UNIVERSITI TEKNOLOGI MARA

DEVELOPMENT OF A NOVEL NATURAL FREQUENCIES PREDICTION TOOL FOR LAMINATED COMPOSITE PLATES USING INTEGRATED ARTIFICIAL NEURAL NETWORK (ANN) - SIMULINK MATLAB

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ABSTRACT

Vibration analysis of structures is crucial for understanding failure mechanisms. Typically, physical tests have been the common approach, but they are expensive, time-consuming, and labor-intensive. Finite Element (FE) programming is an alternative, but it requires strong theoretical and mathematical knowledge, along with programming skills. Analytical methods are also viable but become complex with composite materials, requiring extensive mathematical computation. Thus, there is a need for an accurate yet user-friendly natural frequencies prediction tool. This study aims to develop a novel MATLAB®/Simulink® program called AJ Natural Frequency Predictor (AJNatFreP) based on the Classical Laminate Plate Theory (CLPT) integrated with Artificial Neural Networks (ANN). The program provides an efficient means to calculate natural frequencies for laminated composite plates, and it includes a user-friendly Graphical User Interface (GUI). The program is trained to predict natural frequencies with acceptable accuracy, utilizing various input configurations. The model's accuracy was assessed through comparisons with 3D elasticity solutions, finite element simulations, and other published literature references. The study conducted 16 case studies, and the program's predictions were validated using analytical methods and compared to FE modal results. The highest error observed between the FE modal and AJNatFreP was only 2.15%. Convergence analysis and numerical verification were performed to establish accurate FE models for free vibration analysis of laminated composite plates. The study explored various factors influencing natural frequencies, including aspect ratio, principal moduli ratio, anti-symmetry plies, volume fiber fractions, and skew angle of laminated composite plates. The prediction tool utilises an Artificial Neural Network (ANN) with a two-layer feed-forward algorithm and ten hidden layers, using Levenberg-Marquardt as the training algorithm. The ANN's adequacy in predicting natural frequencies was verified, with an R^2 value exceeding 0.9999 and an MSE of 107.527. Several case studies evaluated the performance of the prediction tool, showing good agreement with other lamination theories, such as FSDT (less than 3%) and HSDT (less than 7%). Comparison with experimental results demonstrated errors of less than 5%. A paired t-test confirmed the significant improvement of the prediction tool compared to other laminated composite theories, with the t-test value exceeding the 95% confidence statistical t-value. In conclusion, this study introduces a novel, user-friendly prediction tool (AJNatFreP) that accurately calculates natural frequencies of laminated composite plates. This tool offers a valuable contribution to the field, aligning with the goal of simplifying methods while producing accurate results in the context of free vibrations of laminated composite plates.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

The combination of different materials has been used for many thousands of years to achieve better performance. In other words, a composite material can be defined as a combination of two materials or more and becomes useful or gives superior properties when combined [1]. Laminated composites are in the category of crucial elements in the field of new materials. In recent years, laminated composites have been applied extensively in the areas of aircraft, aerospace, defense, and transportation industries sue to their excellent properties such as high strength, high stiffness-to-weight ratio, high damping and outstanding design ability [2].

In the last decade, many researchers have shown their support for enhancement of mechanical properties in composite materials. Because of their excellent properties, this has driven the best approach to look for another kind of material and the answer has been composites. The composite is a combination of at least two physical and artificially unique materials to create a different helpful material. To be specific, there are two classifications of composites which are those made of natural fibre and those made of artificial fibre. Composites made of natural fibre utilize a stringy (fibrous) material, for example, wood, cotton and so forth. In the interim, artificial fibres incorporate Glass, Carbon and Kevlar. The artificial fibre has high quality, has protection from consumption, does not have environmental impact, is electrically nonconductive and does not lose its quality under high temperature working conditions. The trend of using composite materials is increasing and widely followed in design. These composites possess different properties with their changes of fibre orientation, stacking sequence and volume friction [3]. Most of these structures undergo dynamic loading during their service period. Maximum damage occurs if there is resonance. Therefore, vibration analysis is very important for the design of structures to get its response in advance and accordingly, the structural vibrations can be controlled by taking necessary steps to avoid resonance [4]. Modes shapes of vibration on laminated composite materials have