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PERFORMANCE ASSESSMENT AND OPTIMIZATION OF KENAF FIBER REINFORCED SHAPE MEMORY POLYMER COMPOSITES

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ABSTRACT

Rising global concern over environmental degradation and reliance on non-renewable resources has increased demand for sustainable smart materials. Shape memory polymer composites (SMPCs), known for their thermal-trigered shape recovery, are promising but limited by the environmental impact of synthetic reinforcements. This study explores kenaf fiber (KF) as a natural reinforcement in SMPCs, using glass fiber (GF) as a benchmark. A total of 174 specimens were fabricated with shape memory polyurethane (SMPU) at fiber weight percentages of 5%, 10%, 15%, 20%, 25%, 30%, 40%. Characterization included Tensile Test, Thermogravimetric Analysis (TGA), Dynamic Mechanical Analysis (DMA), Thermomechanical Analysis (TMA), Fourier Transform Infrared Spectroscopy (FTIR), and Scanning Electron Microscopy with Energy Dispersive X-ray (SEM-EDX) was conducted. Response Surface Methodology (RSM) was applied for optimization. Results confirmed a trade-off between KF and GF. GF achieved the highest tensile strength, 39.27 MPa and stiffness, 36.35 GPa whereas KF provided greater ductility and energy absorption, with elongation at break of 4.25% compared to 1.2% for 20GF. Thermal analysis showed higher degradation onset for GF, 303°C compared to KF, 271°C, while DMA indicated superior storage modulus for GF, 7780.9 MPa at 40GF compared to 1927.7 MPa for 30KF. However, KF demonstrated stronger damping which is tan delta of 0.41 and higher shape recovery of 93% at 30KF, while GF achieved better fixity of 75% at 30GF. RSM identified the optimum condition at 25.49% KF and 47.10°C, yielding a storage modulus of 1189 MPa and loss modulus of 215.85 MPa. In conclusion, KF-SMPCs offer competitive mechanical and smart functionality with environmental advantages, making them suitable for semi-structural, vibration sensitive, and adaptive systems in automotive, civil, and aerospace sectors contributing to the development of greener, smarter composite materials.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Shape memory polymers (SMPs) are a category of shape memory materials (SMMs) that have attracted significant attention for their ability to regain their original shape after significant deformation in response to various stimuli, such as temperature (heat), moisture, light, magnetism, pH value and more (Luo et al., 2021). Among these stimuli, heat is the most widely used and practical for engineering applications. SMPs offer several advantages over other SMMs, such as shape memory alloys (SMAs), including lightweight properties (Leng et al., 2009), high strain capacity (Singhwane et al., 2023), simple processing and high adaptability to various stimuli (Hewage et al., 2020; Luo et al., 2024), making them suitable for a broad range of applications in biomedical, aerospace, textile, and civil industries. Despite substantial progress, further research into SMPs remains essential.

Among SMPs, shape memory polyurethane (SMPU) stands out due to its remarkable properties, including a wide range of shape recovery temperature, high recoverability, ease of fabrication, cost-effectiveness, and biocompatibility (Nissenbaum et al., 2020). These properties make SMPU a promising material suitable for a wide range of applications, from building coatings and aviation to biomedical uses. However, SMPU alone has a relatively low modulus and mechanical strength, which restricts its use in structural or load-bearing applications.

The development of SMPs and their composites has progressed notably over the past few decades. SMPs were first introduced in the 1980s, with polyurethane-based SMPs gaining popularity due to their thermal responsiveness. In the early 2000s, shape memory polymer composites (SMPCs) emerged as a solution to enhance the relatively low mechanical strength of SMPs by incorporating reinforcements. Between 2010 and 2015, research emphasized optimizing activation temperatures and mechanical properties to broaden their application scope. From 2016 onward, the focus has shifted towards the development of multi-stimuli responsive SMPCs for advanced engineering uses (Sanaka et al., 2024).