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Analysis of Mechanical Properties and Machining of Natural Fiber Reinforced Bio-Composites: A Comparative Study

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Abstract

In the recent years with greater emphasize on the environmental and sustainability aspects of engineering materials, natural fiber reinforced composites (NFRCs) are gaining more importance because of their numerous advantages. Several researchers have developed NFRCs using various natural fibers as well as matrix materials and have also investigated their machinability. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated applications. Natural fiber composites can be either biodegradable or partially biodegradable, with both forms are considered as eco-friendly and therefore are used for reducing consequent problems regarding the environment. The research presents fabrication and experimental characterization analysis of mechanical properties of a class of bio-composite in which polypropylene is reinforced with date palm frond fibers and pine needles. The comparison analysis is presented for the two kinds of bio-composites to determine the preferred bio-composite in industrial applications. Bio-composite sheets were fabricated with controlled processing parameters based on a small Central Composite Design (CCD) method in order to develop a statistical model for response using fractional design of experiment. In the Design of Experiment (DoE) procedure, certain significant factors affecting the overall behavior are identified, and then the process to identify best performance to meet desired output to improve quality and reliability. The experimental design of bio-composite panels includes three different factors with three different levels; fiber loadings (10, 30, and 50 vt. %), fiber length (10, 30, and 50 mm), and alkali treatment (1, 2, and 3 wt. %). The Tensile and Flexural Strengths of specimens prepared according to ASTM standards were measured by direct physical testing. Then, the statistical modeling is used to estimate the optimal combination of fabrication parameters. The Response Surface Methodology (RSM) is also adopted in the analysis of interactions among the input factors and their effect on overall mechanical properties of the fabricated composite. Bio-composite panels are fabricated according to the optimized parameters using nonlinear regression modelling to investigate the bio- composite machinability under dry drilling and end-milling operations. Each machining process is planned based on design of experiments (DoE) tools and statistically analyzed based on Response Surface Methodology (RSM) and systematically learned using Fuzzy Logic (FL). Hence, Analysis of Variance (ANOVA) and Quadratic models were used to develop mathematical models for the process responses and the models validation are

implemented using confirmatory tests. Finally, optimization using Design Expert software is used to predict the best combination of the machining parameters to achieve the minimum delamination under both drilling and end-milling separately. It is found that the developed bio-composites could serve as potential material in broad range of industrial
applications in which high strength is not the main design requirement.