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Experimental investigation on the thermal characteristics of Kevlar/hemp intraply hybrid composites: Influence of various weaving designs

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Highlights

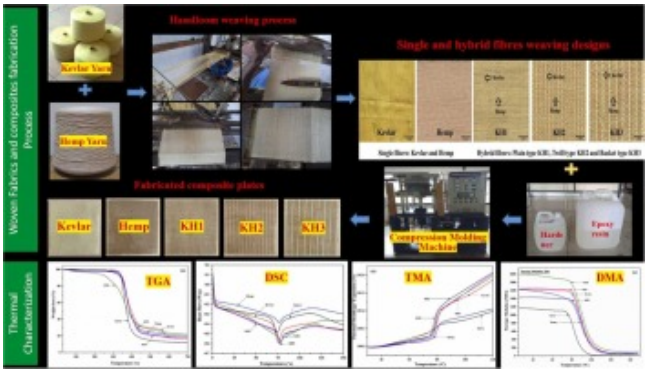
- The work explores the thermal behaviour of composites made from a novel blend of traditional and sustainable materials.
- Highlights the effect of various patterns, providing insights into optimizing performance based on structural arrangements.
- Reveals enhancements in heat resistance offering implications for applications in high-temperature environments.
- Sustainable approach reducing reliance on non-renewable resources while improving performance in thermal applications.

Abstract

In this work, several weaving designs of intra-ply woven fabric Kevlar/hemp fiber (KHE) reinforced epoxy hybrid composites are developed and their thermal characteristics are examined. Thermogravimetric analysis showed that intra-ply hybrid of plain and basket weave designs possessed highest thermal stability. The different weaving patterns of KHE hybrid composites have no effect on the glass transmission temperature

(T_g) value as inferred from the differential scanning calorimetry results. The thermomechanical analysis clearly demonstrates the superior dimension stability of the hybrid composites with basket weave. Dynamic mechanical analysis reveals that twill weave KHE have exhibited the maximum storage modulus (2021 MPa), loss modulus (210 MPa) and lower tan delta (0.3090) values compared to all other composites. Based on the obtained results, it is denoted that all the fabricated KHE hybrid composites displayed improved thermal performance. It may be suitable for applications in thermal insulation panels, fire-resistant clothing, and automotive underbody shields.

Graphical Abstract



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Introduction

Intra-ply hybrid composites refer to composite materials that are composed of a single layer or ply of material, such as a polymer matrix reinforced with fibers, where two or more types of reinforcing fibers are combined within that same layer (Dehkordi et al., 2010). These reinforcing fibers can be of different materials, such as carbon, glass, aramid, or natural fibers, and they are strategically arranged to take advantage of the specific properties of each fiber type (Ouarhim et al., 2020, Sangilimuthukumar et al., 2023a, Jeyaguru et al., 2023a, Karthik et al., 2023). The key idea behind intra-ply hybrid composites is to create a material that exhibits a combination of properties from the different types of fibers used (Jeyaguru et al., 2022a, Fayaz et al., 2022, Karthik et al., 2022). For example, Kevlar fibers provides higher thermal stability and good heat resistant, while hemp fibers may offer good thermal insulation properties (Naveen et al., 2019, Sair et al., 2018, Velumayil and Palanivel, 2022, Ramesh and Anand, 2021). By combining these fibers within a single ply, the resulting composite material can achieve a balance of these properties, making it suitable for specific applications that require a tailored set of characteristics (Flynn et al., 2016). The arrangement and proportion of the different fiber types within the ply can be adjusted to meet the requirements of the intended application, optimizing factors like strength, stiffness, toughness, and weight (Rajak et al., 2019, Al-Maharma and Sendur, 2018, Jeyaguru et al., 2023a, Sangilimuthukumar et al., 2022). Numerous sectors, including sporting goods, automotive, and aerospace, use intra-ply hybrid composites extensively, where specific performance requirements need to be met with a single-layer composite material (Agarwal and Pai, 2022, Jeyaguru et al., 2023a, Muthukumar et al., 2021).

An intraply of weaving design and the arrangement of different fibers can significantly impact the mechanical and thermal properties of composite material (Rajesh et al., 2020). Here are a few common weaving designs