Erosion Behavior of Natural Fiber Reinforced Polymer Composites: A Taguchi Approach

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1. INTRODUCTION & OBJECTIVE

Abstract

This research investigates the erosion behavior of natural fiber-reinforced polymer composites using a hand layup process with glass, Sisal fibers, and epoxy resin. Employing Taguchi's design of experiments and an air jet erosion test rig, the erosion rates were analyzed through ANOVA and Taguchi's S/N ratios. The study also compared erosion values between natural fiber-reinforced composites and pure epoxy samples under minimum and maximum wear-loading conditions. The results demonstrated superior erosion resistance in natural fiber-reinforced composites. Additionally, stand-off distance was identified as a significant factor influencing wear rate. These findings enhance the understanding of erosion behavior in natural fiber-reinforced composites, offering valuable insights for aerospace, automotive, and other industrial applications.

Keywords: Natural Fibers, Wear, Erosion, Taguchi, ANOVA.

Literature Review

Composites consist of two or more components with distinct physical and chemical properties. Natural fiber-reinforced polymer composites utilize plant-based fibers within a matrix material, offering advantages for mechanical engineering applications. They exhibit a remarkable balance of lightweight and high strength, with constituent materials like jute, coir, rice husk, sisal, and hemp being abundant, affordable, durable, biodegradable, and possessing low density [1]. Despite these merits, natural fiber composites have drawbacks such as poor surface characteristics, low impact strength, and high moisture absorption [2]. However, as an eco-friendly alternative to synthetic fibers, sisal fibers demonstrate high tensile strength and thermal stability [3]. Combining carbon sisal fibers with polymer resin through hand layup or compression molding yields promising materials for aerospace, automotive, sports goods, engineering, and defense [4].

Fabrication of composite

The composite was fabricated using the hand layup, layering glass fibers at 0 degrees and sisal fibers at 45 degrees. Epoxy resin served as the matrix material, providing strong adhesion and uniform fiber distribution, resulting in desired mechanical characteristics.

Research Aim

The research aims to investigate the erosion behavior of natural fiber-reinforced polymer composites using a hand layup process, assessing the effects of various parameters such as impingement angles, stand-off distance, and pressure. The study aims to advance the understanding of erosion in these composites for potential applications in aerospace, automotive, and other industries.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

The research utilized the Taguchi method to investigate the erosion behavior of natural fiber-reinforced polymer composites. By adopting this methodology, the study significantly reduced the number of experiments needed from 27 to 9, employing the L9 orthogonal design.

This optimization not only saved valuable time but also conserved resources. The investigation focused on three crucial parameters: impingement angle, pressure, and stand-off distance. To determine the impact of each control factor on the erosion rate, the study utilized the S/N (signal-to-noise) ratio analysis. Considering the objective of minimizing the erosion rate, the "smaller is better" characteristic was selected for evaluation [5]:

The results of the S/N ratio analysis revealed stand-off distance to be the most influential factor in minimizing erosion rate. This finding highlighted the significant role of the spatial distance between the erodent and the composite material in governing the material loss rate due to erosion. Further examination through an ANOVA table showcased the percentage contribution of each control parameter to the erosive wear, with stand-off distance showing the highest impact on erosion rate reduction (Table 1).

Table 1 ANOVA results of erosion

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Impingement angle (C1)	2	49.092	24.546	1.92	0.343
Pressure (C3)	2	2.283	1.142	0.09	0.918
Stand-off distance (C2)	2	96.627	48.313	3.77	0.210
Error	2	25.624	12.812		
Total	8	173.626			

In terms of visual analysis, optical microscopy was employed to study the morphological characteristics of the eroded specimens. The examination revealed detailed micrographs focused on samples subjected to a 60-degree angle during erosion testing. The comprehensive findings obtained from this study provide valuable insights into the erosion behavior of natural fiber-reinforced polymer composites. These insights pave the way for designing and optimizing erosion-resistant materials, with potential applications in aerospace, automotive, and various other industries.

Significant Conclusions

1. Stand-off distance significantly influences erosion rate, making it a critical factor for erosion-resistant composite design.
2. The Taguchi method efficiently reduced experimentation, saving time and resources in analyzing erosion behavior.

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