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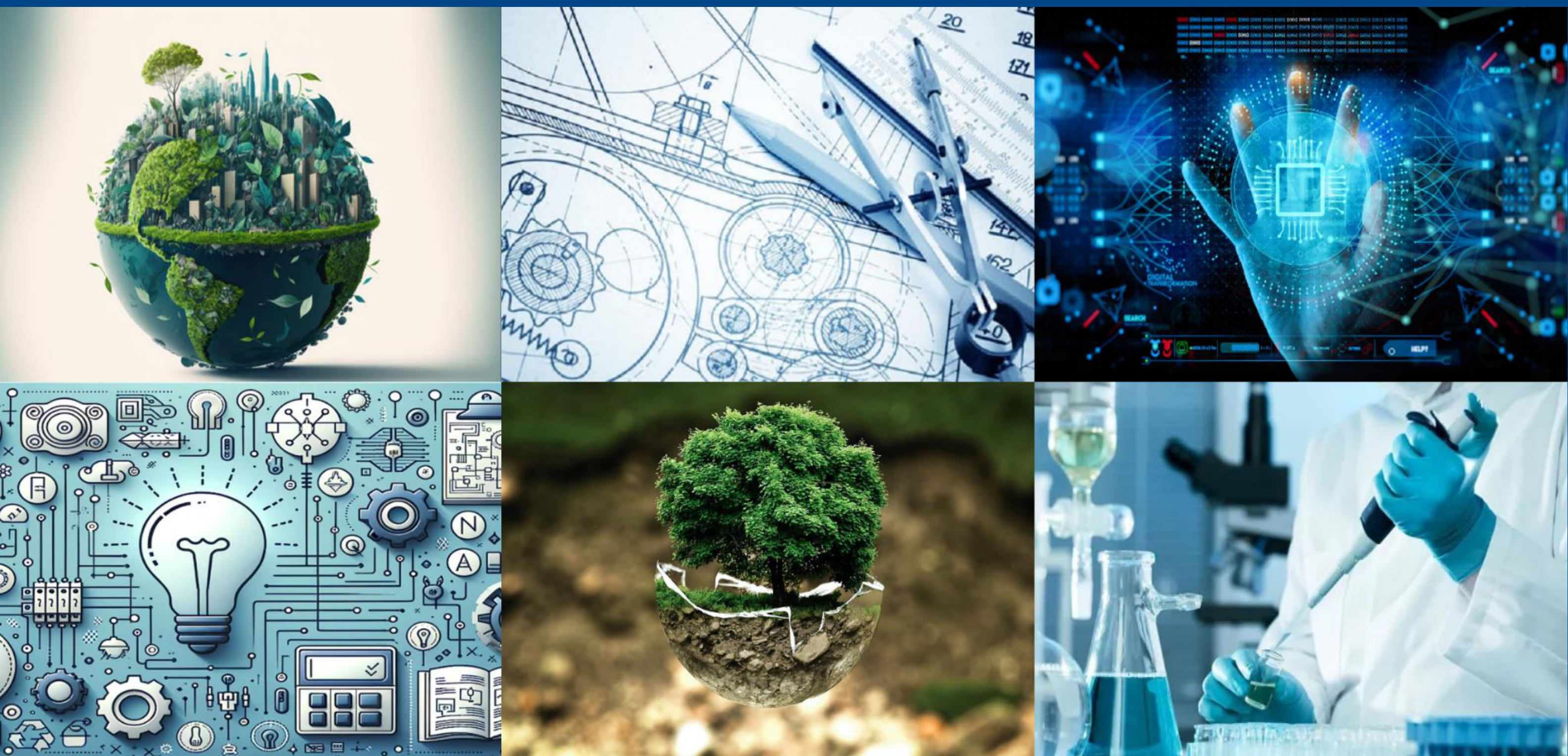

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Experimental Study on the Thermal Behavior of Ceramic/Basalt/Glass/Aluminum FML Composite Sheet

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ABSTRACT: Fiber Metal Laminates (FMLs) are hybrid composite materials that combine the advantages of both metals and fiber-reinforced polymers. This study investigates the thermal behavior of a novel multi-material FML composed of ceramic, basalt, glass fibers, and aluminum. The thermal stability, degradation, and transition characteristics were analyzed using Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), and Dynamic Mechanical Analysis (DMA). The results indicate enhanced thermal performance due to the inclusion of ceramic and basalt fibers, which improved heat resistance and stability at elevated temperatures. The composite structure shows potential for applications in high-temperature environments such as aerospace and automotive sectors.

I. INTRODUCTION

Fiber Metal Laminates (FMLs) represent an advanced class of materials where alternating layers of metal and fiber-reinforced polymers are used to achieve improved mechanical and thermal performance. Among the challenges in using composites in thermal environments is the ability to withstand high temperatures without significant degradation in mechanical integrity or thermal expansion.

This research focuses on the thermal characterization of a hybrid FML comprising ceramic fibers, basalt, glass fibers, and aluminum sheets. Ceramic and basalt fibers are known for their high thermal resistance and low thermal conductivity. Glass fibers provide balanced mechanical support, while aluminum offers ductility and barrier protection.

The objective of this study is to:

- Analyze the thermal degradation temperatures.
- Identify the glass transition temperatures.
- Examine the storage modulus and loss factor under varying temperature ranges.

The synergistic interaction among the four different reinforcement materials is expected to offer a composite with superior thermal resistance and stability.

II. MATERIALS AND METHODS

2.1 Materials Used

- **Aluminum Sheets (AA2024)**: 0.5 mm thick layers used as outer skins.
- **Basalt Fibers**: Sourced from natural volcanic rock, known for heat resistance.
- **Glass Fibers (E-glass)**: Used for structural reinforcement.
- **Ceramic Fiber Mat**: High-temperature-resistant mat (Al_2O_3-based).
- **Epoxy Resin**: LY556 with HY951 hardener used as the binding matrix.

2.2 Fabrication Process

The FML was fabricated using a hand lay-up followed by compression molding. The layer configuration was:

- [Al / Epoxy + Ceramic / Basalt / Glass / Epoxy / Al]

Curing was done at 100°C for 3 hours under 5 MPa pressure.

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2.3 Testing Methods

- **TGA (Thermogravimetric Analysis)**: Performed from 30°C to 800°C under nitrogen atmosphere.
- **DSC (Differential Scanning Calorimetry)**: Conducted from 25°C to 250°C to determine glass transition (Tg).
- **DMA (Dynamic Mechanical Analysis)**: Storage modulus, loss modulus, and damping factor (tan δ) were measured from 30°C to 200°C at 1 Hz frequency.

III. RESULTS AND DISCUSSION

3.1 Thermogravimetric Analysis (TGA)

The TGA curve showed three distinct stages of weight loss:

- **Stage 1 (30–150°C)**: Moisture evaporation with ~2% weight loss.
- **Stage 2 (150–400°C)**: Decomposition of the epoxy matrix, ~30% loss.
- **Stage 3 (400–650°C)**: Thermal degradation of basalt and glass fibers. The residual mass (~42%) confirms the presence of thermally stable ceramic and metallic content.

3.2 Differential Scanning Calorimetry (DSC)

The DSC curve indicated:

- **Glass Transition Temperature (Tg)**: Found at **138.4°C**.
- The presence of ceramic mat delayed the Tg shift, indicating its contribution to thermal insulation.

3.3 Dynamic Mechanical Analysis (DMA)

- **Storage Modulus (E′)**: High initial stiffness (~3.1 GPa at room temp) decreased steadily with temperature.
- **Loss Modulus (E″)**: Peak observed at ~140°C, coinciding with the Tg.
- **Damping Factor (tan δ)**: Peak value of **0.86** at 140°C, indicating moderate energy dissipation due to fiber-matrix interaction.

The addition of ceramic fibers and basalt layers increased both thermal stiffness and delayed damping behavior due to their high thermal resistance.

3.4 Comparative Insight

Compared with traditional Glass/Aluminum FMLs, the inclusion of basalt and ceramic improved:

- Onset degradation temperature by ~45°C.
- Overall weight retention after 600°C.
- Shifted Tg by ~10–15°C upward.
- Reduced peak tan δ, indicating more stable energy dissipation.

IV. APPLICATIONS AND IMPLICATIONS

The developed Ceramic/Basalt/Glass/Aluminum FML shows excellent potential for applications in:

- **Aerospace skins and fairings**: Due to high thermal resistance.
- **Automotive heat shields**: Lightweight yet thermally robust.
- **Defense-grade ballistic panels**: With combined heat and impact resistance.

Moreover, the multilayer synergy opens avenues for customization based on specific thermal and structural needs.

V. CONCLUSION

This study presents a novel multilayered FML composite using ceramic, basalt, and glass fiber reinforcements bonded with epoxy and sandwiched between aluminum sheets. Thermal characterization revealed:

- Enhanced decomposition resistance.
- Elevated glass transition behavior.
- Improved modulus retention at high temperatures.

Such hybrid composites pave the way for multifunctional materials in thermally demanding sectors.

REFERENCES

1. Zhang, Z. et al. (2021). Thermal and mechanical performance of basalt-based FMLs, Composites Part B, 203, 108474.
2. Singh, A. et al. (2019). Influence of ceramic fibers on hybrid composites, Materials Today: Proceedings, 18, 4450–4456.
3. Raghavendra, R. & Srinivasan, K. (2020). Dynamic Mechanical Analysis of Fiber Reinforced Laminates, Polymer Composites, 41(2), 549–558.
4. ASTM D5418-15. Standard Test Method for Thermal Conductivity of Composites.

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