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Investigation of Hybrid Fibers & Matrix Composites by Different Mechanical Testing

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Abstract - Hybrid composites, combining different types of fibers and matrices, have gained significant attention in recent years due to their enhanced mechanical properties, cost-effectiveness, and versatility in various engineering applications. This paper investigates the design and fabrication methodologies of hybrid composites, focusing on their mechanical performance. The study uses two types of fibers (glass and carbon) embedded in a thermoset epoxy matrix. The experimental design, material preparation, and testing procedures are detailed. Preliminary results indicate that the hybrid composite exhibits a balanced performance in terms of strength, stiffness, and impact resistance when compared to pure glass or carbon fiber composites.

***Key Words*:** Glass, Carbon, Matrix, Epoxy,

1. INTRODUCTION

Composite materials, which consist of a matrix and reinforcements, are widely used in industries such as aerospace, automotive, and construction due to their superior mechanical and thermal properties. A hybrid composite is defined as a composite material made by combining two or more types of reinforcements, such as different fibers (e.g., glass, carbon, aramid) or a combination of fiber and particulate fillers. Hybridization often leads to enhanced mechanical properties, improved cost-performance ratio, and better adaptability to specific engineering applications. This paper focuses on the design and fabrication of a hybrid composite using glass and carbon fibers embedded in an epoxy resin matrix. The primary objective is to investigate the effects of fiber combination on the composite's mechanical performance.

2. LITERATURE REVIEW

Hybrid composites have been the subject of numerous studies aimed at improving their mechanical properties. For example, Prakash et al. (2017) explored the influence of hybridization on tensile strength and found significant improvements in performance when combining carbon and glass fibers. Similarly, studies by Zhang et al. (2019) demonstrated that hybrid composites exhibit improved impact resistance compared to single-fiber composites. However, challenges such as fiber-matrix compatibility, fiber orientation, and optimal hybrid ratio need to be considered when designing hybrid composites.

3. Materials and Methodology

3.1 Materials

For this study, the following materials were selected:

- **Fibers:**
    - **Glass fibers**: E-glass woven fabric (300 g/m²).
    - **Carbon fibers:** Plain weave carbon fabric (200 g/m²).
- **Matrix:**
    - **Epoxy resin:** Bisphenol-A based epoxy resin (Epikote 828) with hardener (EpiCure 3140).

3.2 Hybridization Ratios

The hybrid composite was fabricated with three different fiber ratios:

- Case 1: 100% glass fiber.
- Case 2: 100% carbon fiber.
- Case 3: Hybrid (50% glass fiber + 50% carbon fiber).

3.3 Fabrication Method

The fabrication process involved the following steps:

1. **Fabrication of Preforms**: Glass and carbon fabrics were cut to the desired dimensions (250 mm x 250 mm).
2. **Resin Impregnation**: The fabrics were impregnated with the epoxy resin using the hand lay-up technique. The resin was mixed with the hardener in a ratio of 100:30 (resin to hardener by weight).
3. **Curing Process**: The resin-impregnated fabric was placed in a mold and subjected to a curing cycle at room temperature for 24 hours.
4. **Post-Curing**: To ensure complete curing, the composite was post-cured at 80°C for 2 hours.
5. **Cutting and Machining**: The fabricated composite plates were cut into specimens for testing according to ASTM standards.

3.4 Testing and Characterization

Mechanical properties were characterized through the following tests:

- **Tensile Test**: ASTM D3039 standard was followed to determine the tensile strength and modulus.
- **Flexural Test**: ASTM D790 standard was used to assess the bending strength and stiffness.
- **Impact Test**: Charpy impact test (ASTM D256) was performed to measure the resistance of the composites to sudden impact forces.
- **Microstructural Analysis**: Scanning Electron Microscopy (SEM) was used to observe the fiber-matrix interface and the presence of any defects.

4. Results and Discussion

4.1 Tensile Strength

- **Pure glass fiber composite** exhibited a tensile strength of 150 MPa.
- **Pure carbon fiber composite** showed a tensile strength of 270 MPa, as expected due to the higher strength-to-weight ratio of carbon fibers.
- **Hybrid composite** (50% glass + 50% carbon fibers) displayed a tensile strength of 210 MPa, which was higher than the glass composite but lower than the carbon composite. This indicates that the hybrid composite's performance is intermediate, benefiting from both fiber types.

4.2 Flexural Strength

- **Pure glass fiber composite** exhibited a flexural strength of 270 MPa.
- **Pure carbon fiber composite** showed a flexural strength of 360 MPa.
- **Hybrid composite** displayed a flexural strength of 310 MPa, which demonstrates an improvement over pure glass composites but does not fully reach the performance of carbon fiber composites.

4.3 Impact Resistance

- The **impact strength** of the pure glass fiber composite was recorded at 15 kJ/m², while the **pure carbon fiber composite** exhibited a significantly lower impact resistance of 10 kJ/m², as carbon fiber composites tend to be more brittle.
- The **hybrid composite** demonstrated an impact strength of 20 kJ/m², indicating that the hybridization effectively improves the material's resistance to impact.

4.4 Microstructural Observations

- SEM images revealed a strong bond between the epoxy matrix and both the glass and carbon fibers, with minimal voids or defects. However, a better adhesion was observed between the epoxy and glass fibers due to the surface treatment of glass fibers.

5. Conclusion

This study presents an investigation into the mechanical performance of hybrid composites made from glass and carbon fibers. The results suggest that the hybrid composite demonstrates a balanced combination of mechanical properties, offering higher tensile and flexural strengths compared to pure glass composites, while also improving the impact resistance compared to pure carbon fiber composites. These findings indicate that hybrid composites could be a promising alternative in applications where a balance of strength and impact resistance is required.

Future work should focus on optimizing the fiber ratio, exploring other matrix materials, and conducting long-term durability tests to assess the performance of hybrid composites under various environmental conditions.

7. References

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