Influence of Layer Thickness on Impact Property of 3D-Printed PLA

Dr. Tahseen Fadhil Abbas[1], Dr. Farhad Mohammad Othman[2], Hind Basil Ali[3]

[1] Assistant Professor, Department of Production & Metallurgy Engineering, University of Technology, Iraq.
[2] Assistant Professor, Department of Materials Engineering, University of Technology, Iraq.
[3] Lecturer, Department of Materials Engineering, University of Technology, Iraq.

---***---

Abstract - *The title of this research is given to the different techniques which used for manufacture various objects is three-dimensional printing. The technology of additives manufacturing in the thermoplastic materials prototypes is used to fused deposition technique. The current study will focus on the effect of the thickness of the layer on the mechanical properties of samples of polylactic acid. Izod impact test was performed on specimens. According to ISO standards, test samples are made for different thickness of the layer (0.1, 0.15, 0.2, 0.25 and 0.3 mm) were built using a polylactic acid (PLA) 3D printing system and their impact strengths were tested and the other parameters include print speed, shell thickness, infill density, and part orientation. Increasing layer thickness from 0.1 mm to 0.3 had a more positive effect on the mechanical properties while the time of printing the sample would be decreased with increasing of layer thickness. The optimal impact strength of polylactic acid (PLA) samples was found at a layer thickness of 0.3 mm.*

***Key Words*: 3D printing1, Polylatic acide (PLA)2, Layer thickness3, Fused Deposition Modelling4, Impact strength5.**

1. INTRODUCTION

The technologies of Fused Deposition Modeling (FDM) or synonyms as 3D printing has emerged and widely spread all over the world since 1980s. The demand on fabricating three-dimensional parts has increase year by year and thus making this technology becomes as one of the best options for 3D printing machine. The FDM was originally own by Stratasys Inc. and patented by Crump can be said at the beginning of commercializing the 3D printing. The concept of FDM system where filament fed into the liquefier by the help of motor, and melted. The melted material will then deposit layer by layer until a complete part is finished. The simple and flexible of FDM system making this technology popular among the users [1].

Each of the print orientation, layer thickness and raster angle represent the process parameters that are available for each of these machines. Furthermore, the main factor in improving FMD systems is process parameters that focus on mechanical properties. Using appropriate process parameters in a FDM systems, it can be manufactured parts with improving mechanical properties [2].

Moreover, determination the effects of production parameters on the mechanical properties of printed three-dimensional parts, some work has been completed. Anoop et al. [3] mentioned to the raster angle and orientation, layer thickness, raster width, and air gap all these are important factors and should be taken in the FDM system, therefor stated that tensile, deviation, impact and bending force are strongly influenced by these parameters.

2. METHODOLOGY

2.1 Fused Deposition Modeling (FDM)

The rapid growth of rapid prototyping technology is fused deposition modeling (FDM) because of its ability to build complex geometrical parts at a reasonable building time [4].

Scott Crump who is the founder of Stratasys has been developed Fused Deposition Modeling (FDM). By extrusion (usually thermoplastic material), FDM process is created through the nozzle that passes through X and Y to create a two-dimensional layer. The heaters surrounding a separate nozzle to protect two plastics at a temperature higher than their melting point directly so that they flow through the nozzle and form the layer according to the tool path. Each separate extrusion materials which form parts of the deposit and the structure of the support layer nozzles. Plastic hardens immediately after the flow of the nozzle and bonds to the layer below. At one time the layer is built, the platform goes down, and the extruding nozzle is extrusion onto the other layer and the process is repeated until the object is finished. Figure (1) an outline diagram of the FDM process [5].

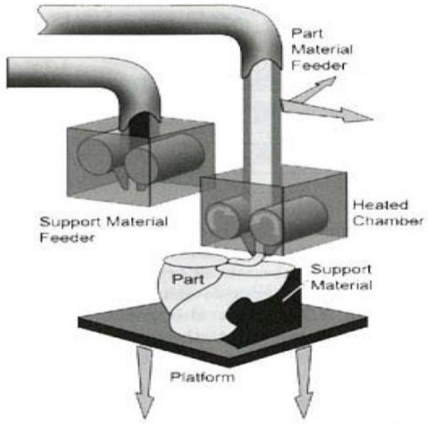


Fig -1: Diagram of FDM processes

The first model of the 3-Dimentional of fragment in the CAD software was designed. Then, the model is in the form of stereo lithography (STL) and then sent to the core program. After a period of time, The device is capable of full physical embodiment, which is very similar to the product part of the CAD model [6, 7]

PLA as a leading candidate is thermoplastic, high polymer coefficient, high strength which can be made of renewable resources annually to produce various components for use in industrial packaging or medical device market biocompatible / bio absorbable. It is easy to be able to standard plastic processing equipment for the production of molded parts, film, or fiber. polylactic acid (PLA) is a material great used in FDM systems [8, 9].

3. Experimental setup

The tests were performed under 5 different layer thicknesses as marked in Table (1) the thickness of the layer deposited by the nozzle is known as the layer thickness.

3.1 Mechanical Characteristic

The reaction of the material to mechanical stress is known as the mechanical behavior of the part. The applied force causes deformation of the component depending on the applied force direction, mechanical properties and size of the engineering components. This paper will present the printed samples of the impact property with a parameter different layer thickness. The tests were performed according to ISO 180 is the method for Izod impact testing at temperature of 23°C the specimens were loaded until they broken [10].

The impact of material properties represent its ability to absorb and disperse energies used to measure the strength of material under impact or shock loading. And it expresses the strength of impact (J / m²) is calculated by dividing the energy of the impact on the cross-section area at fracture and expressing in the following equation: [11]

$$\text{Impact strength (Gc)} = \frac{\text{Uc}}{\text{Ac}} \tag{1}$$

Where:
Gc: Impact Strength of Material (J/m2).
Uc: Energy of Impact (J).
Ac: Cross-Sectional Area of the Sample (m2).

3.2 Test Specimens

Test samples were designed using UGNX 9.0 program and generally the dimension follow the ISO 180 Engineering models were exported as files Stereolithography in STL format for import by FDM program. The geometric models are shown in Fig. (2).

Ultimaker 2+ was used as a 3D printer to print five samples according to the design of the experiment. In addition polylactic acid filament (PLA) was used to build the samples. The degree of extrusion temperature 235 ° C, while retaining the extrusion speed of 50 mm / sec. throughout the experiment, these parameters were constant.

Samples with five layer thicknesses (0.1, 0.15, 0.2, 0.25 and 0.3 mm) were built by 3-dimentional printing of PLA and tested for impact strengths. The samples were loaded until they broke.

The parameters of the work are with different of layer thickness (0.1, 0.15, 0.2, 0.25 and 0.3 mm) while the other parameters are kept constant (Print speed: 100mm/s, infill density:

80%, Shell thickness: 1.2 mm, part orientation at 45°)

The layer thickness is known as the height of the deposited slide from the nozzle. The parameter of layer thickness is used to study the effect of building thicker or thinner layers on the quality of the results [4].

Five samples (3 to 7) were tested in similar conditions for compressions test that taken as results. According to ISO 180 standard the impact test was performed.

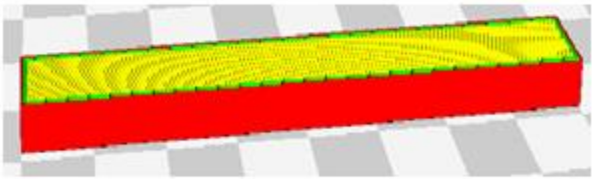


Fig -2: samples of impact test which dimensions (80*10*4).

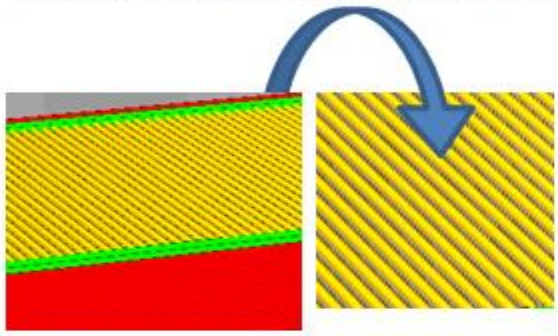


Fig -3: sample of impact test at layer thickness 0.1mm

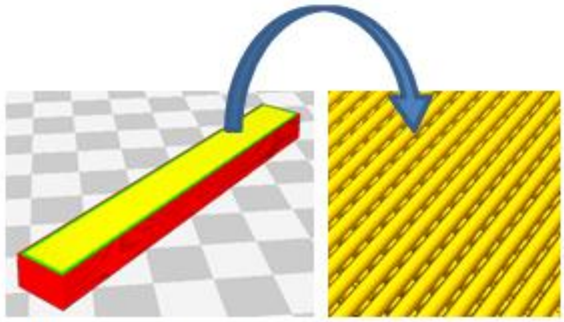


Fig -4: sample of impact test at layer thickness 0.15 mm

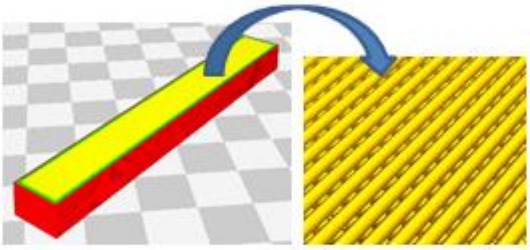


Fig -5: sample of impact test at layer thickness 0.2 mm

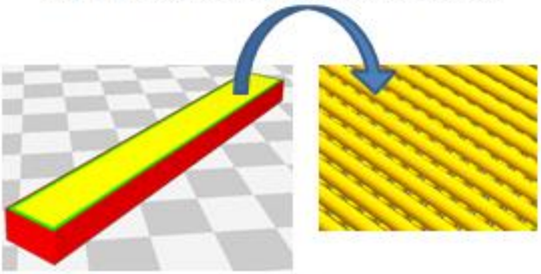


Fig -6: sample of impact test at layer thickness 0.25 mm

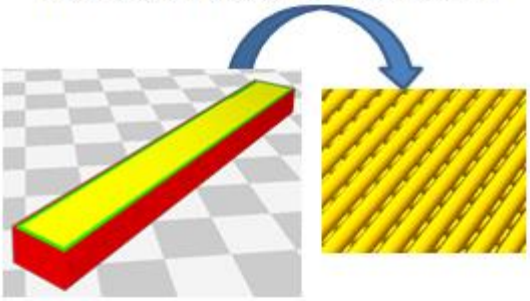


Fig -7: sample of impact test at layer thickness 0.3 mm

4. Results and Discussion

All the five samples were fabricated using the 3D machine and impact test was performed as shown in the Table (1).

Table -1: Impact Strength in Different Layer Thickness.

No. of test	Layer thickness (mm)	Building Time (min)	Impact strength(KJ/ m)
1	0.1	25	16.7
2	0.15	18	15.8
3	0.2	14	15.2
4	0.25	11	14.5
5	0.3	9	13.9

Column 4 in Table (1) shows the results of impact test and impact strength calculation for different layers thickness (0.1, 0.15, 0.2, 0.25, 0.3mm). Of the calculated values, it observed that thickness of the layer can lead to high impact strength.

In at angles of 45°samples were printed, At a 45 degree angle, Rectangular filaments were directed to the loading direction, the strongest production is to the loading direction. During impact tests, Samples are subjected to pressure to align in the axial direction Because of the building additive, which can cause single layers to slide along each other until the sample finally breaks.

The five experiments of impact strength are as shown in chart-1 which represent minimum the strength of impact for PLA is 13.9 (kg / m) while the maximum impact strength of the PLA is 16.7 (kg/m). The test results refer to the impact strength samples of the 3D-printed PLA samples increased with decreasing of layer thickness.

For the FDM technique, the time decreased because It depends on the direction of the part, which affects its height. Villalpando and Urbanik (2011) assumed that building time.

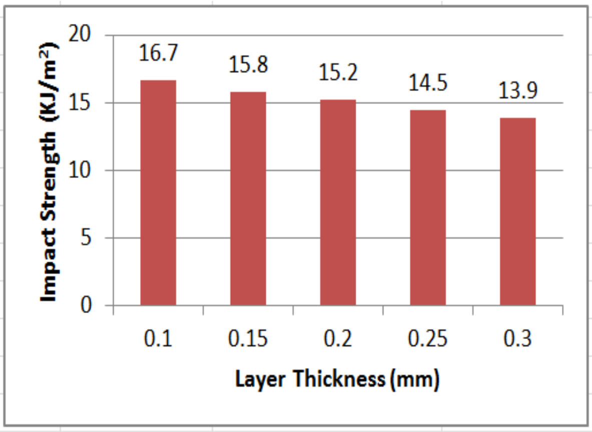


Chart -1: Impact Strength (KJ/m^2) vs. Layer Thickness (mm)

decreases when a less material has been deposited. Chart -2 demonstrates the relation between the time building Vs the layers thickness for FDM technique.

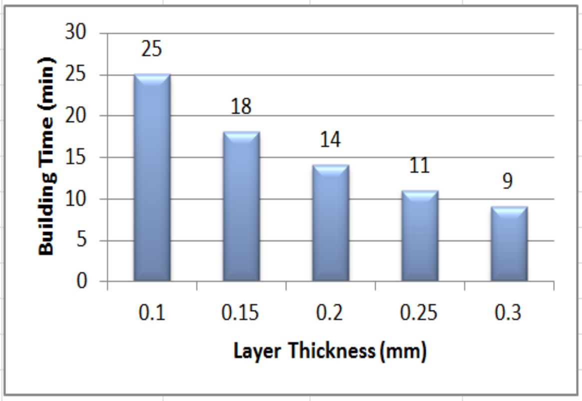


Chart -2: Building Time (min) vs. Layer Thickness

5. Conclusions

This work shows the effectiveness of layer thickening as one of the affecting parameters of the process of FDM for the properties on the strength of the part, on the impact strength. The standard sample experiments of PLA have been conducted in 3-dimental printing machine under the environment and standard specification. The strength of the segment of FDM is differentiated with the process parameter, "layer thickness". The analysis shows that the smallest layer thickness is the higher the strength the segment will be. Low impact strength with an increase in thickness of the layer higher than 0.1 mm. The build time of printing the samples would be decrease with increasing of layer thickness.

6. References:

[1] Terry Wohlers, "Rapid Prototyping & Tooling State of the Industry Annual Worldwide Progress Report," United States of America, 2001.

[2] C. S. Lee, S. G. Kim, H. J. Kim, and S. H. Ahn, "Measurement of anisotropic compressive strength of rapid prototyping parts," Journal of Materials Processing Technology, vol. 187-188, pp. 627-630, 2007.

[3] A. K. Sood, R. K. Ohdar, and S. S. Mahapatra, "Parametric appraisal of mechanical property of fused deposition modelling processed parts," Materials & Design, vol. 31, pp. 287-295, 2010.

[4] F. Rayegani and G. C. Onwubolu, "Fused deposition modelling (FDM) process parameter prediction and optimization using group method for data handling (GMDH) and differential evolution (DE)," The International Journal of Advanced Manufacturing Technology, vol. 73, pp. 509-519, 2014.

[5] I. L. SERIES, "Rapid Prototyping & Manufacturing Technologies," The Hong Kong Polytechnic University Industrial Centre, 2012.

[6] Alireza Asaa , Saeid Abazaryb, and Abolfazl Masomia, "Experimental Study of the Effect of the Build Direction on the Compressive Strength of Components made of Fused Deposition Modeling (FDM) Method and a Three-Dimensional Printer," International Journal of Current Engineering and Technology, vol. 3, pp. 81-84, 2013.

[7] R. Hashemi Sanatgar, C. Campagne, and V. Nierstrasz, "Investigation of the adhesion properties of direct 3D printing of polymers and nanocomposites on textiles: Effect of FDM printing process parameters," Applied Surface Science, vol. 403, pp. 551-563, 2017.

[8] S. Farah, D. G. Anderson, and R. Langer, "Physical and mechanical properties of PLA, and their functions in widespread applications - A comprehensive review," Adv Drug Deliv Rev, vol. 107, pp. 367-392, Dec 15 2016.

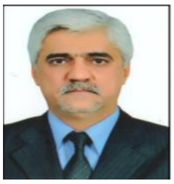
[9] V. Kovan, G. Altan, and E. S. Topal, "Effect of layer thickness and print orientation on strength of 3D printed and adhesively bonded single lap joints," Journal of Mechanical Science and Technology, vol. 31, pp. 2197-2201, 2017.

[10] D. K. G. b. N. Mohammed Raffic , Palaniappan P. L , P. RajeshKannan , N. S. Santhanabharathi , S. Venkatramanan "Effect of Fdm Process Parameters in ABS Plastic Material," International Journal on Mechanical and Production Engineering, vol. 3, pp. 14-23, 2017.

[11] P. K. Mallick, FIBER-COMPOSITES Materials, Manufacturing, and Design REINFORCED vol. 13: Taylor & Francis Group, LLC., 2007.

BIOGRAPHIES

Dr. Tahseen Fadhil Abbas (Assistant Professor), Production & Metallurgy Engineering Department, University of Technology, Iraq.



Farhad Mohammed Othman , (Assistant professor). Materials Engineering department, university of Technology, Iraq.

Hind Basil Ali, (Lecturer). Materials Engineering Department, University of Technology, Iraq.