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An Investigation of New Design of Light Weight Structure of (ABS/PLA) by Using of Three Dimensions Printing

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Abstract
In present paper, light weight structure of (ABS/PLA) consist of honey comb core with skin layers as sandwich structure, the design includes design of the core with increasing the infill parentage of (10%, 30%, 50%, 70%, 90% and 100%) by increasing of hexagonal pores volume to test tensile strength, also includes the different between the heat and adhesive joining to prepare the sandwich structure panels for stiffness test. The samples are prepared by 3D Printing technique, type fused deposition modelling FDM and the (3D desktop printer) type of printing machine is used to conduct this work. Different mechanical and physical properties (tensile strength, stiffness, specific strength, etc.) are tested. The results show improvement of, specific strength. Tensile strength and modulus with increasing of pore size (hexagonal) reduction for tensile test samples, heat joining gives lower stiffness than adhesive joining of flexural strength test.

Keywords
3D printing, honeycomb structure, ABS/PLA

1. Introduction

Rapid prototyping RP is a technology in which a part can be build layer by layer to a desired geometry based on computer aided design CAD model. Fused deposition modeling FDM, as one of additive manufacturing AM type, accomplishes the layer-by-layer build by deposition a material, extruded through a nozzle in a raster pattern to a final part [1]. It uses a variety of thermoplastic materials such as ABS-like colored materials, polycarbonate-like and other plastics that are distinguished by their relatively high stability at elevated temperatures in 80-190°C range [2].

A sandwich panel is build up by two thin skins, also called the facings, separated by a light weight core. Usually face is thin sheet, while core is formed of; honeycomb (hexagonal, square and flex core), corrugated, balsa wood and cellular shapes [3]. The faces carry the tensile and compressive stresses, while core's function is to support the thin faces so that they do not buckle (deform) inwardly or outwardly and to keep them in specific relative position to each other to increase the thickness of laminate without causing a great weight increase [3, 4].

To accomplish this, the core must have several important characteristics; low density, enough shear modulus and shear strength so as not the faces slide over each other, stiffness to keep the distance between faces constant and finally thermal and acoustic insulation [3, 4]. On the other side, faces (skins) must have; high stiffness to give high flexural rigidity, high tensile and compressive strength, impact resistance, surface finish, environmental and wear resistance [3].

These mentioned properties consider general requirements for the cores and faces, so most applications not necessary require all of them.

In past research, fabrication and testing of sandwich structures have been performed with predominately-flat construction due to timely and expensive tooling required to create intricate shapes from existing core materials [5]. Now, it could fabricate both of skins and core as a flat sandwich with easily controlled different core designs by 3D printing and test it as one batch production without using adhesive to join faces with core which is the good benefit of this study.

A study on the tensile strength of polycarbonate parts made by Stratasys FDM with varying process parameters such as air gap, raster width and raster angle was made. The main result was the experimental identification of the tensile strength for parts made from FDM and its comparison with the tensile strength of the moulded and extruded PC parts [7]. The experimental testing of ABS materials carried out by different research teams to determine the strength of FDM is reported and discussed giving a complete view of the effects produced by the different geometrical parameters [8]. In the attention is focused on the determination of the tensile strength, yield strength and modulus of elasticity for different values of build orientations of polycarbonate materials, which is, together with ABS, widely used for this kind of application [9].

In present paper, it is conducted tensile samples by 3D printing with different core size (hexagonal) infill density (percentage) in form of sandwich (core and skins) from PLA (ingeo 4032D stable I standard characteristics) as a feed stock filament to investigate effect of pore size volume (hexagonal) on specific strength, modulus and weight benefit. It is also made two sandwich panel samples of PLA core and ABS (Chimei 757 table II standard characteristics) skins with same one percentage infill 10%, but used different joining methods; heat and epoxy adhesive to investigate flexural stiffness.

2. Experimental Work

2.1. Materials

Two materials are used in this work are acronitrial butafene styrene and poly lactic acid (ABS/PLA), the general characterization of them are shown in the Tables 1 and 2, below:

Table 1. Standard characteristics of ABS

Characteristic	ABS Chimei 757	
	Value	ASTM Method
Density	1.05	D792
Tensile strength, Kg/cm^2	470	D638
Tensile elongation	25%	D638
Melting temperature, ^0C	220-250 ^0C	

Table 2. Standard characteristics of PLA

Characteristic	PLA ingeo 4032D	
	Value	ASTM Method
Density, g/cc	1.24	D1505
Tensile strength, Kpsi	15	D882
Tensile elongation, %	180	D882
Melting temperature, ^0C	155-170	D3418

2.2. Machine technique

Nearly most 3D printing machines involves the following standard steps ; Design the model by CAD software, conversion to STL format, file transfer to 3D printing machine for slicing, machine set up, build the part, removal the part, post processing and application [6]. Tensile samples are designed by free CAD software according to ASTM D 638 I with dimensions shown in Figure 1.

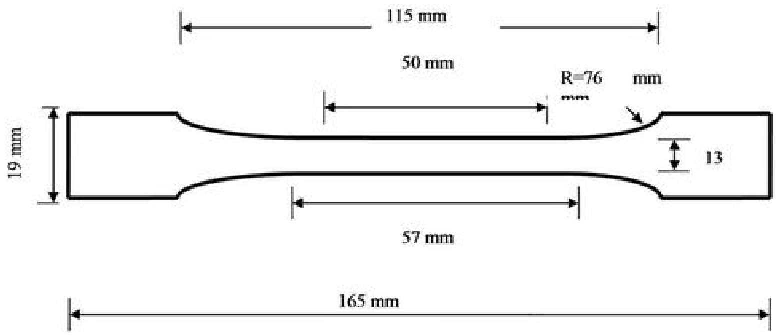

Fig. 1. Showing tensile samples dimensions

2.3. Sandwich panel samples

Sandwich panel sample designed according to ASTM C393-00 with dimensions of LXWXH (150 mm, 30 mm, 13.6 mm) with reference to the panel shear rigidity [10].

First sandwich panel sample is built at one step from core (PLA) and faces (ABS) where printing machine joined the faces with cores by heat fusion (Fig. 3), while second sample is built at two steps. First build the core and faces at two batches separately then adhesive (join) faces with core by epoxy type Nitoprime 25 from Fosroc company (Fig. 2).

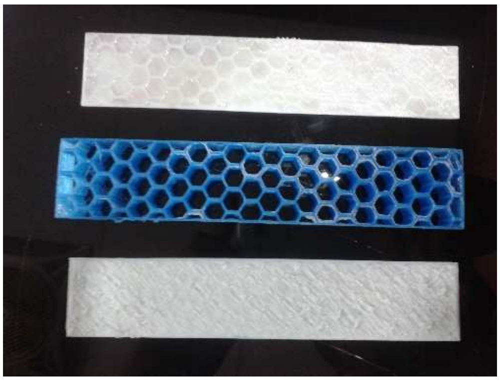

Fig. 2.Two batch production

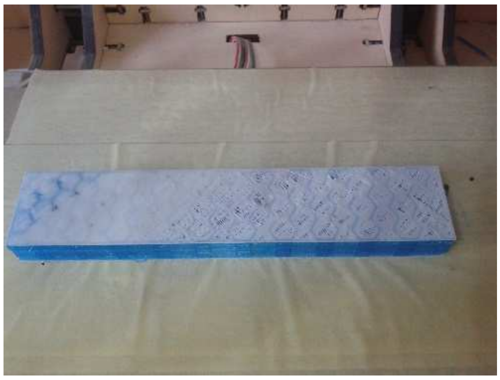

Fig. 3.One batch production

After manipulation and conversion to machine file format so as to slice the designed part, then set up the machine to values shown in table III and build the samples by 3D desktop printer machine (shown in Figure 4) of PLA filament.

Table 3. 3D printing machine set up values

Machine set up value name	Value
Melting temperature	220^{0}C for PLA, 250^{0}C for ABS
Printing nozzle head speed	60 mm/s for ABS, 90mm/s for PLA
Bed temperature	30^{0}C for PLA, 100^{0}C for ABS
Layer thickness	0.2 mm
Infill density	10%, 30%, 50%, 70% and 100% for tensile test, 10% for sandwich panel
Nozzle diameter	0.4 mm

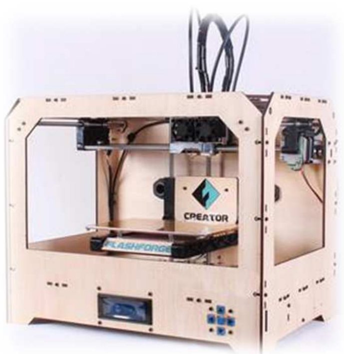

Fig. 4. 3D desktop printer machine

Infill patterns for the core can be chosen of different shapes such as honeycomb, line, rectilinear, concentric, Hilbert curve, Archimedean chords and octagram spiral cores by slicing software. It is depended honeycomb core infill pattern hexagonal type at this paper due to its same better stiffness in walls. Whenever infill density decreases from 90% to 10%, larger hexagonal and less contact honeycomb walls with faces get as shown in Figure 5.

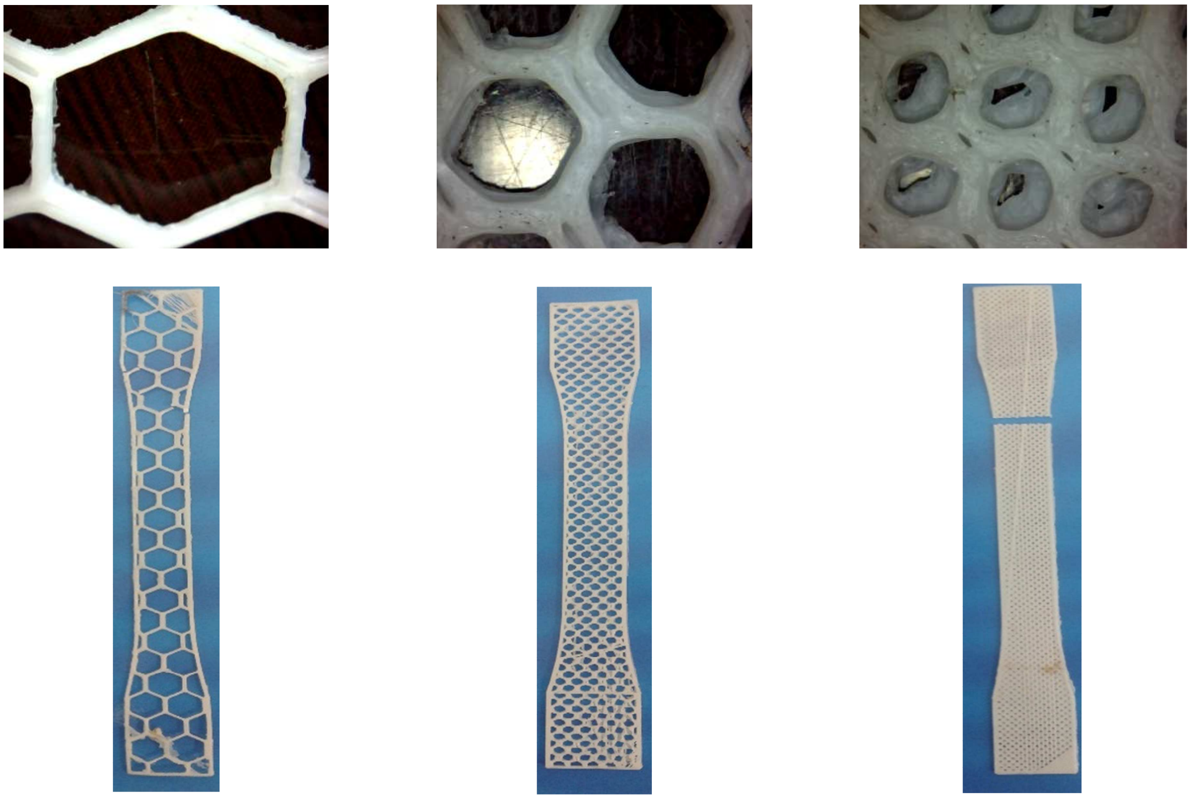

Fig. 5. Showing core design geometry

It is tested three samples of each infill density by microcomputer Controlled Electronic Universal Testing machine model WDW-E. Building geometry of hexagonal cores is parallel to applied unidirectional tensile load as shown in Figure 6.

Fig. 6. Showing building geometry of hexagonal and applied direction

Samples designed consist of two parts; skins (faces) and core, cores as already states are hexagonal of 1.3 mm thickness for tensile and 12 mm for sandwich panel, while faces of 0.8mm for both tensile and sandwich panel.

Deposition molted filament polymer in form of roads that join of each other from sides, top and bottom by fusion mechanism to form faces layers +45/-45º while core layers are in 0/90 ^{0}C.

Usually fabrication of sandwich does in steps from more than two different materials, first making the cores and faces, then adhesive faces with cores by adhesive like epoxy. In 3D printing, tensile and sandwich panel samples are made as one production batch and joining between alternative layers by partial fusion.

3. Results and Discussions

3.1. Specific strength

As shown in Figures 7 and 8, tensile strength increases strongly as long as infill density increases, while modulus increases lightly as compared with tensile strength.

This increasing in tensile and modulus is due to increasing number of honeycombs where more hexagon walls joined with faces that result more walls resist the applied force also this belong to the increase of materials relative to the area of cross section. The results of the improving of the specific strength are very clear in the Figure 9, where there are increasing with increase of strength with light weight of structure.

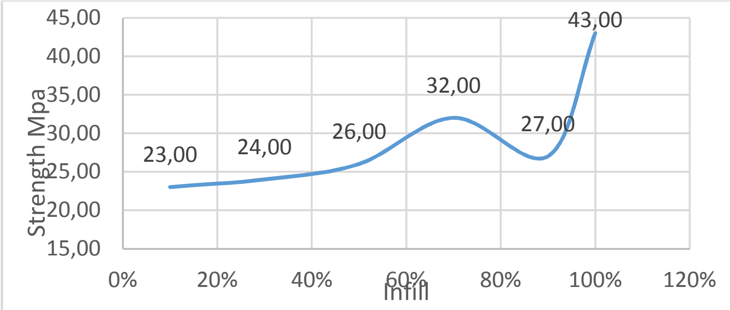

Fig. 7. Tensile strength vs. infill density

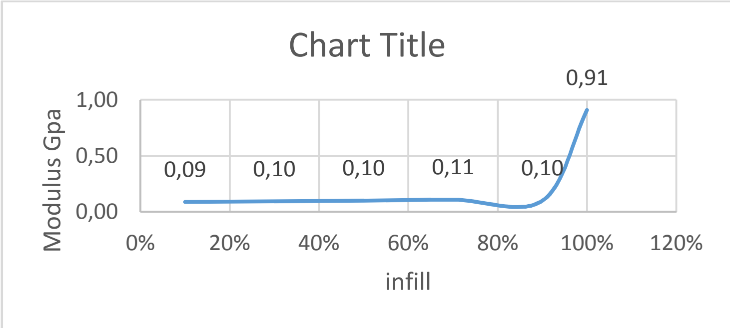

Fig. 8. Modulus vs. infill density

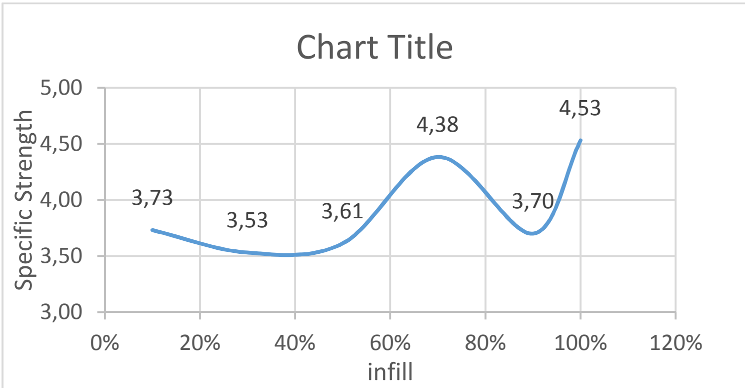

Fig. 9. Specific strength vs. infill

3.2 Bending stiffness

The Figures 10 and 11 show the panel bending stress for different sandwich and panel bending stiffness for different sandwich. It very clear that they improve with the types of sandwich materials types, and the best value is for PLA due to increasing of the shear strength of this materials, while the stiffness is the same behaviour with bending stress.

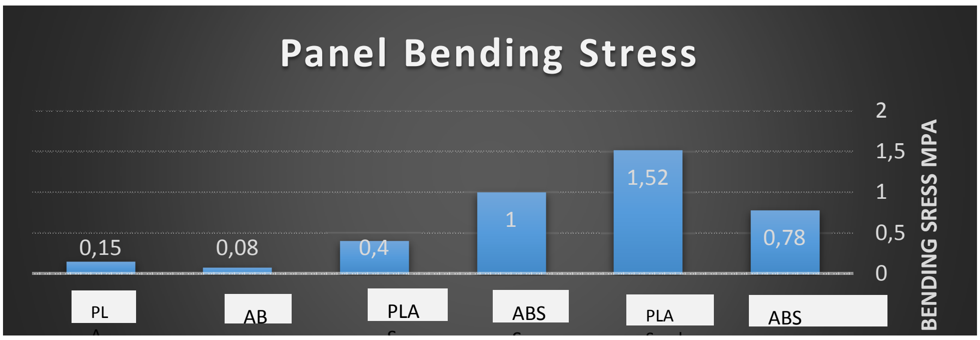

Fig. 10. Panel bending stress for different sandwich

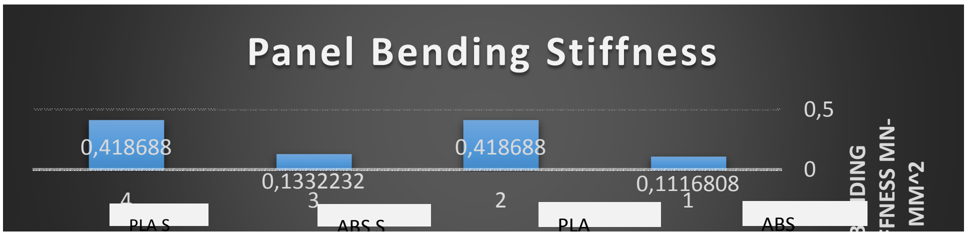

Fig. 11. Panel bending stiffness for different sandwich

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