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Effect of infill Parameter on compression property in FDM Process

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ABSTRACT
The major parameters of FDM are Infill Density, Layer thickness, Shell thickness, Print speed which considered for mechanical testing and dimensional accuracy of the printed specimens. Fused Deposition Modeling (FDM) technology allows users to control the density of models through parameter which is termed air gap or infill. Test specimens were used with infill between 20 and 80%. Therefore, this paper discusses experimental analysis of the influence of infill density on the compressive strength in FDM specimens made of polylactic acid (PLA).The test results indicate that the compressive strength samples of the 3D-printed PLA samples increased with increasing of infill density lower infill values significantly increase the building speed, and the time of printing the sample would be increased also with increasing of infill density.
Keywords: Fused Deposition Modeling, Compressive Strength, Building Time, Infill Density.

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I. INTRODUCTION

Additive manufacturing uses a 3D CAD (Computer Aided Design) model of the desired part by selectively joining materials layer by layer. This 'Solid Freeform' approach to fabricate parts provides unique advantages such as lack of fixtures/jigs, part-independent build set-up, ability to produce multiple designs within a single build among others. The ability to customize part designs, materials provides an ever-growing possibility for limitless real world applications. [2]

Since the late 1980s, AM processes have been investigated, and some have been developed commercially. They include, among others, Stereo lithography (SLA), Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Laminated Objective Manufacturing (LOM), Three Dimensional Printing (3DP), and Laser Metal Deposition (LMD). The materials used in these processes include photo-curable resin, polyamide, wax, acrylonitrile-butadiene-styrene (ABS), polycarbonate, metal/ceramic/polymer powders, adhesive coated sheets, etc. Using AM technology, three dimensional parts are fabricated directly from CAD models and built in a layer-by-layer manner [1, 3].

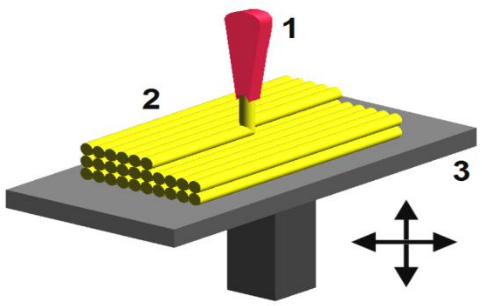

Fig. 1 Schematic model of Fused Deposition Modeling (1-nozzle, 2-building material, 3-movable table) [1]

Fused Deposition Modeling (FDM)was used Fig.1 and it is relatively cheaper, easier to set-up with lower consumable and maintenance cost [4].

With the ever-increasing interests in using 3D printing, CAD and STL. It is important to identify which infill patterns and densities will provide ideal strength for different applications. This is of great significance because in material, the CAD model (as an STL file does not have any information on the infill pattern). The CAD model also contains no information concerning loading during usage, which can vary widely in different parts and therefore require different material properties [1, 5].

The material cost and production time taken to create a product. Infill density parameter will affect the mechanical performance and production economics of a material extrusion part [6].

II. EXPERIMENTAL SET-UPS, AND PROCEDURES

The materials tested in this study were polylactic acid (PLA) which was used to produce samples in an Ultimaker+2. The specimen geometries followed specifications outlined in ASTM D695 specimens. These specimens and select dimensions for both specimen types are shown in Figure (2). Specimens were created in by NX 9.0 software, exported in stereo lithography (STL) format, and then imported into each 3Dprinter's respective slicer software to create the G-code used to print each specimen.

The work described the influence of infill density % on the mechanical properties of polylaticacide (PLA) samples. The infill percentage of the part, the amount of printed material that the printed part will have inside it, needs to be specified. This parameter can vary from 0 % up to 100 %. When the setting is 0 %, the printed part will only have an external surface (which will depend only on shells thickness) but it won't have any printed material inside the external surface. If the percentage value is higher than 0 %, the machine will lay material inside the part, using a specific laying geometry pattern that will depend on the printer manufacturer [7].

Samples with three infill density % (20, 35, 50, 65 and 80 %) were built by 3D printing of PLA and tested for compressive strengths. The samples were loaded until they broke.

The parameters of the work are with different of infill density (20, 35, 50, 65 and 80 %) while the other parameters are kept constant (Print speed: 75mm/s, layer thickness: 0.1mm, Shell thickness: 1.6 mm, part orientation at 90°).

The mechanical tests were carried out on universal materials testing machine, equipped with a 50-kN load. Five samples were built and tested under identical conditions for each mechanical test was taken as the results. The compressive test was performed according to the ASTM D695 Standard at a loading rate of 2 mm/min.

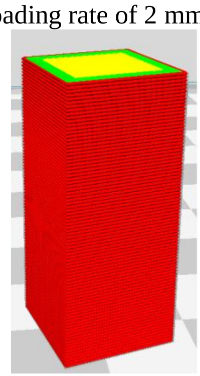

Figure (2) samples of compression test which dimensions (12.7*12.7*25.4).

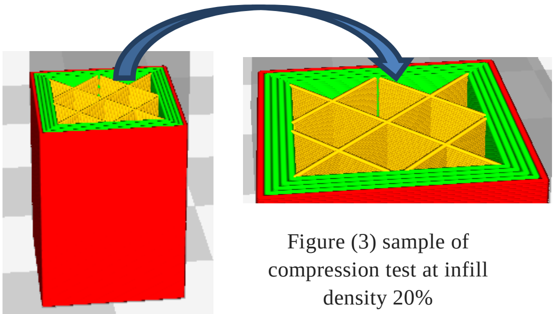

Figure (3) sample of compression test at infill density 20%

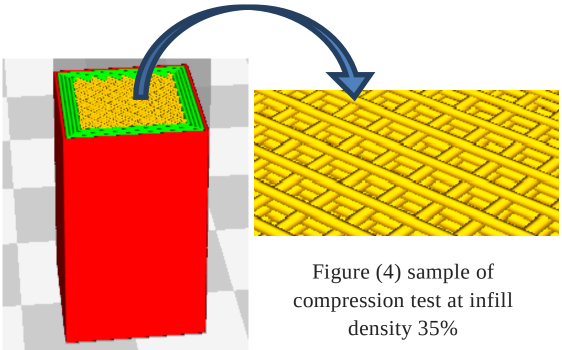

Figure (4) sample of compression test at infill density 35%

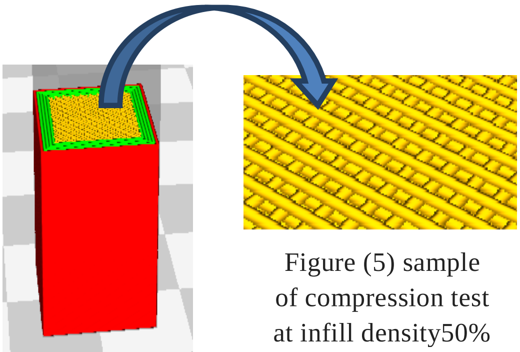

Figure (5) sample of compression test at infill density50%

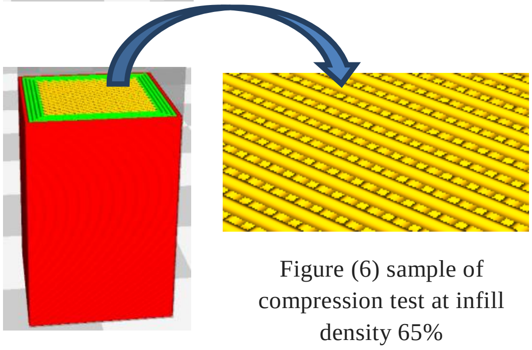

Figure (6) sample of compression test at infill density 65%

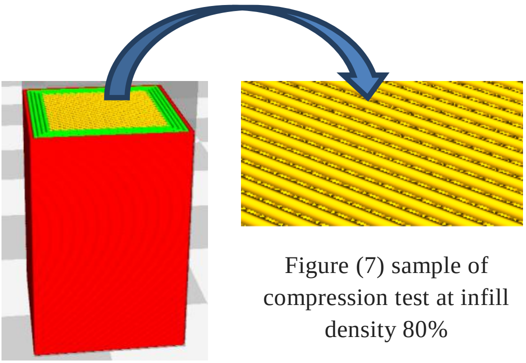

Figure (7) sample of compression test at infill density 80%

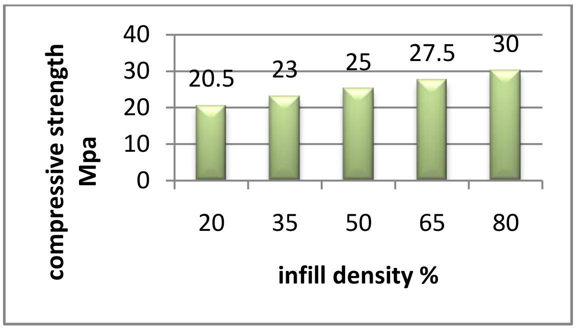

Fig. (8) compressive strength vs. infill density

III. RESULTS AND DISCUSSION

III.I. INFLUENCE OF INFILL DENSITY ONCOMPRESSIVE STRENGTH OF PLA

Table (1) shows the practical mean values of mechanical tests for the 3D-printed PLA samples. From table (1) it can be noted that the samples built with a 80% infill density had the greatest strengths in compression tests. The strength of samples with a 20% to 65% infill density increased significantly. We can also see that samples built with part orientation angle of 90° had the increase of mechanical strengths. The layer thickness had great influence on compressive strengths. Because the compressive sample was cubic and there was effect of the part orientation angle.

Table (1) compressive strength in different infill density.

No.of test	Infill density %	Time (min)	Compressive strength at 90°
1	20	26	20.5
2	35	28	23
3	50	31	25
4	65	33	27.5
5	80	35	30

As indicated in Table (1) the compression test of the PLA samples were significantly affected by the infill density %. In samples printed at angles of 90° the filaments were oriented rectangular to the load direction, producing the strongest to the load direction.

The influence of the infill percentage on compressive strength was analyzed by using the compression test results Fig. (8) shows that the compressive strength was the highest for solid as expected. This relationship is almost linear; thecompressive strength is proportional to the infill percentage. Results show that the maximum compressive strength, (30 MPa), is obtained when using 80 % infill density.

printing consists of a rectangular pattern (which has strength in all directions and is reasonably fast to print). The size of the rectangular will depend on the infill percentage that is set: the higher the infill percentage the smaller the infill rectangular**.**

III.II. Influence of building time on compressive strength of PLA

This manufacturing difference has a significant effect on the effective printing time. As can be observed in Figure (9), the effective printing time will be longer than for 80%. This is caused by the size of the rectangular, since when the infill percentage is high, the size of the rectangular is small and the nozzle has to travel a longer distance to print the same element.

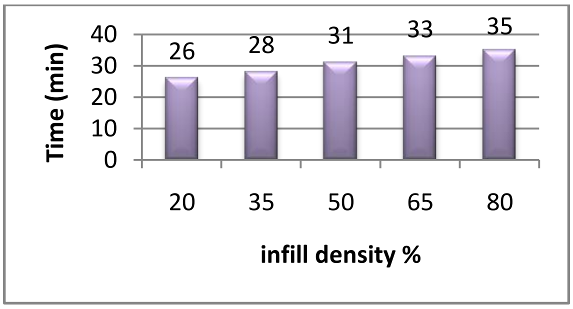

Fig. (9) timevs. infill density

IV. CONCLUSION

Real world applications of AM are ever-growing because of the ability to customize designs, material and color selection. With the growing number of CAD repositories in websites, access to STL files for printing is even easier. The focus of this study was to study the compression property to the production time. The results revealed that the maximum compressive strength for PLA parts (30 MPa) is reached at 80 % infill density. Generally, 3D printing users select smaller infill in order to reduce printing time or save material. Some general recommendations can be given for this ultimaker+2:

- When looking for fast printing but not mechanical resistance, small infill density percentages are recommended.

If a user wants high mechanical resistance and a fast process, it is preferable to use 80 % infill density.

From this study, it was found that printing solid infill is beneficial in the case of compression samples when compared to non-solid infill patterns.

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