 show that the specimens after compression test. This test was set maximum load on a computer is 10 000N.

Figure 13: Brinell hardness test

Figure 14: Tensile test

Figure 15: Compression test

Tensile Strength

Table 1: Result for tensile test

Specimens	Raster Angle (˚)	Maximum Load (N)	Maximum Stress (N/mm²)	Elastic Modulus (N/mm²)	Percent Elongation After Rupture (%)
Adhesive Epoxy	45	1118.5	9.06	60.47	4.889
Fiber Glass	45	2601.5	14.79	93.20	3.39
Painting	45	1016.0	8.46	41.96	3.8142
ASG Joint Compound	45	788.5	6.97	87.15	2.139
Default	45	743.0	7.64	31.33	2.399

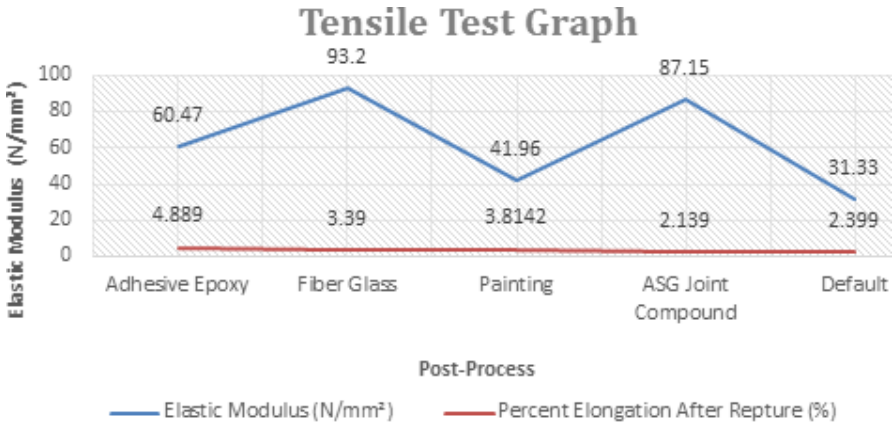

Figure 16: Graph for elastic modulus and elongation after rupture (%)

From Table 1, the result shows that the highest value for maximum stress is post-process fiber glass. The graph shown that the highest value for elastic modulus in term of tensile strength is post-process fiber glass as in Figure 16. This happens due to the fact that fiber glass is having yarn that has a high strength-to-weight ratio. Fiber glass yarn is twice as strong as steel wire and the lowest value is RP with set default (no post-process).

Brinell Hardness Test

Table 2: Result for Brinell hardness number

Specimens	Raster Angle (°)	Brinell Hardness Number
Adhesive Epoxy	45	7.2303
Fiber Glass	45	84.9449
Painting	45	4.701
ASG Joint Compound	45	4.015
Default	45	3.9963

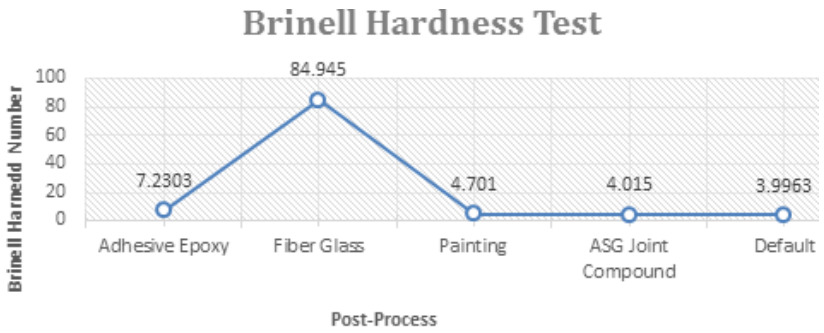

Figure 17: Graph for result Brinell hardness number (BHN)

From the data get from hardness test that get from hardness number calculation, the highest value is post-process fiber glass which is 84.495. This occurs because in term of compressive test, the fiber glass is a composite resistance attack. It is also a tight structure so that when indenter applied to the specimen, it can prevent from damage and breakage. For the lowest value of BHN is with no post-process.

Compression Test

Table 3: Result for compression test

Specimen	Raster Angle	Maximum Load (N)	Maximum Stress (N/mm^2)	Deformation (%)
Adhesive epoxy	45	13.71	9560	5.3
Fiber glass	45	0.01	9.50	2.88
Painting	45	2691	3.86	0.63
ASG joint compound	45	2320	3.33	3.77
Set default	45	2317	3.32	3.02

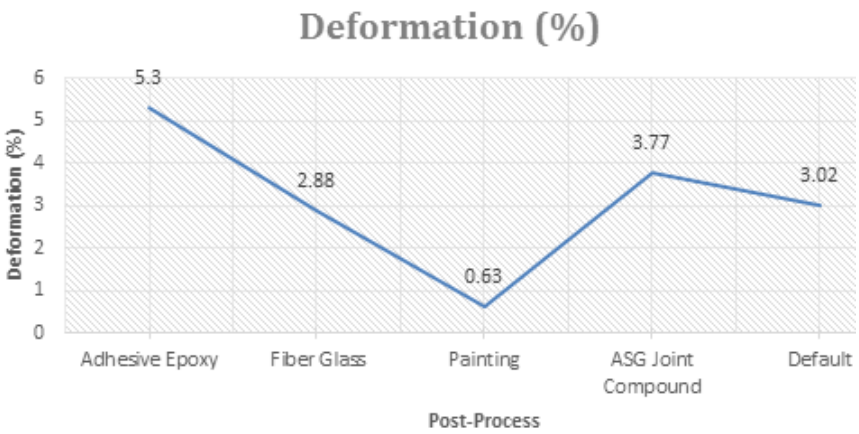

Figure 18: Graph of compression result of deformation (%)

From Figure 18, the lowest deformation that occurs after compressive test is painted with putty filler which is 0.63%. This occurs because the specimen is coated by putty filler with 3 layers and then the specimen was coated again with paint. Putty filler act as a hardener for specimens and it gives more strength to face the pressure from compression test done [5].

CONCLUSION AND RECOMMENDATIONS

In this study the tensile strength, hardness and compressive properties of FDM prototype treated with fiber glass, paint with putty filler, adhesive epoxy and ASG joint compound have been analyzed. In preceding studies, the post-process treatment resulted in dramatically improve the surface finishing of ABS prototypewhich showing that fiber glass is higher to increase hardness and tensile but slightly lower in compression test. The study has been completed in the present study with hardness test, tensile test and compressive test that agreed with preceding studies, which resulting in increasing hardness and tensile strength.

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