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Fabrication and Mechanical Testing of Boron, Silicon Carbide and Polyster Fiber Hybrid Composites Reinforced with Graphite Powder

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Abstract- This study explores the fabrication and testing of hybrid composites made from Boron,Silicon Carbide,Polyster Fibers reinforced with Graphite powder and epoxy resin. Using a layering technique, the composites were evaluated for strength, durability, and suitability in engineering applications. Results showed that Graphite Powder enhanced stiffness and hardness, while hybrid fiber composites outperformed single-fiber ones due to better load sharing and fiber–matrix bonding. The Boron+SiC+Polyster Fibers+Graphite Powder hybrid composite exhibited the best mechanical performance when comparing with other results.

Index Terms Boron, Silicon Carbide, Polyster,Graphite Powder,Mechanical properties, Tensile Strength,Flexural Strength.

I. INTRODUCTION

Natural fibers, which occur in the vegetable or animal kingdom, exhibit a polymeric nature in terms of their chemical composition. In contrast, natural fibers found in minerals resemble crystalline ceramics. A distinguishing characteristic of natural fibers is their typically heterogeneous composition, consisting of various compounds, whether chemical or physical in IRE 1713306 nature. Synthetic fibers can be further classified into polymers, metals, ceramics, or glass, with a unique subclass known as whiskers. Whiskers, being monocrystalline and short, boast exceptional strength, approaching theoretical limits due to the absence of crystalline imperfections like dislocations and grain boundaries. These whiskers usually obtained through vapor phase growth, exhibit diameters of a few micrometers and lengths ranging from a few millimeters, resulting in aspect ratios (length/diameter) that can vary from 50 to 10,000. However, a drawback of whiskers lies in their non uniform dimensions and properties. Natural fibers offer notable advantages, including low density, suitable stiffness, mechanical properties, and high disposability and renewability. They are recyclable and biodegradable, contributing to environmental sustainability. Over the past decade, there has been increased interest in composites of polymers reinforced by natural fibers, such as Jute, Coir, and Hay fibers, which exhibit excellent reinforcing capabilities when compounded with polymers. The unique aspect of designing parts with fiber-reinforced composite materials lies in the ability to tailor mechanical properties to suit specific applications, aiming for an optimal weight-to-strength ratio.

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II. MATERIAL OVERVIEW

This chapter describes the materials used, fabrication process, and testing methods adopted for the development of hybrid composite materials. The composite is prepared using Boron, Silicon Carbide, Polyster fibers as reinforcement, Graphite powder as filler, and epoxy resin as the matrix material. The fabrication is carried out using the sandwich (layering/hand lay-up) technique, followed by mechanical testing to evaluate the performance of the composite.

POLYSTER FIBER: Polyester fiber is a synthetic polymer-based fiber primarily composed of polyacrylonitrile (PAN). It was developed as an alternative to wool due to its soft, warm, and lightweight characteristics. The fibers are produced by a process called wet or dry spinning of the polymer solution, resulting in long, continuous filaments. Polyester fibers are resistant to sunlight, chemicals, and moths, making them durable for long-term use. These fibers are extensively used in knitwear, upholstery, carpets, and outdoor fabrics because of their warmth and colorfastness.

SILICON CARBIDE FIBER: Silicon Carbide fibers are inorganic ceramic fibers made from silicon and carbon atoms. These fibers are produced through pyrolysis of polymer precursors, such as polycarbosilane. SiC fibers are extremely strong, stiff, and thermally stable, maintaining their mechanical integrity at temperatures exceeding 1500°C. They are primarily used in aerospace, nuclear, and turbine components, especially as reinforcement in metal and ceramic matrix composites. SiC fibers exhibit excellent oxidation resistance, corrosion resistance, and dimensional stability, making them suitable for harsh environments where metals would fail.

BORON FIBER: Boron fiber is an inorganic high-strength fiber produced by chemical vapor deposition (CVD) of boron on a tungsten filament core. It is extremely stiff and strong, though brittle and costly. The fiber's surface has an amorphous boron coating that contributes to its high compressive and tensile strength. Boron fibers are used in aerospace structures, sporting goods, and high-performance composites where stiffness and dimensional stability are critical. They are often embedded in epoxy or aluminum matrices to create lightweight, high-strength composites.

BORON FIBER SILICON CARBIDE FIBER POLYESTER FIBER

GRAPHITE POWDER: Graphite powder is a finely ground form of graphite, a crystalline carbon material known for its excellent electrical conductivity, lubrication properties, and resistance to high temperatures. In engineering, it is often added to composites to improve mechanical strength and wear resistance. Artists also use graphite powder for shading, blending, and creating textures in drawings.

GRAPHITE POWDER

EPOXY RESIN

EPOXY RESIN: Epoxy exhibits excellent additive characteristics, along with high mechanical strength, minimal contraction, chemical resilience, high permeation density, low viscosity, and enhanced electrical resistance capacity. Boron, Silicon Carbide, Polyster fibers can all serve as reinforcement options for it.

III. MATERIAL FABRICATION

Step 1: Preparation of fibres

Cleaning and Cutting of fibres: Boron, Silicon Carbide, Polyster fibers were cleaned and prepared for the fabrication process. If they are not pre cut, cut the fibres to the required length for your composite.

Drying: Ensure that the fibres are properly dried to remove any moisture, as moisture can reduce the adhesion between the fibres and the resin.

Step 2: Preparation of Resin Mixture

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Resin Preparation: Mix the polymer resin with the hardener or catalyst as per the manufacturer's instructions. Ensure proper mixing to achieve the desired consistency for lay-up

Step 3: Incorporating Graphite Powder
Preparation of Graphite Powder: Measure the required amount of Graphite powder (10g). The amount will depend on the type of composite you want to create. Mix the Graphite powder thoroughly with the resin. You can use a mixing stick or an electric mixer to ensure an even distribution of the Graphite powder in the resin. This will create a uniform mixture.

Step 4: Layering Process according to Compositions
Take a polyethylene sheet and apply wax on it and next apply the resin. After applying the resin place a Boron fibre and apply resin on the fibre and after that place a Silicon Carbide fibre and then Polyster fibre.Repeat this process according to the required compositions.

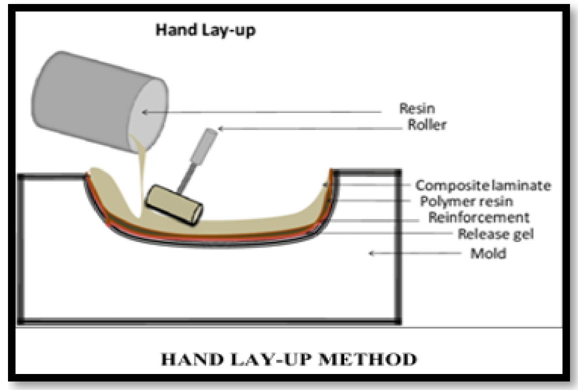
Composition of Composites:

- Composition A: Boron+10grms Graphite Powder
- Composition B: Polyester Fiber+10grms Graphite Powder
- Composition C: SiC Fiber+10grms Graphite Powder
- Composition D: Boron + Polyester Fiber +10grms Graphite Powder
- Composition E: SiC Fiber + Boron+10grms Graphite Powder
- Composition F: Polyester Fiber + SiC Fiber +10grms Graphite Powder
- Composition G: Boron + Polyester Fiber + SiC Fiber +10grms Graphite Powder

Step 5: Curing and Hardening:
Curing:After layering, allow the composite to cure at room temperature or according to the resin manufacturer's instructions (usually 24-48 hours).

Step 6: Extracting And Cutting
Extracting: Once the composite has cured, it is carefully removed from the polyethylene sheets.
Cutting: Then the composite specimen is trimmed to the desired dimensions using cutting tools.

Step 7: Testing and Evaluation
Mechanical Testing: Performed mechanical tests on the fabricated composite specimen, such as tensile test, flexural test, impact test and hardness test.



IV. METHODS OF TESTING

TENSILE TESTING: The tensile test is conducted to determine the tensile strength and elongation behaviour of the composite material under axial loading conditions. In this test, the specimen is subjected to a gradually increasing tensile load until failure occurs. It provides essential information about the ability of the material to resist pulling forces and helps in understanding its strength and ductility characteristics.

ROCKWELL HARDNESS TESTING: The hardness test is performed to determine the resistance of the composite material to surface indentation and wear. It provides an indication of the surface strength and durability of the material. In this test, specific load is applied through an indenter, and the hardness value is measured based on the indentation produced.

FLEXURAL TESTING: The flexural test is conducted to determine the flexural strength and stiffness (modulus) of a composite material when subjected to bending forces. In this test, a specimen typically a flat rectangular bar is supported at two points and loaded at either one or two points in the center until it deforms or breaks.

IMPACT TESTING: The impact test is conducted to determine the toughness and energy absorption capacity of the composite material under sudden loading conditions. In this test, the specimen is subjected to a high-speed impact, and the energy absorbed during fracture is measured

V. RESULTS AND DISCUSSION

5.1 TENSILE TEST

Table: 1 - Tabulated Results of Tensile Test

Composition	Composite Type	Load(N)	Tensile Stress(N/mm2)
A	Boron+ Graphite Powder(10g)	5900	113.75
B	Polyster+ Graphite Powder(10g)	3200	61.58
C	SiliconCarbide+Graphite Powder(10g)	6100	117.30
D	Boron + Polyster+ Graphite Powder(10g)	4832	92.92
E	Silicon Carbide + Boron+ Graphite Powder(10g)	5990	115.19
F	Polyster + Silicon Carbide+ Graphite Powder(10g)	5500	105.76
G	Boron + Polyster + Silicon Carbide+ Graphite Powder(10g)	6228	119.71

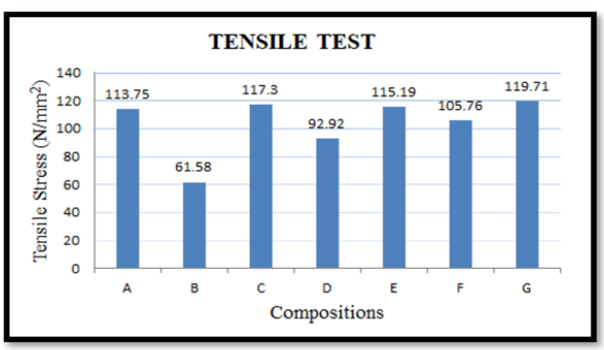


Fig: Composite vs Tensile stress graph

COMMENT: It is observed from the above graph that the Boron + Polyster + Silicon Carbide + 10 grams of Graphite Powder produced the highest tensile, indicating that combining all three fibers results in the strongest composite material

5.2 FLEXURAL TEST

Table: 2 - Tabulated Results of Flexural Test

Composition	Composite Type	Flexural Load(N)	Flexural Stress(N/mm2)
A	Boron+ Graphite Powder(10g)	550	515.625
B	Polyster+ Graphite Powder(10g)	430	403.125
C	SiliconCarbide+Graphite Powder(10g)	460	431.25
D	Boron + Polyster+ Graphite Powder(10g)	495	464.25
E	Silicon Carbide + Boron+ Graphite Powder(10g)	440	412.5
F	Polyster + Silicon Carbide+ Graphite Powder(10g)	405	379.68
G	Boron + Polyster + Silicon Carbide+ Graphite Powder(10g)	620	581.25

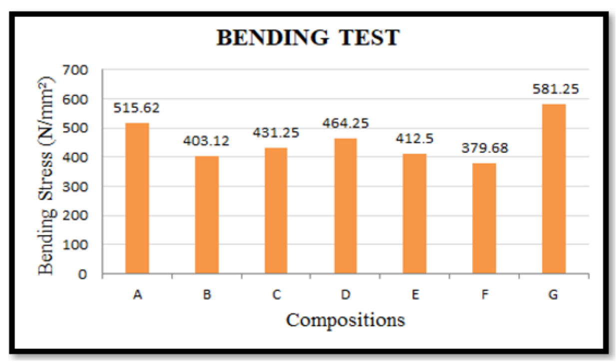


Fig: Composite vs Flexural stress graph

COMMENT: It is observed from the above graph that the Boron + Polyster + Silicon Carbide + 10 grams of Graphite Powder produced the highest flexural strength, indicating that combining all three fibers provides better load-bearing capacity and improved mechanical performance.

5.3 ROCKWELL HARDNESS TEST

Table:3 - Tabulated Results of Rockwell Hardness Test

Composition	Composite Type	Rockwell Hardness Number
A	Boron+ Graphite Powder(10g)	45
B	Polyster+ Graphite Powder(10g)	28
C	SiliconCarbide+Graphite Powder(10g)	39
D	Boron + Polyster+ Graphite Powder(10g)	41
E	Silicon Carbide + Boron+ Graphite Powder(10g)	59
F	Polyster + Silicon Carbide+ Graphite Powder(10g)	42
G	Boron + Polyster + Silicon Carbide+ Graphite Powder(10g)	55

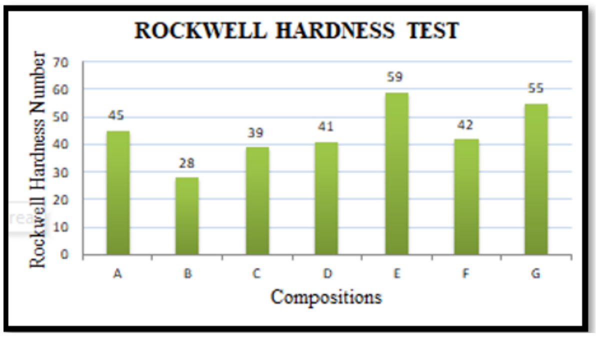


Fig: Composite vs Hardness Number graph

COMMENT: It is observed from the above graph that The Silicon Carbide + Boron+ 10gm of Graphite Powder composite showed the highest hardness number among the seven compositions i.e.59

5.4 IMPACT TEST

Table:4 - Tabulated Results of Impact Test

Composition	Composite Type	Impact Energy (J)	Impact Stress (J/mm²)
A	Boron+ Graphite Powder(10g)	140	3.50
B	Polyster+ Graphite Powder(10g)	98	2.45
C	SiliconCarbide+Graphite Powder(10g)	116	2.90
D	Boron + Polyster+ Graphite Powder(10g)	110	2.75
E	Silicon Carbide + Boron+ Graphite Powder(10g)	129	3.22
F	Polyster + Silicon Carbide+ Graphite Powder(10g)	120	3.00
G	Boron + Polyster + Silicon Carbide+ Graphite Powder(10g)	152	3.80

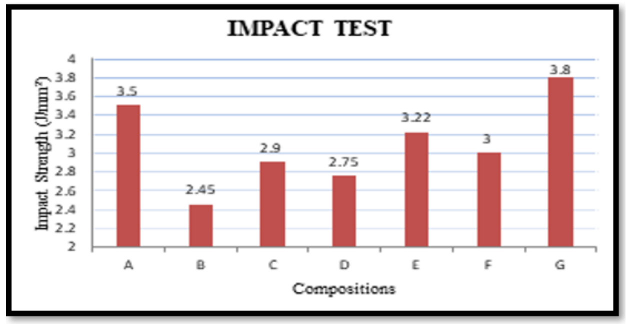


Fig: Composite vs Impact Stress graph

COMMENT: It is observed from the above graph that the Boron + Polyster + Silicon Carbide + 10 grams of Graphite Powder composite showed the highest impact strength indicating that this combination can absorb more energy before fracture and has better resistance to sudden loads.

VI. CONCLUSIONS

1. Hybrid composite with Boron ,Polyster, Silicon Carbide and Graphite Powder has been successfully fabricated by hand lay-up technique.
2. The mechanical testing like tensile, flexural, impact, and Rockwell hardness tests were conducted.
3. Among all the fabricated specimens, the tensile test is maximum in Boron + Polyster + Silicon Carbide + 10 grams of Graphite Powder and minimum in Polyster + 10gm of Graphite Powder.
4. The impact stress is maximum at Boron + Polyster + Silicon Carbide + 10 grams of Graphite Powder and minimum in Polyster + 10gm of Graphite Powder.
5. The rock well hardness for fabricated specimen is maximum at Silicon Carbide + Boron+ 10gm of

Graphite Powder and minimums at Polyster + 10gm of Graphite Powder.

6. Flexural stress for fabricated specimen is maximum at Boron + Polyster + Silicon Carbide + 10 grams of Graphite Powder and minimum at Polyster + Silicon Carbide + 10gm of Graphite Powder.

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