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Integrated AHP-TOPSIS and RSM Approach for Optimizing Sustainable Hybrid Composites

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INTRODUCTION & AIM

The development of sustainable hybrid composites that combine natural and synthetic fibers provides an environmentally responsible yet high-performance solution for modern engineering applications. In this work, a **data-driven optimization framework** integrating the **Analytic Hierarchy Process (AHP)**, **Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)**, and **Response Surface Methodology (RSM)** is proposed to determine the best stacking sequence in **jute-glass-carbon fiber-reinforced epoxy laminates**.

The main aim is to optimize the key mechanical properties - **tensile strength, flexural strength, modulus, and break strain -** while maintaining a balance between stiffness and ductility for structural applications.

METHOD

Materials and Fabrication: Epoxy resin (LY556) and hardener (HY590) were used as the matrix, reinforced with jute, glass, and carbon fibers. Six laminate configurations (C_1-C_6) were fabricated using the hand lay-up method and tested for tensile and flexural properties in accordance with ASTM D3039/D790 standards.

Data Analysis and Decision Frame-work:

- ANOVA and Tukey's HSD confirmed statistically significant differences among all configurations.
- AHP was used to assign weights to each mechanical property based on their importance.
- TOPSIS ranked the laminates according to their closeness to the ideal solution.
- RSM modeled the nonlinear influence of laminate type and stacking sequence on mechanical performance.
- Finally, a desirability-based multi-objective optimization identified the most balanced design.

RESULTS & DISCUSSION

Mechanical Performance:

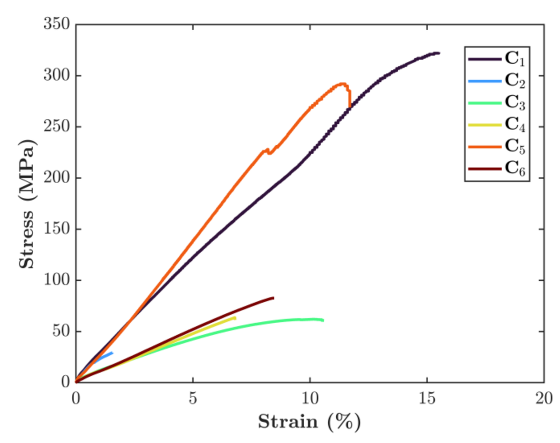
- **C1 (Jute-Glass-Carbon Balanced)** exhibited the **highest tensile strength (301 MPa)** and **maximum ductility (16.93%)**.
- **C5 (Carbon-Glass Cross-ply)** achieved **superior flexural strength (228 MPa)** and **tensile modulus (7.72 GPa)**, making it ideal for stiffness-critical applications.

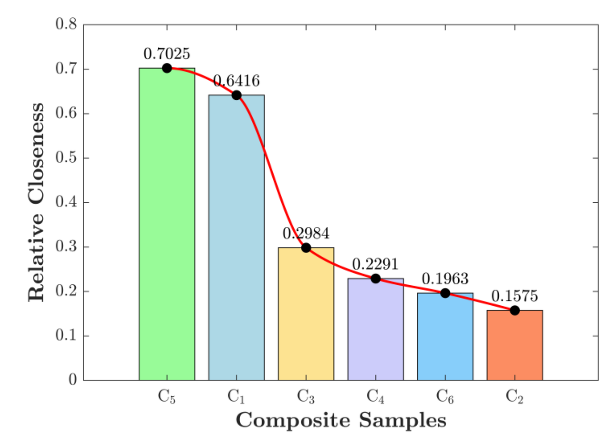
AHP-TOPSIS Ranking:

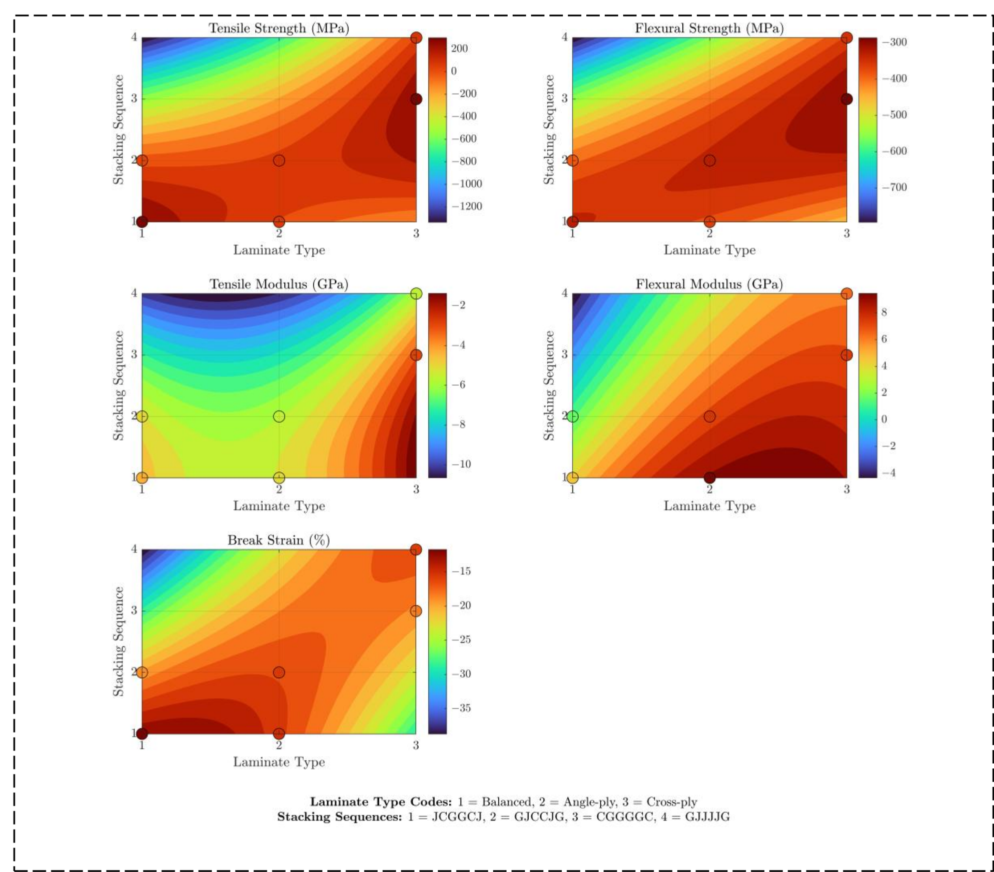
1. **C5 (CG4C)** - Best suited for high-stiffness structural use.
2. **C1 (JCGs)** - Preferred where flexibility and energy absorption are key.

RSM Validation:

RSM models showed a strong correlation ($R^2 > 0.90$) between predicted and experimental results. The cross-ply laminate (C5), with carbon fibers on the outer layers, consistently appeared in high-performance regions across all response surfaces.







CONCLUSION

The AHP–TOPSIS–RSM framework identifies optimal laminates, balancing strength, stiffness, and ductility: C5 suits high-stiffness needs, C1 maximizes ductility and energy absorption, with a reproducible and adaptable design approach

FUTURE WORK / REFERENCES

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