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Study Reinforcement Patterns for Hardness and Impact of 3D Printed Carbon/Glass Fiber- Nylon

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Abstract

The purpose of this paper was to investigate the hardness and impact properties of 3D printed Carbon/Glass fiber hybrid composites. Automative and aircraft industrial are usually used composites. Mixing of two composite materials was improving mechanical properties and reduce ongoing costs. This study also illustrates the method of samples that needs to be prepared for experimental, samples made of polymer-based materials reinforced by carbon and glass fiber hybrid composites at various building angles. The idea behind the study was to investigate the effects of various orientation angles in sections {45°, 30°, and 180°} on the hardness and impact properties of the parts. The aim was to assess the results of changes in the orientation angle of the building relative to hardness and impact properties of the hybrid composite characterization process. The experimental work found that; The best effect of building orientation angle in Hardness at 45° and in Impact at 180°.

Keywords: Additive Manufacturing (AM) · Hybrid Composites · Building Orientation Angles. Mechanical Properties

1. Introduction

Today fiber reinforcement polymer composites were gaining popularity and these polymer composites were finding ever increasing usage for a wide variety of industrial applications such as car and aircraft industrial. In the past decade, many researchers made considerable efforts for better understanding the mechanical properties of polymer composites reinforced with different types of fibrous materials [1-2]. Recently, glass fibers (G.F) and carbon fiber (C.F) were often used as reinforcements to improve the strength and stiffness of polymer -based composites [3]. Today's economic competition requires engineers and designers to develop technology to accelerate the production of products for various markets. Such methods were additive manufacturing techniques (AM), representing a promising approach to establishing complex geometry that reduces production cycle time and cost. Create a 3D structural layer with printable materials for each layer duction cycle time and cost [4]. Over the past decade, FFF had been developed as a great rapid prototyping (RP) technology that was usually used in 3D printing. This technique showed significant efficiency in creating prototypes with reduced time and cost, giving production companies a competitive advantage [5]. In recent years, rapid manufacturing had replaced highspeed prototyping as a major application in 3D printing [6]. To create functional end use components using FFF technology, it was essential to evaluate the mechanical properties of the resulting Polymer materials. Although a considerable proportion of AM components were now composed of different materials for end use purposes, the industry was increasingly turning to composite materials for 3D printing [7]. Composites had succeeded in increasing the durability of the materials, but currently there were serious problems in the collection of plastic waste in the environment. [8]. AM technique has been developed to create physical models rapidly by using (3D) computer-aided design (CAD) input information, exempt from the need for traditional tools or programming. AM refers to a set of technologies that enable the layer-by-layer creation of objects using 3D model data, this technology had demonstrated promise as a viable alternative to traditional material processing methods in diverse industries [9]. Additional design flexibility companies to quickly develop early design ideas for prototypes, final products, succeed efficiently and

quickly. Therefore, in order to create a 3D model of int erest, we recommend creating a 3D model of interest w ith this technology. There were several ways to do it. FFF had gained popularity in low-volume and customized manufacturing sectors due to its cost-effectiveness, rapid and secure operation, as well as its flexible modification capabilities [8]. FFF is used not only in functional prototypes, but also in industries such as aerospace, automotive, medicine, and biomechanical. To run FFF; a stereolithography file (STL) derived from the CAD model is installed in the Slicer tool. The Slicer tool divides a 3D model into layers of different heights, converting the height and other conditions that are preferred to Good, which can be interpreted by a printer, into G-code illustrate processes step in Figure.1 [10-11].

Fig. (1) Process Steps in 3D Printing

Emphasizing the significant components within the extrusion unit, along with the deposition of the extruded composite. To investigate the orientation angle on the hardness and impact properties noted in composite test samples, samples are printed in different orientations on the 3D printer. The properties of the composite samples were evaluated to provide a comprehensive understanding of their behavior. This article outlines the fabrication techniques, experimental procedures, and findings from the characterization of composite printed samples as represent in Figure 2.

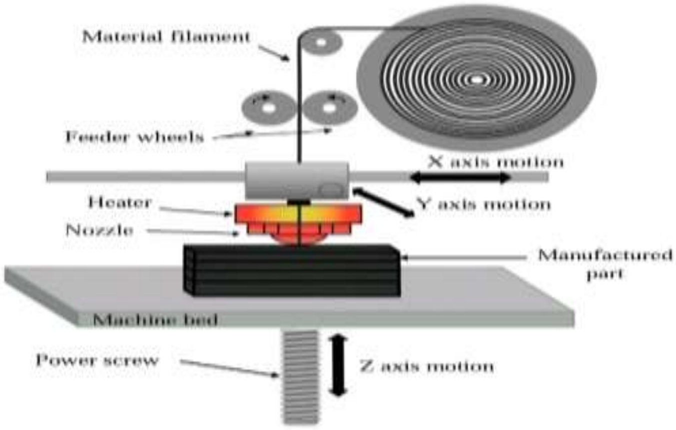

Fig. (2) Schematic of the FFF procedure with specific components inside the extrusion unit [12].

The Slicer tool converts the desired height and other specifications into G code, so that the printer understands. After interpreting the G code, the printer melts the selected polymer filaments with a capacitor at the corresponding temperature and extrudes the polymer material & reinforced fiber in a liquefier at the appropriate temperature and extrudes the polymeric material. In this study, Carbon/Glass fiber using in reinforcement Nylon for making Carbon/Glass fiber reinforced Nylon Composite, specimens using the Fused Filament Fabrication (FFF) technique. Investigating the influence on Hardness and Impact tests were carried out using (Nylon100%, Nylon84%+ CF16%,Nylon68%+CF16%+GF16%) in three different building orientation angles (180°, 30, 45°).

2. Material and Methods

2.1. Materials and samples preparation

2.1.1. Design the samples

In this study, samples are preparing for Hardness Test according to ASTM Standard D2240 [24] and Izod impact test according to ASTM standard 256 D [19,20] for composite material. The samples' geometry to investigate their behavior according to Hardness test and Impact test as Figure 3 and they were printed using 3D printer. NX software was used to create the 3D CAD file, which was then exported in STL format, the G-code (PLG file) is necessary to printing each sample, Polygon software was utilized as a 3D Markforged's Eiger [13]. To get the part, the printing process involved generating STL and PLG files for each sample type with the specified orientation angles.

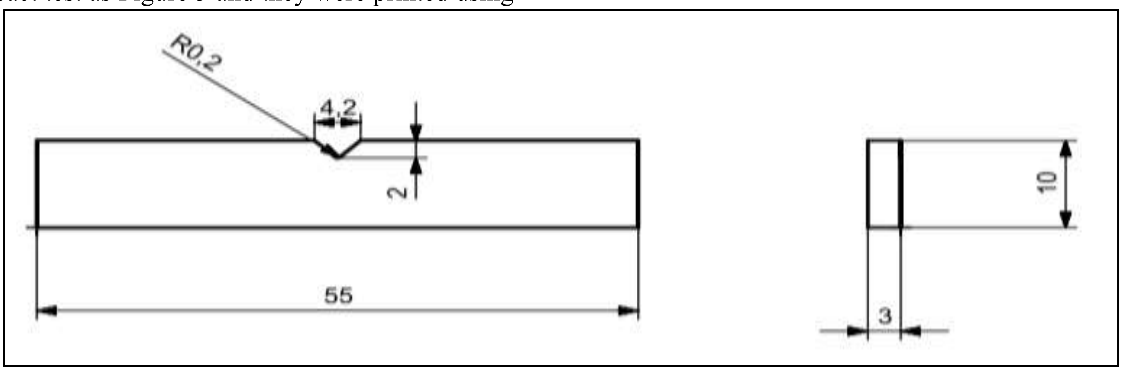

Fig. (3) sample according to ASTM Standard dimensions in mm

2.1.2. Materials the samples

The investigation was conducted to evaluate how the building orientation angles of a 3D-printed part affect in hardness and impact properties. This study CF & GF reinforced Nylon, in three different building orientation angles (180°, 30°, 45°) for base materials and Reinforced Isentropic building material Figure (4,5). Samples dividing to three groups:

1) Nylon100% building orientation angles (180°, 30°, 45°)

2) Nylon 84% building orientation angles (180°, 30°, 45°) + CF16% Isentropic Fill

3) Onyx 84% (Nylon 68% + CF16%) building orientation angles (180°, 30°, 45°) + FG16% Isentropic Fill.

Nylon is famous base material, it comes in many forms and usage nearly in all manufacturing, Onyx contain from Nylon with carbon fiber [24].


a) 180°


b) 45°

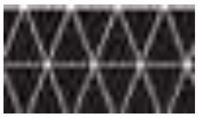
c) 30°

Fig. (4) shape different building orientation angles for Base Material

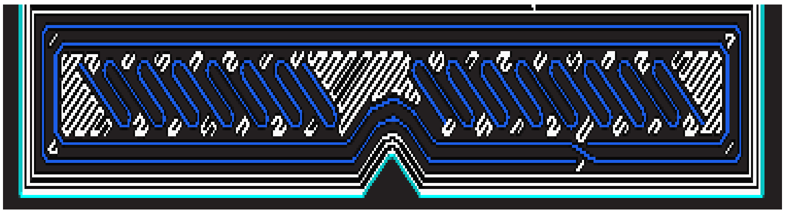

Fig.(5) shape Reinforced Isentropic Fill Material.

Study showed that there were differences in hardness and impact properties at the printing building orientation angles as shown in Figure 4. The samples thickness printed aligned in Z-axis of the printer's build table. The length of the sample in X-axis mm, while the width in Y-axis. Base Material was four layers and Roof & Flower, Fiber Material was five layers, 37% Fill density as represent in Figure 6.

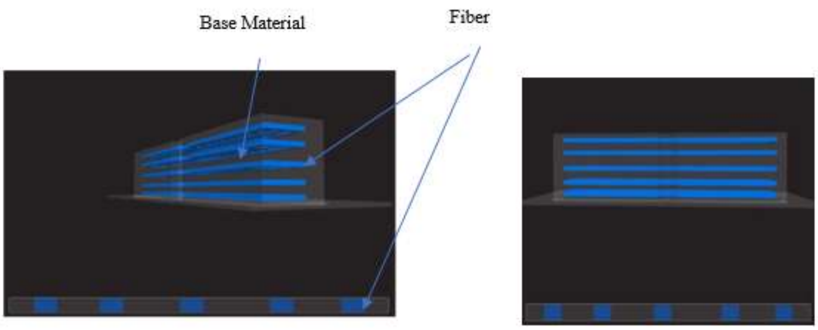

Fig.(6) Base Material was four layers and Roof & Flower, Fiber Material was five layers

2.1.3 Software programing

-CAD Software, illustrate in Fig.3

-Eiger - Markforged's slicing software [8,19]

2.1.4 Setup the markforged

This study samples printed using Markforged 3D-Printed. shown in Figure 6.

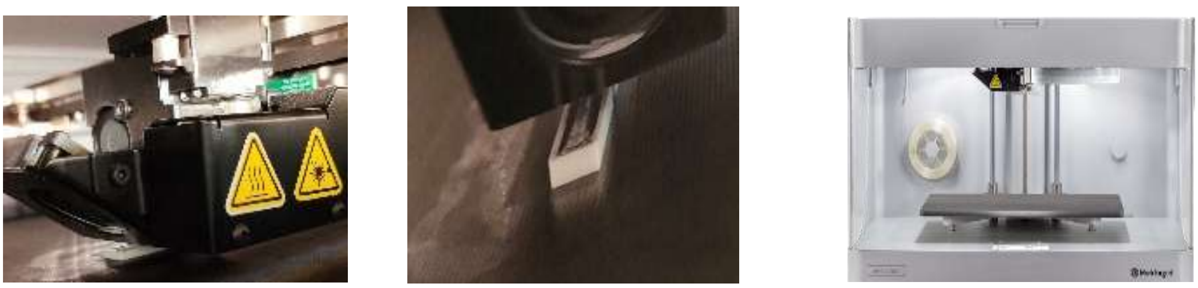

Fig.(7) Markforged 3D-Printed & Specimen

Markgorged 3D-Printed had two nozzle one for base material 0.9 mm diameter and one for fiber 0.4 mm Max. diameter. STL file is supply the 3D printing software and the necessary setting have been done for base material and fiber individually as it requires. Then the 3D Printing process takes place. First Materials heated then extruded from nozzle, to become layers. The carbon fiber becomes very soft state. And getting part as soon as it comes from the nozzle [23].

2.2 Experimental Test

2.2.1 Hardness test

This research specimens in ASTM D2240 Digital hardness testers according to shore A in the experimental procedure for each Hardness test. The machine used was in Figure.8. Takes five reading at upper surface in direction of printing in and get the mean value for each specimen.

Fig.(8) General view of the hardness tester

2.2.2 Impact test

Notched-bar impact test of material provides information on failure mode under high velocity loading conditions leading sudden fracture where a sharp stress raiser (notch) is present. Zwick-Roell used in impact test, Izod pendulum hummer 2.75 j [25], samples according to ASTM 256 D [19]. Get three specimen readings and take average.

3. Results and Discussion

3.1. Hardness test

The change of Shore A hardness values of the composites according to the reinforcement composition (carbon/ glass fiber) and building orientation angles according to the ASTM D2240 standard is given in Figure 9; the mean hardness values were 94.65 for Nylon 100% at 45° orientation building angle, the mean hardness values were 95.66 for Nylon 84% + 16% C.F at 45° orientation building angle, the mean hardness values were 92.6 for Nylon 68% + 16% C. F+16% G.F at 45° orientation building angle and the highest mean hardness value was in Nylon 84% + 16% C.F reinforced composites at 45° orientation building angle.

That means when the same composite; best building orientation angle was 45°, this orientation increasing the resist deformation and increasing the hardness.

According composite; by adding C.F the hardness improving but by adding G.F the ability of composite to resist deformation was decrease.

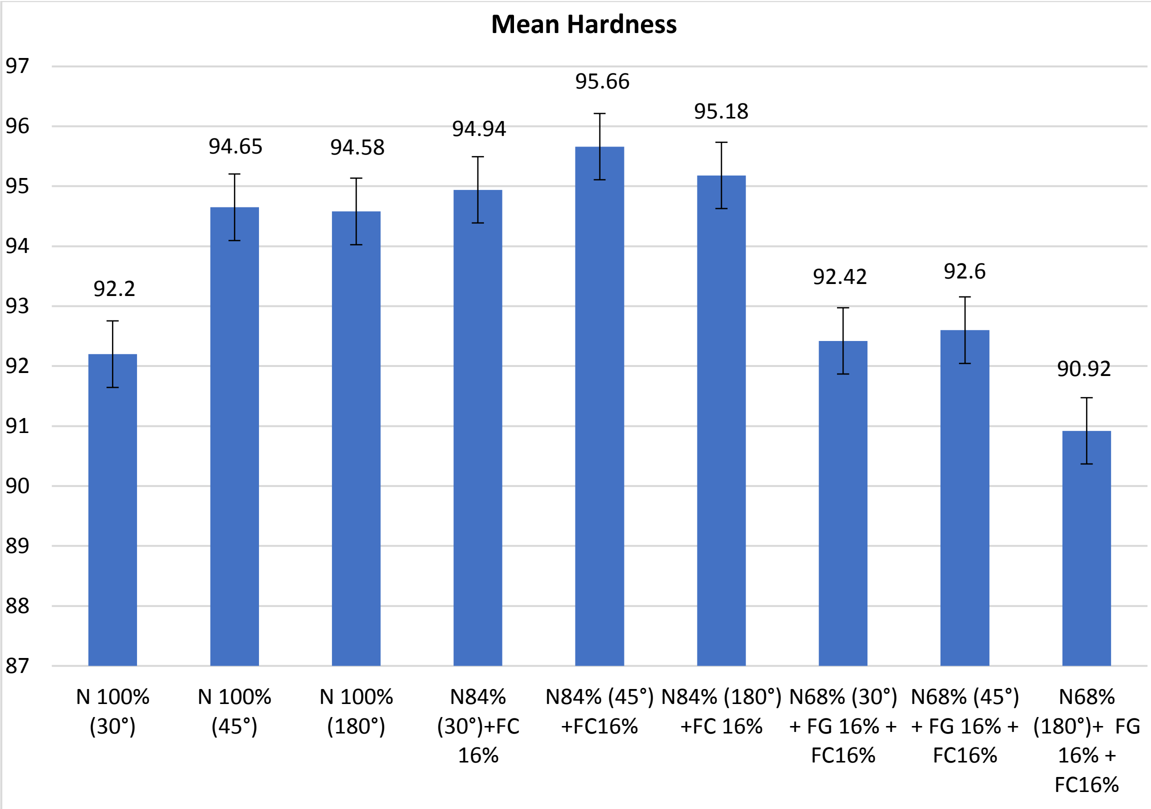

Fig.(.9) Shore A hardness values of Carbon/Glass fiber reinforced Nylon base material according to ASTM D2240

3.2. Impact test

The change of Impact Load values observed for samples of the composites according to the reinforcement composition (carbon, glass fiber) and building orientation angles according to the ASTM **256 D** standard is given in Figure 10; the mean impact load values were 0.091 J for Nylon 100% at 180° orientation building angle, the mean impact load values were 0.069 J for Nylon 84% + 16% C.F at (30°&180°) orientation building angle ,the mean impact load values were 0.209 J for Nylon 68% (180°) +F. G 16%+F.C 16% at (30°&180°) orientation building angle and the mean highest Impact Load values was 0.209 J for Nylon 68% + 16% C. F+16% G.F at (30°&180°) orientation building angle

That means when the same composite; best building orientation angle was 180°, this orientation increasing the ability to absorb energy before fracture. According composite; by adding C.F this ability decreasing but by adding G.F the ability of composite to absorb energy before fracture very increasing and that clear in Fractured Impact specimen in Figure.11.

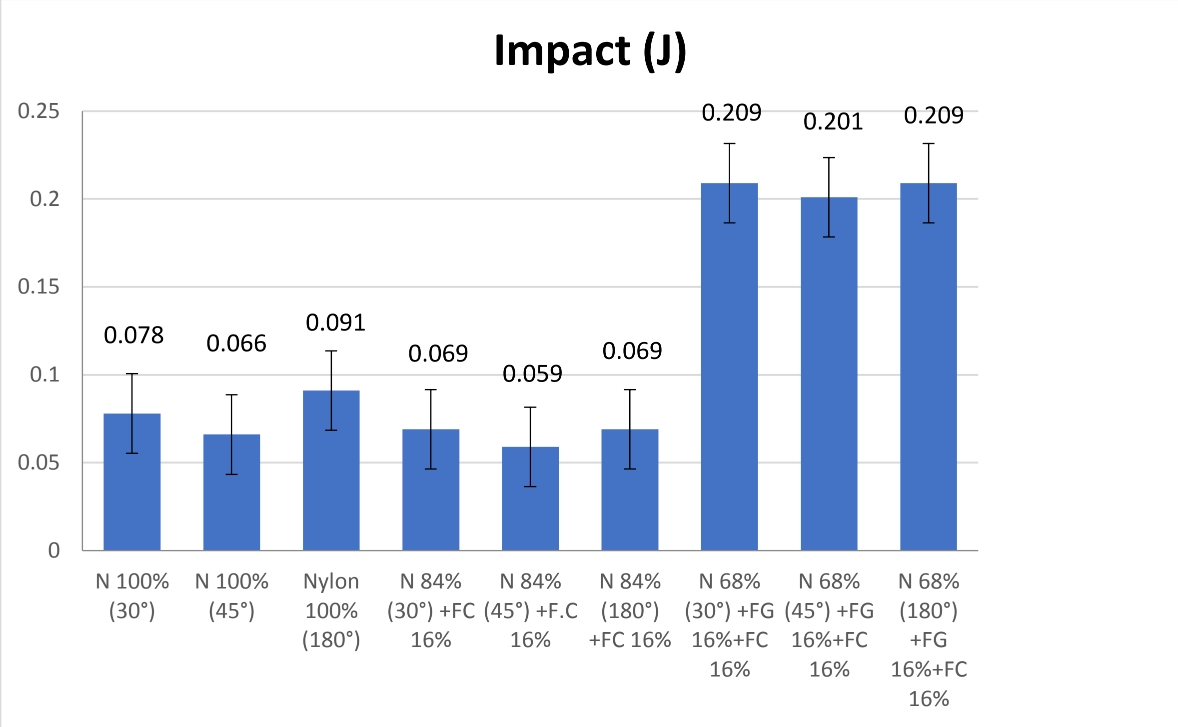

Fig.(10) Impact Load values observed for samples of Carbon/Glass fiber reinforced Nylon base material according to ASTM 256 D in different orientation building angles.

a- Nylon 100% b- Nylon 84% (45°) +F.C 16% c- Nylon 68% +F. G 16%+ C.F 16%

Fig.(11) Fractured Impact specimen

4 Conclusion

The carbon fiber and glass fiber reinforced hybrid composites in different building orientation angles have been fabricated by Markforged 3D-Printing. Experimental evaluation of mechanical properties like hardness and impact of hybrid composites as per ASTM standards has been successfully completed. The highest Hardness value in Nylon 84% + 16% C.F reinforced composites at 45° orientation building angle is 95.66 H. The highest Impact value in Nylon 68% (180°) +F. G 16%+F.C 16% reinforced composites at the same 180°orientation building angle is 0.209 J.

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