Aerodynamic and Structural Feasibility Assessment of Recycled Plastic-Based Shear Webs in Wind Turbine Blades Using ANSYS and Python Automation with Additive Manufacturing Design Considerations

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Abstract

The accumulation of plastic waste presents a significant environmental challenge, particularly in rapidly urbanizing regions such as Chennai, India. Concurrently, the wind energy sector faces sustainability limitations due to the non-recyclable nature of conventional blade materials such as fiberglass composites. This study investigates the feasibility of utilizing recycled plastics for shear web components in wind turbine blades through a simulation-driven approach.

Dominant plastic waste streams, including high-density polyethylene (HDPE), polypropylene (PP), and polyethylene terephthalate (PET), were evaluated based on mechanical properties and availability. A representative wind turbine blade section was developed using a standard airfoil profile. Aerodynamic loading conditions were estimated and applied to a structural model to simulate realistic operating scenarios.

Finite element analysis (FEA) was performed in ANSYS to evaluate stress, deformation, and safety factors under bending and centrifugal loads. A Python-based automation framework was developed to streamline post-processing and enable rapid comparison across multiple material cases.

Additionally, manufacturability was assessed using additive manufacturing design principles, including anisotropy, layer orientation effects, and geometric constraints associated with fused deposition modeling.

Results indicate that recycled plastics are not suitable for primary load-bearing structures but demonstrate potential for secondary applications such as shear webs in low-load configurations. The integration of aerodynamic modeling, structural simulation, and computational automation provides a scalable framework for evaluating sustainable materials in wind energy systems.

Keywords

Wind Energy, Recycled plastics, Finite Element Analysis, Additive Manufacturing, Python Automation.