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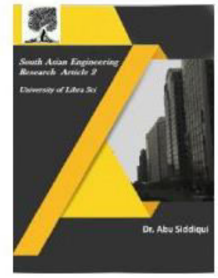

EXPERIMENTAL INVESTIGATION AND OPTIMIZATION OF PROCESS PARAMETERS IN FDM PRINTED CARBON FIBRE REINFORCED PLA

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ABSTRACT

Micro Air Vehicles are the logical successors to modern aircraft and advancements in automated technology. In recent years, the use of Micro Air Vehicles (MAV) and Unmanned Aerial Vehicles (UAV) are playing important roles in different applications. It is used in many aspects of military and civil broadly, such as aerial photogrammetry, warzone, reconnaissance, attack missions, surveillance of pipelines, and interplanetary exploration and so on. The current trend in aircraft structural design is to use composite materials as primary structural elements. The main motivation for this work is Comparative research, simply put isthe act of comparing two or more things with a view to discovering something about one or all of the things being compared. This technique often utilizes multiple disciplines in one study. When it comes to method, the majority agreement is that there is no methodology peculiar to comparative research. We are going to perform tests like Tensile, Compression and Flexural on the 3D Printed standard specimens of PLA and CARBON FIBER REINFORCED PLA by changing the printing parameters to find their mechanical properties by using FDM. The Strength of the parts fabricated by FDM process can be enhanced further by application of Carbon fibre reinforcing in Plastics to turn them into composite materials, which exhibit excellent mechanical properties during their actual use in real worldproblems.

Keywords: Nozzle hole, Brake power, Emission analysis, VCR Engine

1. INTRODUCTION

In recent years, the biodegradable composites draw many attentions in aerospace applications (MAV), as the increasingly serious environmental pollution problems caused by thermosetting composites. Mohanty et al. (2000) reviewed the application of biopolymers and considered that the biopolymers offer environmental benefits including biodegradability, renewability and less greenhouse gas emissions. PLA is a kind of biodegradable material derived from renewable resource and possesses good mechanical properties, which makes it promising an ecologically friendly material for composite applications. At least one species of bacterium in the genus Nocardia can degrade PLA with an esterase enzyme. Japanese scientists have isolated a bacterium Ideonellasakaiensis that possesses two enzymes which can break down the PLA into smaller pieces that the bacterium can digest. A colony of I. sakaiensis can disintegrate a plastic film in about sixweeks.

Figure 1 Mini Drone

3D printing method is widely investigated in processing the thermoplastic resin of PLA due to the good characteristics of strong operation, low cost and no need of tooling or mold. The printing techniques of polymer materials mainly include the Stereo Lithography Apparatus (SLA) and Fused Deposition Modelling (FDM). The fused deposition modeling with low costs of printing device and thermoplastic materials is a better choice for industrial production. Various devices and parts have been printed by the FDM. Hutmacher et al. (2001) and Ahn et al. (2002) investigated the mechanical strengths and anisotropic material properties of FDM manufacturedparts.Carbonfiber powder reinforced composites with the microstructures and mechanical performances being tested. Matsuzaki et al.(2016) proposed that the continuous fiber reinforced composites could be fabricated by the 3D printing and the technique has potential to become the next-generation composite fabrication methodology. Mori et al. (2014) printed a sandwich structure with carbon fibers placed between lower and upper plastic plates and heated after 3D printing to bond the carbon fibers with the plastics. These printing methods mention above can manufacture continuous carbon fiber reinforced thermoplastic composites. However, the curved printing path can be printed, and the weak infiltration between fiber and resin reduced the performance of printed composites.

To develop the 3D printing of continues carbon fiber reinforced PLA composites with curved structures and higher mechanical strength for practical applications, we proposed a prototyping approach for the rapid and continuous printing. The novel extrusion nozzle and path control methods were designed to print curved composite structures. And mechanical properties of tensile strength and flexural strength were tested to make the comparison between printed samples with or without carbon fibers.

The carbon fiber reinforced composite exhibits better mechanical property than that of PLA. Thus, the modification of carbon fiber bundles was introduced by infiltration in the PLA sizing agent before printing, for further improvement of the composite mechanicalproperties.

2. FUSED DEPOSITION MODELING

FDM is the second most widely used rapid prototyping technology, after stereolithography. A plastic filament,

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approximately 1/16 inch in diameter, is unwound from a coil (A) and supplies material to an extrusion nozzle (B) as shown in Figure 1.8 Some configurations of the machinery have used plastic pellets fed from a hopper rather than a filament. The nozzle is heated to melt the plastic and has a mechanism which allows the flow of the melted plastic to be controlled. The nozzle is mounted to a mechanical stage (C) which can be moved in horizontal and vertical directions.As the nozzle is moved over the table (D) in the required geometry, it deposits a thin bead of extruded plastic to form each layer. The plastic hardens immediately after being squirted from the nozzle and bonds to the layer below. The entire system is contained within an oven chamber which is held at a temperature just below the melting point of the plastic.Thus, only a small amount of additional thermal energy needs to be supplied by the extrusion nozzle to cause the plastic to melt. This provides much better control of the process.

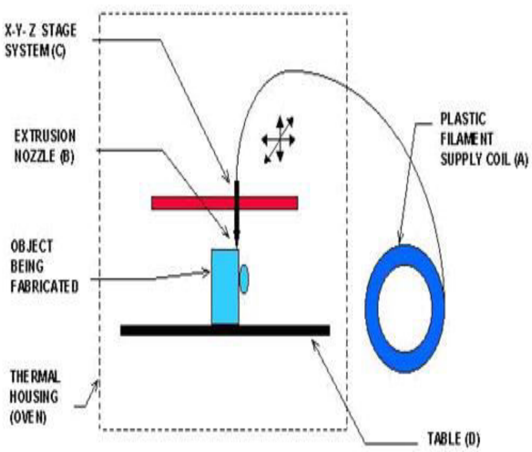

Figure 2: Fused Deposition Modeling

3. Generalized FDM process

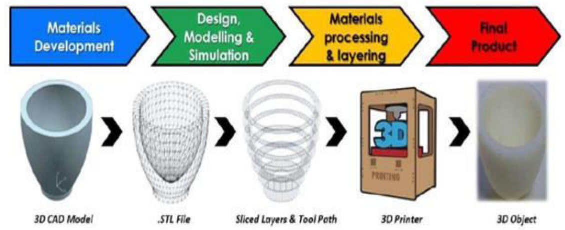

Figure 3: Generalized FDM process

4. Fabrication of FDM Parts

FDM works on an "additive" principle by laying down material in layers; a plastic filament or metal wire is unwound from a coil and supplies material to produce a part. FDM begins with a software process which processes an STL file (stereolithography file format). During the pre-processing stage, the wall thickness of the CAD model was offset so as to account for the metal foil thickness that would be realised during the deposition phase. Figure shows the ASTM standard dimensions for the samples fabricated.

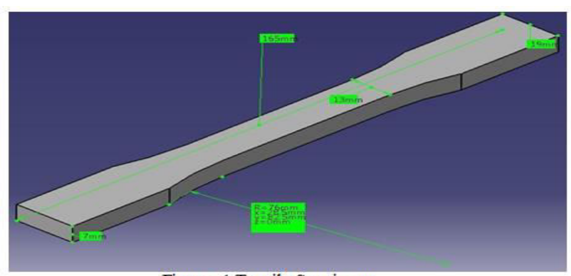

Figure: 4 Tensile Specimen

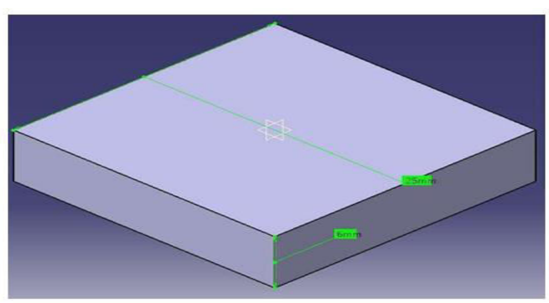

Figure: 5 Hardness Specimen

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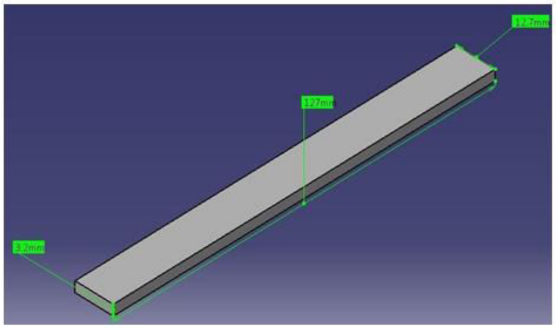

Figure: 6 Flexural Specimen

5. 3D Printed specimen samples:

The CARBON FIBER REINFORCED PLA material specimens printed by 3D printer "PRAMAN 250*300" according to ASTM standards.3D Printers can make complex shapes that fit through tight spaces or bend around structures, saving material costs. The specimens can be made without the need to first produce expensive tools. And it can be built as a single piece, rather than in multiple sections, eliminating assembly lines and cutting labour costs.

Figure 7 : Tensile Specimen (Carbon fiber PLA) (ASTM D638)

Fig 8 : Flexural Specimen (ASTM D790)

Fig 9 : Hardness specimen (ASTM D785)

6. Evaluation of Mechanical properties

6.1 Tensile Test

A tensile test, also known as tension test, is probably the most fundamental type of mechanical test one can perform on material. Tensile tests are simple, relatively inexpensive, and fully standardized. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, reduction in area, tensile strength, yield point and yield strength.

6.2 Flexure Testing

The stress–strain behavior of polymers in flexure is of interest to a designer as well as a polymer manufacturer. Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis.

6.3 Hardness Test

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. More simply put, when using a fixed force (load) and a given

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indenter, the smaller the indentation, the harder the material. Indentation hardness value is obtained by measuring the depth or the area of the indentation using one of over 12 different test method.

6.4 Specimen Parameters

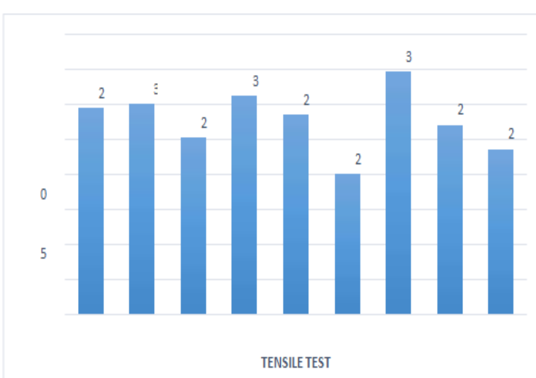
Table 1 Specimen parameters based on Taguchi L9

SAMPLE NO.	PARAMETERS		
	PRINT SPEED (mm/sec)	INFILL DENSITY (%)	LAYER HEIGHT (microns)
1	80	80	100
2	100	60	100
3	60	40	100
4	100	80	200
5	80	40	200
6	60	60	200
7	60	80	300
8	80	60	300
9	100	40	300

7. COMPARISION OF ULTIMATE LOAD (KN) OF CARBON FIBER PLA AND PLA

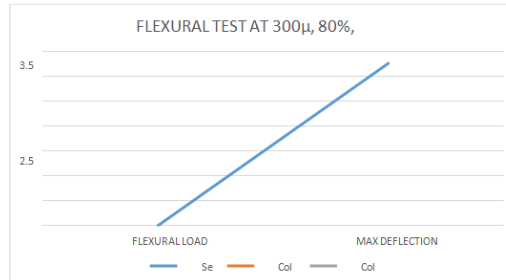
COMPARISION OF PLA AND CARBON FIBER PLA AT 300μ, 80%, 60 mm/sec

Graph 1: Comparison of ultimate load in KN



8. FLEXURAL TEST

Graph 2: Flexural test



9. RESULTS

9.1 Tensile test:

The geometrical data input to the computer is taken from the tensile test configuration according to ASTM D638 standards. The specimen is fixed in the testing machine and the movable jaw is adjusted for the gauge length of 45 mm. The tensile load is gradually applied till the specimen is broken at the average max. Values of 1.68 - 2.98 KN. The load then falls to zero.

The maximum tensile strength obtained for Carbon Fiber PLA and for PLA from the experimental value is 34.629 MPa and 34.192 MPa respectively, where the variation is noticed to be 1.28% increase in Carbon fiber PLA.

9.2 Flexural test:

The specimen geometry for 3-point bend test as per ASTM D 790 standard. The specimen is held in the testing machine as a simply supported beam and load is gradually applied at the centre. When the applied load reaches ultimate value the specimen breaks and subsequently the load falls to zero.

The flexural strength obtained by experimental analysis is 255.08N/mm2. This flexural test is performed under maximum

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parameter which is obtained in tensile test i.e.., at 300µ, 80%, 60 mm/sec.

9.3 Shore Hardness Test:

The hardness number is observed in case of Carbon Fiber PLA is 52, 52, 53 respectively.So, the final values are calculated in case of experimental analysis as well as by using statiscal approach and final graphs are recorded.

10. CONCLUSION

The experimental results indicated that the tensile strength of carbon fiber reinforced PLA is 1.28% higher than pure PLA sample. The following conclusions were drawn from this study.

Compared with pure plastic specimen, adding carbon fibre into plastic materials could increase tensile strength and Young'smodulus.Carbon fiber PLA specimen with 300µ layer thickness, 80% infill density, 60 mm/sec print speed had the largest mean value of tensile strength. The ultimate tensile strength of fabricated specimen with 300µ layer thickness, 80% infill density, 60 mm/sec print speed could increase 1.28% when compared with pure PLA specimen.The values obtained by the test on specimens which are printed based on Taguchi L9 parameters are analysed in Minitab software and the optimum printing parameters are obtained on SN Ratio and MEANS, theyare

100µ layer thickness, 80% infill- density, 80mm/sec print speed (SNRatio).

100µ layer thickness, 80% infill- density, 80mm/sec print speed(MEANS).

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