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# DESIGN AND ANALYSIS OF AN AEROSPACE BRACKET BY ADDITIVE MANUFACTURING WITH CONTINUOUS FIBER REINFORCED PLASTICS

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## ABSTRACT

This research investigates the effects of building parameters for 3D printing Carbon Fiber Reinforced Polymers (CFRP) and Glass Fiber Reinforced Polymers (GFRP) their effect on topologically optimized complex models. In this study specimen with an infill ratio of 40% (constant Triangular, Rectangular and Hexagonal infill pattern) was followed. From the results it can be observed that found to have the best performance recording a length extension in tensile and highest flexural strength can be obtained. a static analysis and topology optimization for the 3D printed material (Nylon with CFRP (Onyx)) to be performed on an industrial part for its design validation. As per our work we are making the Aerospace Bracket by using this Carbon fiber material which is of light weight and strong while compared to the material used now. The Design of the Aerospace Bracket is designed by using the standard CATIA Software. This study will help industries to use these 3D printing parameters where a metal-based components needs to be replaced with CFRP.

**Keywords:** 3D Printing, CFRP, GFRP, Onyx, Infill ratio, Infill Pattern.,

## 1. INTRODUCTION

### 3D PRINTING

3D printing, also known as additive manufacturing, is a revolutionary technology that enables the creation of three-dimensional objects from a digital file. Unlike traditional manufacturing processes that involve subtracting material through cutting or drilling, 3D printing builds objects layer by layer, allowing for complex and intricate designs.

**The 3D printing process typically involves the following steps:**

**Design:** Creation of a digital 3D model using computer-aided design (CAD) software or 3D scanning.

**Slicing**: The 3D model is sliced into thin horizontal layers to prepare it for printing.

**Printing:** The 3D printer reads the sliced file and deposits material layer by layer to create the physical object.

### OBJECTIVE OF PROJECT

The objectives of 3D printing encompass a range of goals, including technological advancements, industrial applications, and societal benefits. Some of the key objectives of 3D printing include:

Innovation and Design Flexibility, Cost-Effective Production, Customization and Personalization, Reduced Time-to-Market, Aerospace and Defense Applications

Sustainability and Waste Reduction**:**

**Application of 3D Printing**

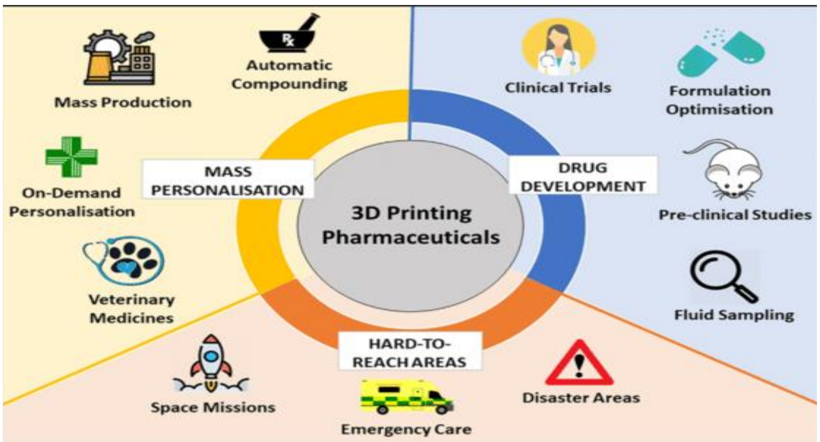


**Fig.1**

## 2. MATERIAL SELECTION

Material selection refers to the process of choosing the most suitable material for a specific application or product design. It involves considering various factors such as mechanical properties, cost, availability, environmental impact, and manufacturing requirements.

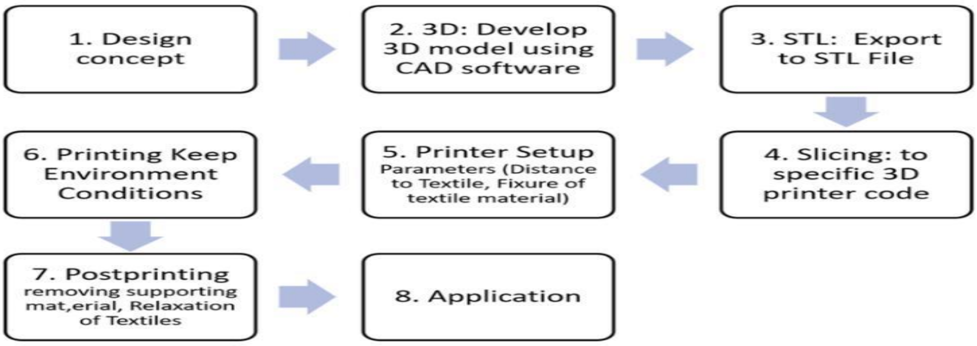


**Fig 2 .** Steps in 3D Printing

### 2.1 3D PRINTING MATERIALS

3D printing, also known as additive manufacturing, utilizes various materials to create three-dimensional objects based on digital models. Several types of materials can be used for 3D printing, each with its own unique properties and applications. Some common 3D printing materials include:

1.Plastics

2.Resins

3.Metals

4.Ceramics

5.Composites

. **Fig 3.** 3D Printing Filament

### 2.3 NYLON WITH CARBON REINFORCED POLYMER

. **Fig 4.** CFRP Filament

### 2.4 PROPERTIES OF CFRP FILAMENT

| Property | Value |
|---|---|
| Shore Hardness | 45D |
| Density | 1.3 g/cm3 (1300 kg/m3) |
| Heat Deflection | 21% to 85°C |
| Shrinkage | Very Low, When Cooling to Elevated Ambient Temperature |

**Fig.5**

### 2.5. NYLON WITH GLASS REINFORCED POLYMER

**Fig 6.** GFRP Filament

Nylon with glass fiber reinforced polymer, often referred to as nylon-GFRP, is a composite material that combines the properties of nylon with the added strength and stiffness of glass fibers. This composite material is created by incorporating glass fibers into a nylon matrix, resulting in a product that exhibits improved mechanical properties compared to standard nylon materials.

### 2.6. PROPERTIES OF GFRP

| Trade Name | Density ($g/cm^3$) | Tensile Strength (MPa) | Modulus of Elasticity (GPa) | Extension to Break (%) | Coefficient of Thermal Expansion ($10^{-6}$/°C) |
|---|---|---|---|---|---|
| E-glass | 2.5 | 3450 | 72.4 | 2.4 | 5.0 |
| S-glass | 2.5 | 4580 | 85.5 | 3.3 | 2.9 |
| C-glass | 2.5 | 3300 | 69 | 2.3 | n/a |
| AR-glass | 2.27 | 1800–3500 | 70–76 | 2.0–3.0 | n/a |

**Fig.7**

### 2.7. ONYX PLASTIC MATERIAL

. **Fig 8.** Onyx Plastic Materials

Onyx is a proprietary engineering-grade thermoplastic material developed by Markforged, a 3D printing technology company. It is known for its high strength, durability, and heat resistance, making it suitable for a wide range of industrial applications. Onyx is commonly used as a base material for composite 3D printing, where it can be reinforced with continuous strands of carbon fiber, fiberglass, or Kevlar to create parts with even greater strength and stiffness.

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### 2.7 PROPERTIES OF ONYX PLASTIC MATERIALS

| Property | Test Standard | Onyx | Nylon |
|---|---|---|---|
| Tensile Strength (MPa) | ASTM D638 | **36** | **54** |
| Tensile Modulus (GPa) | ASTM D638 | **1.4** | **0.94** |
| Tensile Strain at Break (%) | ASTM D638 | **58** | **260** |
| Flexural Strength (MPa) | ASTM D790* | **81** | **32** |
| Flexural Modulus (GPa) | ASTM D790* | **2.9** | **0.84** |
| Flexural Strain at Break (%) | ASTM D790* | **N/A**** | **N/A**** |
| Heat Deflection Temperature (°Celcius) | ASTM D648 Method B | **145** | **44-50** |
| Density (g/cm^3) | N/A | **1.18** | **1.10** |

**Fig.9**

## 3. DESIGN OF AEROSPACE BRACKET

### 3.1 CATIA SOFTWARE

CATIA is a multi platform 3D software suite developed by Dassault Systems, CATIA is a solid modelling tool that unites the 3D parametric features with 2D tools and also addresses every design-to-manufacturing process. In addition to creating solid models and assemblies, CATIA also provides generating orthographic, section, auxiliary, isometric or detailed 2D drawing views. CATIA provides the capability to visualize designs in 3D.

### 3.2 DESIGN

Drafting Workbench allows you to create an orthographic projection or drawing (CATA Drawing) directly from a 3D part (CATA Part) or assembly (CATA Product). A CATA Drawing contains a structure listing similar to a specification tree

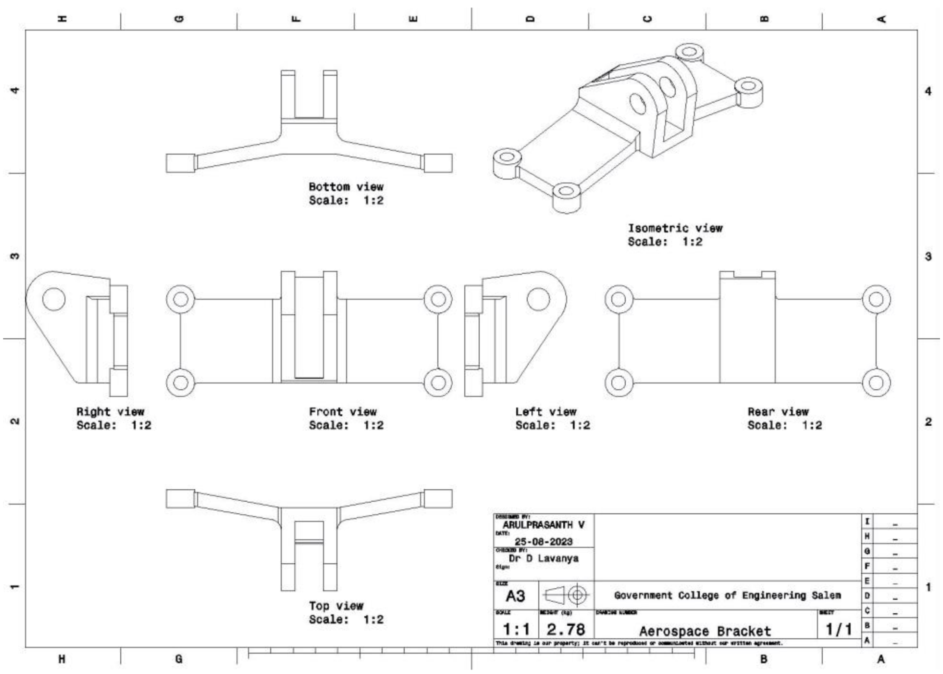


**Fig 10. Drafting**

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### 3.2 PRODUCT

The product in Catia is an assembly of parts that, in terms of building the assembly with constraints, will use the assembly as a whole. To Assemble a CATIA V5 Part in an Existing Assembly. 1. Click Component > Assemble > Assemble with an assembly open.

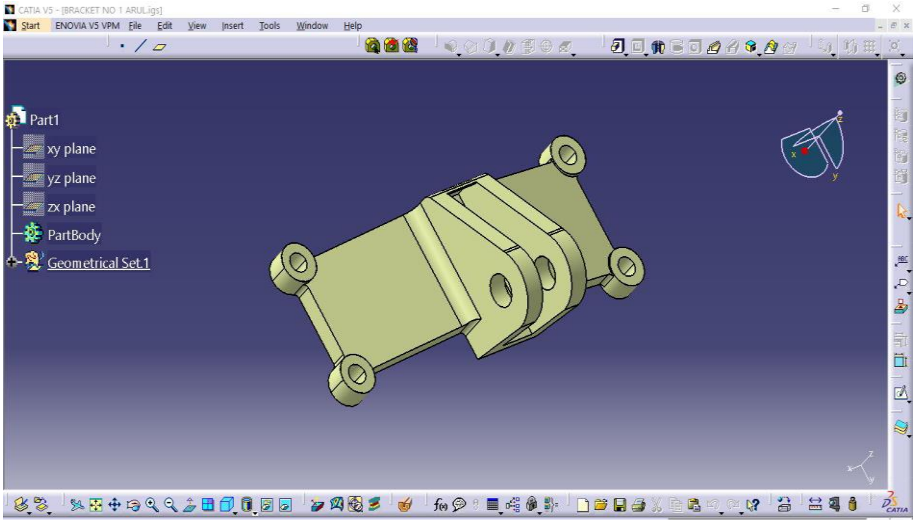


**Fig.11**

## 4. PREPARATION OF PRODUCTS

### 4.1 3D PRINTING MACHINE

The Mark forged Mark Two is a professional-grade 3D printer that offers industrial-level capabilities and is known for its ability to print with high-strength materials. It is produced by Mark forged, a leading company in the field of industrial 3D printing. The Mark Two is particularly well-regarded for its composite 3D printing capabilities, which enable the creation of strong, robust, and functional parts for various applications.

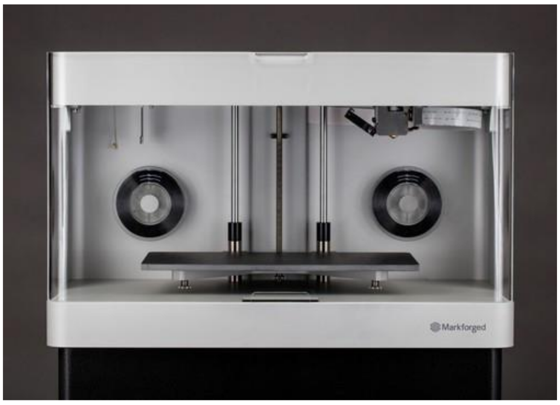

**Fig. 12.** 3D Printing Machine

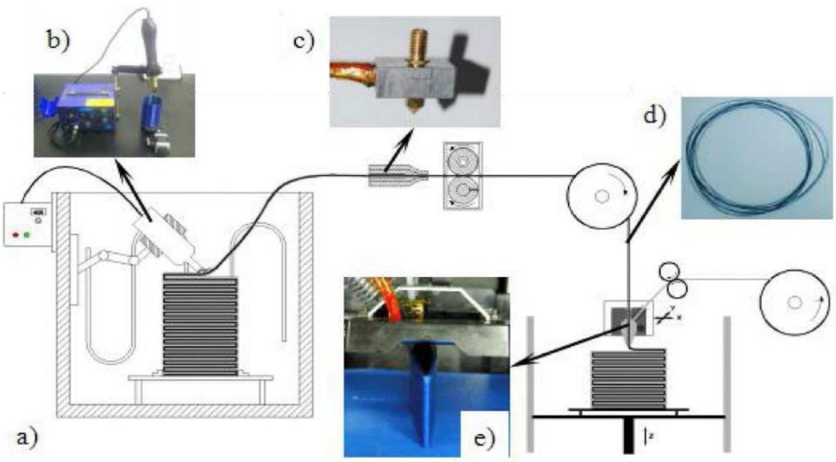


**Fig.13.** Manufacturing Process of 3D Printing

**Fig.14. Printing of Products**

**GEOMETRY SPECIFICATION OF PRODUCTS**

The preparation of specimen is based on the required specification which is tabulated below

| Specification of specimen for Tensile Test | |
|---|---|
| Length | 165mm |
| Breadth | 13mm |
| Thickness | 3mm |

| Specification of specimen for Flexural Test | |
|---|---|
| Length | 125mm |
| Breadth | 13mm |
| Thickness | 3mm |

The specimen is fabricated based on the above parameters and the specimens are prepared under the ASTM D - 638 STANDARDS for Tensile test, ASTM D – 790 for Flexural test.

FABRICATED SPECIMEN

**parameters and the specimens are prepared under the ASTM D - 638 STANDARDS for Tensile test**

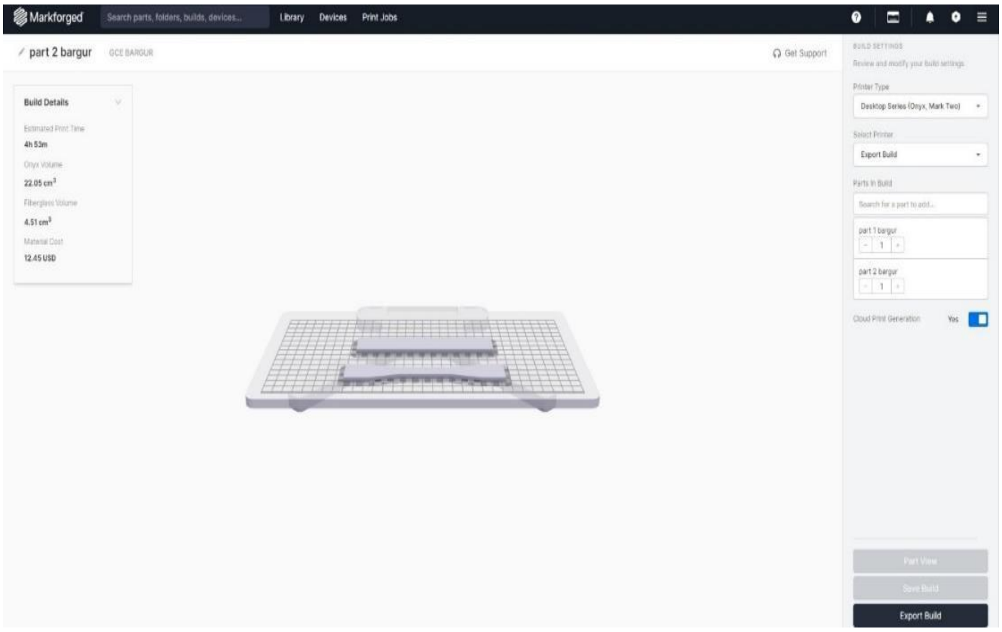


**Fig.15** Slicing the model

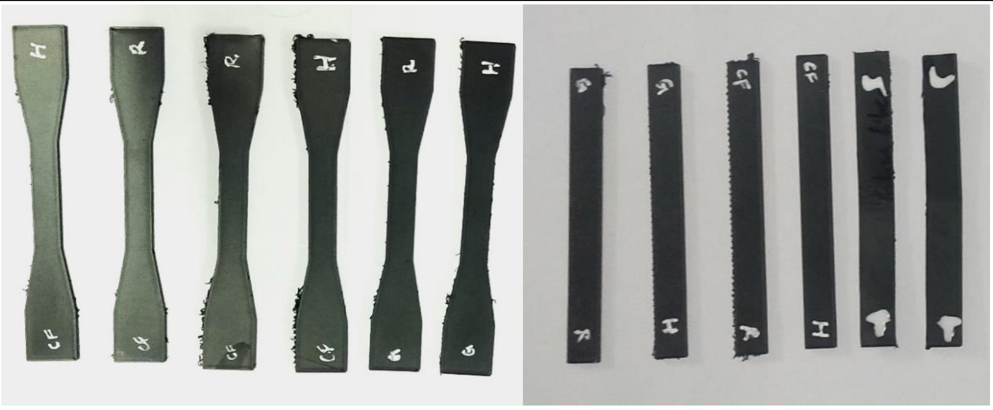

**Fig.16.** Fabricated Tensile And Flexural Test Specimen

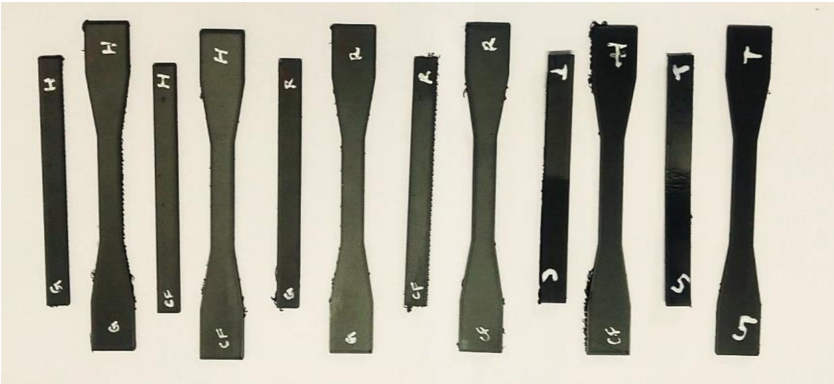

**Fig.17** Fabricated Flexural And Tensile Test Specimen

## 5. TEST ANALYSIS


**Fig 18.-** UTM for Tensile Test

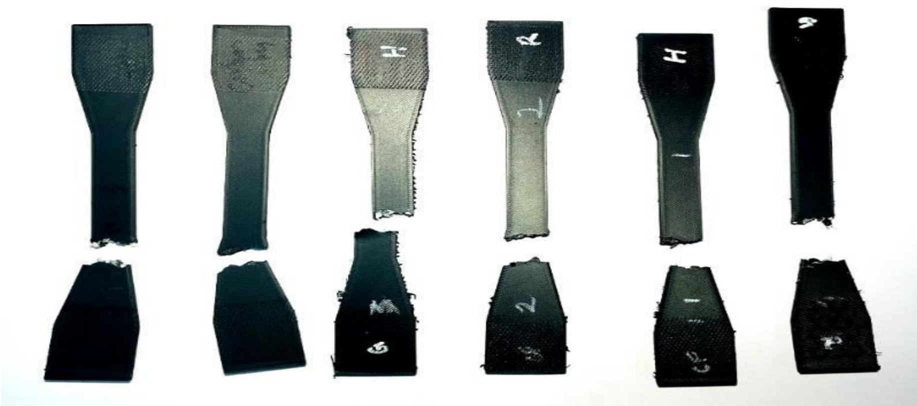

**Fig 19 -** Tensile Testing Specimen

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| | | |
|---|---|---|
| Test Name : TENSILE TEST | Test Type : Normal | Test Mode : Tensile |
| Elongation Device : CrossHead | Test Parameter : Peak Load | Test Speed [mm/min] : 2.00 |

| Sample No. | CS Area[mm²] | Peak Load [N] | %Elongation | UTS [N/mm²] |
|---|---|---|---|---|
| CFRP/ONYX Hexagonal | 39.000 | 2713.142 | 3.870 | 69.573 |
| CFRP/ONYX Rectangle | 39.000 | 2587.319 | 2.220 | 66.345 |
| GFRP/ONYX Hexagonal | 39.000 | 2717.988 | 6.840 | 69.690 |
| GFRP/ONYX Rectangle | 39.000 | 2718.861 | 7.650 | 69.710 |
| CFRP/ONYX Triangle | 39.000 | 2537.023 | 2.330 | 65.050 |
| GFRP/ONYX Triangle | 39.000 | 2714.613 | 10.780 | 69.602 |

Summary Report

| | CS Area[mm²] | Peak Load [N] | %Elongation | UTS [N/mm²] |
|---|---|---|---|---|
| **Min** | 39.000 | 2587.319 | 2.220 | 66.345 |
| **Max** | 39.000 | 2718.861 | 7.650 | 69.710 |
| **Avg** | 39.000 | 2684.327 | 5.145 | 68.829 |
| **Std Dev.** | 0.000 | 64.721 | 2.538 | 1.657 |
| **Variance** | 0.000 | 4188.851 | 6.443 | 2.747 |
| **Median** | 39.000 | 2715.565 | 5.355 | 69.631 |

**Fig 20-** UTM For Flexural Test

**TESTING OF SPECIMEN**

**Fig21**

| Sample Name | CS Area[mm²] | Peak Load [N] | xural Strength(MPa) | Flexural Modulus (GPa) |
|---|---|---|---|---|
| CFRP/ONYX Hexagonal | 39.000 | 191.678 | 122.871 | 3143.786 |
| CFRP/ONYX Rectangle | 39.000 | 203.479 | 130.435 | 3175.481 |
| GFRP/ONYX Hexagonal | 39.000 | 151.437 | 97.075 | 3212.251 |
| GFRP/ONYX Rectangle | 39.000 | 131.650 | 84.391 | 2907.496 |
| CFRP/ONYX Triangle | 39.000 | 117.307 | 75.235 | 1060.897 |
| GFRP/ONYX Triangle | 39.000 | 103.476 | 66.331 | 805.288 |

Summary Report :

| | CS Area[mm²] | Peak Load [N] | ural Strength(MPa) | Flexural Modulus (GPa) |
|---|---|---|---|---|
| **Min** | 39.000 | 131.650 | 84.391 | 2907.496 |
| **Max** | 39.000 | 203.479 | 130.435 | 3212.251 |
| **Avg** | 39.000 | 169.561 | 108.693 | 3109.754 |
| **Std Dev.** | 0.000 | 33.691 | 21.597 | 137.710 |
| **Variance** | 0.000 | 1135.095 | 466.432 | 18964.050 |
| **Median** | 39.000 | 171.557 | 109.973 | 3159.634 |

## 6. CONCLUSION

The present work describes about the tensile and flexural characterization of CFRP and GFRP filament with onyx plastic material with Triangular, Rectangular and Hexagonal infill pattern in experimental results. From the experimental observation the test specimen CRPF with Onyx rectangular pattern have significantly better tensile and flexural strength. The experiment test was furnished to conclude the material stability.As per our work the Aerospace Bracket in Carbon Fiber material which is light weight , strong and have better mechanical and physical characterization

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