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Mechanical Property Evaluation of Fiber Reinforced Polymer (FRP) Smart Composites

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Abstract: *Smart material is one of the upcoming fields in science and technology. The integration of sensing and actuation capabilities in the material to make it SMART is the challenging task. In this research work, an attempt has been made to develop a passive smart material by the integration of electrical inserts in Fiber Reinforced Polymer (FRP) components. Specimens are prepared as per ASTM standards. Mechanical strengths were tested for tensile, flexural, compression and impact. The obtained results have been compared using ABAQUS/CAE V6.12-1 solver. Experimental and Finite Element Analysis (FEA) results show that FRP smart materials possess good mechanical strength to weight ratio. These composites are successful integrated with electrical inserts for tactile sensing capability and replacement of nylon plastic 66/6 quadra-copter arms.*

Keywords: *Smart Material, Tactile Sensing, Fiber Reinforced Plastic*

1. INTRODUCTION

Fiber-reinforced plastic (FRP) is a composite material made of a polymer matrix reinforced with fibers. FRPs have high strength to weight ratio and also possess light, strong and high corrosion resistance properties. Smart materials possess sensing and actuation capabilities. Smart materials can be either active or passive. Active smart materials possess the capability to modify their geometric or material properties, while passive smart material consisting of only sensing capability. Gene et al. [1] have developed various ceramic formulations from their ferroelectric nature and specific areas of application. Neil et al. [2] have shown that, piezoelectric smart materials using shape memory alloys (SHA) and piezoelectric smart materials can be used for force measurements. Schlicker et al. [3] have used the inductive and capacitive sensor capabilities and arrays are used for imaging of buried objects. Staneley Kon et al. [4] have shown both piezoresistive and piezoelectric materials are commonly used to detect strain caused by s structural vibrations in macro-scale structures. Yanlei et al. [5] have used OFBG sensors for measuring strain & temperature. Haibao Lu et al. [6] have investigated sensing and actuating capabilities of SHA polymer composite integrated with hybrid filler. In this paper, a novel tactile sensing mechanism in FRP composite material will be described along with the fabrication process and representative application.

2. SPECIMEN PREPARATION

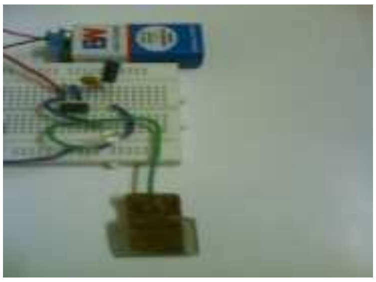
Open mold hand layup method is used for the fabrication of the specimens. Molds are prepared to cast specimens for mechanical testing as per ASTM standard 256 and 638. Glass wool has been used as the reinforcement material and Epoxy (LY 556) resin as matrix material. The copper metal strips are inserted in between the layer to obtain the capacitive tactile sensing. Natural curing process has been used for curing the prepared specimens. The systematic integration of thin copper strip in FRP material not only increases the mechanical properties, but also gives sensing capabilities to the structure. The epoxy and glass fiber layer act as a dielectric media and by varying the thickness of the glass wool/epoxy layer, capacitance can be controlled. Table 1 shows the different proportions of electrical inserts fabricated for mechanical testing of specimens.

Table-1: Various Compositions with Electrical Inserts.

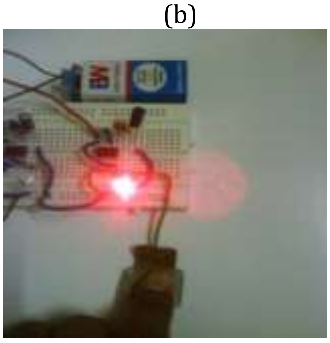
Specimens	Compositions					
	Epoxy		Glass fiber		Copper thin sheet	
Compression	25gm	94.80%	0.97gm	3.67%	0.40gm	1.51%
Flexural	60gm	96.71%	1.40gm	2.25%	0.64gm	1.03%
Izode Impact	40gm	96.17%	0.95gm	2.28%	0.64gm	1.53%
Tensile	50gm	95.02%	1.73gm	3.28%	0.89gm	1.69%

3. TACTILE SENSING OF FRP SMART MATERIAL

Prepared specimens have been tested to verify the sensing capability of the material. The inserts in the specimens are arranged in a suitable pattern to achieve mechanical strength as well as tactile sensing. Figure 1 shows one of the arrangements to check the touch sensing capabilities of the materials. FRP material is connected with the electronics circuit that will process and display the sensed information. Electronic circuit contains microcontroller that will check the sensory circuit in every scanning cycle and display the output according to the touch input.



(a) Before Touch
(b)



(b) After Touch
Fig-1: Specimen with Electrical Insert Working as Capacitive Touch Sensor

4.MECHANICAL STRENGTHS CHARACTERIZATION

The specimens have been prepared as per ASTM standards for flexural, compression, Impact and Tensile are shown in Fig 2. The specimens are tested as per ASTM 638 & 256 test standards with fibers and electrical inserts parallel and perpendicular to the loading directions as shown in Fig 3.

a. Flexural

b. Compression

c. Impact

d. Tensile Specimen
Fig-2: Flat Specimens with Electrical Inserts before Testing

a. Flexural
b.

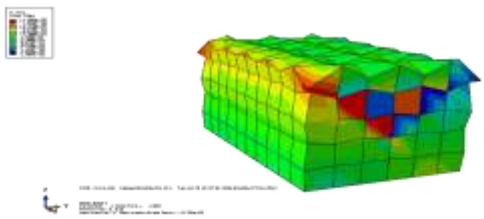
b. Compression

c. Izod Impact

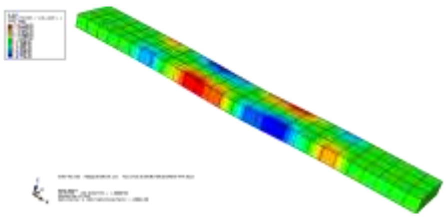
d. Tensile

Fig-3: Flat Specimens with Electrical Inserts after Testing

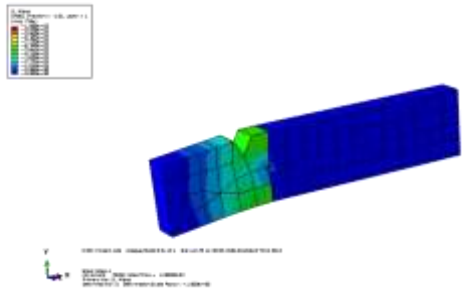
Finite element analysis is analyzed for compression, flexural, Izod-impact and tensile failure using ABAQUS/CAE 6.12-1 solver shown in Fig 4.



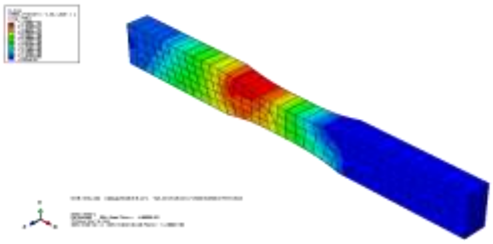
(a) Compression Model



(b) Flexural Model



(c) Izod Impact Model



(d) Tensile Model

Fig-4: Compression, Flexural, Izod- Impact and Tensile Failure Models

Results of experimental and FEA have compared to verify the mechanical strengths of the specimens [Fig 5]. The results show small deviations because of the fabrication method employed. The specimen quality in hand layup method is mainly depends on the skill and expertise of the worker.

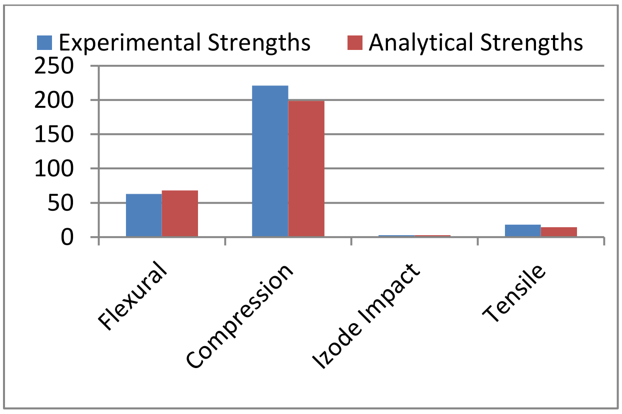


Fig-5: Comparisons of Experimental and Analytical Strengths

FRP materials integrated with metal inserts are used for developing Quadra-copter arms. Developed quadra-copter arms have many features compared to nylon plastic 66/6 arm. The proposed composite quadra-copter arm will have light weight, inbuilt sensing capability and good electrical signals transmission capacity. Figs 6 & 7 shows the Quadra-copter arms made of nylon plastic 66/6 and FRP with metal inserts.

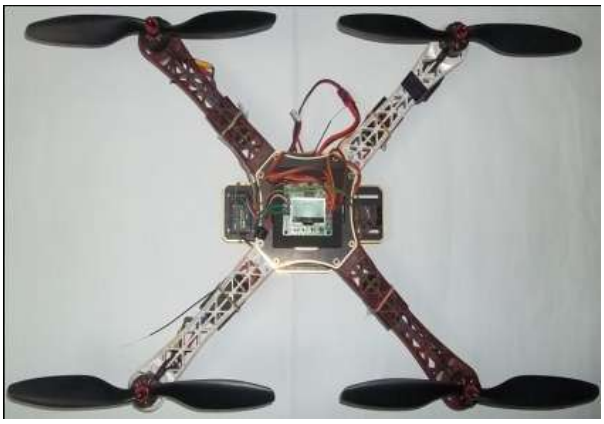


Fig-6: Nylon Plastic 66/6 Quadra-Copter with Arms

Fig-7: Smart Material Quadra-Copter with Arms

5. CONCLUSIONS

- Fiber Reinforced Plastic composites are successfully integrated with electrical inserts by hand-lay- up technique for tactile sensing.
- Experimental and FEA results show that FRP smart materials possess good mechanical Strength to weight ratio.
- The nylon plastic 66/6 quadra-copter arms can be successfully replaced by FRP smart material.

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