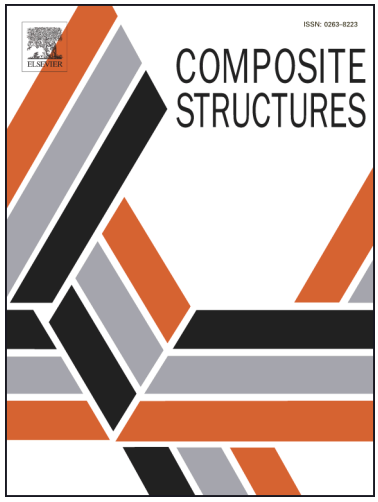

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Dynamic Analysis of Laminated Rotors Using a Layerwise Theory

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Abstract

This paper deals with the dynamic analysis of rotating laminated shafts. A new multi-layer finite element for rotating laminated shaft based on layerwise and shaft theories is formulated and implemented to dispose of a more realistic description of the displacement field through the laminated shaft thickness. This formulation is developed to take into account the influences of stacking sequence, fiber orientation and shear-normal coupling on rotating composite shafts characteristics: natural frequencies and critical speeds and also to analyse the dynamic behaviour of functionally graded material rotating shafts. Obtained results prove that the developed Layerwise Shaft Theory can be effeciently used for rotating laminated shaft dynamic analysis. Furthermore, Layerwise Shaft Theory results revealed that fiber orientations, stacking sequences and shear-normal coupling have a significant effect on the dynamic behaviour of rotating composite shafts and that constituent material properties and power law index have an important influence on the dynamic behaviour of functionally graded material rotating shafts.

Keywords: Rotating laminated shaft, Layerwise theory, Dynamic analysis, Finite element method, Shaft theory

1. Introduction

Systems spinning about their longitudinal axis are used in the most diverse fields of modern technology. They are used as a laminated shaft in aerospace and automotive drive applications [1–5]. In fact, the lamination sequence and material properties of individual lamina provide an added flexibility to designers to adjust the stiffness and the strength of the laminate to agree with the structural stiffness and strength requirements [6–8].

The theoretical concepts and analysis methods help structural engineers to select suitable material for the best performance in a particular laminated shaft application. Therefore, a better understanding of the laminated shaft dynamic behaviour is required to improve their vibration behaviour, eliminate the occurrence of any instability and enhance their efficiency. Singh et al. [9] and recently Gupta [10] summarized many published works on the problem of composite shaft rotor dynamics. Finite element formulations available in the literature, performed for the dynamic analysis of rotating composite shafts, are based on homogenized beam theory such as Equivalent Modulus Beam Theory (EMBT), Modified Equivalent Modulus Beam Theory (Modified EMBT), Simplified Homogenized Beam Theory (SHBT) and Equivalent Single Layer Theory (ESLT) and reduced from shell theory such as Layerwise Beam Theory (LBT). Zinberg and

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