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PREDICTIVE MODELLING OF THE NATURAL FREQUENCIES OF HYBRID COMPOSITES USING NOVEL COMBINED STATISTICAL DESIGN MODELS-REGRESSION FUNCTIONS AND ARTIFICIAL NEURAL NETWORK

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ABSTRACT

A hybrid laminated composite is a laminate created by combining composite layers from several fibre types to create a laminate with the best possible qualities. However, there is still lack of study on predictive modelling about the hybridisation related to vibration behaviour of Carbon/Glass epoxy hybrid laminated composites. In structural design, natural frequency is one of the crucial design parameters in avoiding resonance, which could lead to catastrophic failure. The aim of this study is to develop a prediction model of the natural frequencies of hybrid composite laminates under free vibration. In addition, this study also attempts to enhance the predictive modelling accuracy, where the novel combination of the RSM Statistical Design Models-Regression Functions with the highest accuracy is selected to predict the natural frequencies of hybrid composite laminates using ANN. Finite element models were constructed using ANSYS APDL to investigate the effects of plate thickness, Glass/Carbon Volume Fraction (Vgc), and angle of fibre orientation to the natural frequencies of hybrid composite laminates made of Glass/Epoxy and Carbon/Epoxy under free vibration in an eight-layered lamination scheme of symmetric and anti-symmetric. Design of Experiments (DOE) was utilised to identify the number case of studies and measure important parameters, and each parameter's effect on natural frequencies was thoroughly examined by modal analysis. Optimisation was conducted utilising Response Surface Methodology (RSM) through Analysis of Variance (ANOVA) with comparative study between statistical design models RSM of Custom Design (CD), Box-Behnken design (BBD) and Central Composite design (CCD). An Artificial Neural Network (ANN) was employed in the final stage to predict natural frequencies utilising MATLAB. In addition, datasets comprising 27 and 100 datasets were also evaluated, and their predictive performances were statistically compared using an independent t-test to identify any significant differences between them. The accuracy and robustness of the models are validated through a comparison of predictions generated by ANSYS, RSM, and ANN. The results from finite element analysis, response surface methodology, and artificial neural networks were compared. Numerical validation indicated that the models exhibited a percentage error of 5% for simulation and less than 14% for experimental results, demonstrating sufficient accuracy. The ANOVA results indicated that most influence parameter was the plate thickness. A comparative analysis of various Statistical Design Models-Regression Functions found that the combination of CD-Modified model produced the highest average accuracy of 99.92%. Based on RSM optimisation, the optimal parameters for symmetric laminates were a thickness of 3 mm, fibre angle of 17.12°, 1.0 Vgc (fully Carbon epoxy) generating a maximum natural frequency of 171.88 Hz. For anti-symmetric laminates, the optimal parameters were 3 mm plate thickness and a 1.0 Vgc fully carbon composite orientated at an angle of 17.97° generating a maximum natural frequency of 172.72 Hz. In terms of datasets, the independent t-test revealed that there was no statistically significant difference between 27 and 100 datasets. Between RSM and ANN predictive modelling, RSM has shown overall better results with highest accuracy of 99.97%. Based on these results and findings, it can be concluded that this study has contributed significant knowledge pertaining to the vibrational behaviour of hybrid Carbon/Glass epoxy hybrid laminated composites under free vibration.

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TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION

1.1 Research Background

Composite materials have gained significant interest in multiple engineering fields and are currently considered fundamental to the progression of structural engineering design as illustrated in Figure 1.1 (Alam et al., 2022). The term composite signifies the combination of two or more distinct materials at the macroscopic level to create a third substance with superior performance characteristics (Abdalla, 2025). Typically, these composites comprise a matrix, which functions as the binder and a reinforcing material that enhances strength and stiffness. The collaborative interaction between the matrix and reinforcement leads to improved mechanical performance, especially a superior strength-to-weight ratio. Laminated composite materials have become essential in contemporary engineering applications due to their outstanding mechanical properties, including high specific strength and stiffness, great damping capabilities and remarkable design versatility. As a result, they are extensively utilised in vital sectors such as aerospace, automotive, defence and transportation industries, where performance, efficiency and lightweight structures are essential (Vivek, 2016; Zin et al., 2016).