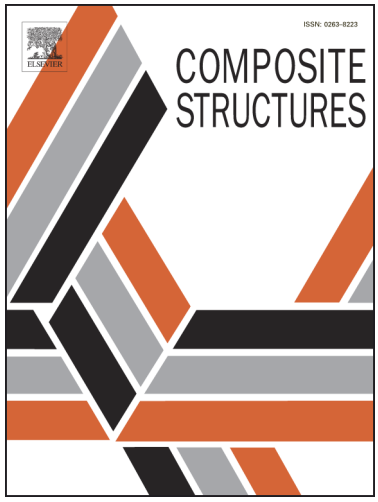

Flapwise free vibration characteristics of a rotating composite thin-walled beam under aerodynamic force and hygrothermal environment

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Flapwise free vibration characteristics of a rotating composite thin-walled beam under aerodynamic force and hygrothermal environment

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Abstract: The flapwise free vibration characteristics of a rotating composite beam under aerodynamic force and hygrothermal environment are studied in this work. The partial differential equation governing the flapwise free vibration of the beam is derived based on D'Alembert's principle. The modal problem is handled utilizing the assumed-modes method. The effects of temperature, humidity, aerodynamic force, rotational speed and ply orientation on the natural frequencies and damping ratios are investigated. Results show that the hygrothermal environment, aerodynamic force, rotational speed and ply orientation have vital influences on the flapwise free vibration characteristics of the beam. The hygrothermal environment and ply orientation have more remarkable effects on the natural frequencies and damping ratios at low rotational speed. The aerodynamic force has small influences on natural frequencies and great effects on damping ratios.

Keywords: free vibration characteristics; rotating composite beam; assumed-modes method; aerodynamic force and hygrothermal environment

1. Introduction

Composite structures, especially fibrous reinforced composite ones, are used increasingly in many engineering applications due to their high stiffness and light weight properties [1-2]. Rotating structures are one important example of the composite beams in industrial applications like wind turbine blades, helicopter blades and aircraft propellers. The centrifugal inertia force due to rotational motion causes the increment of the bending stiffness of the structures, which naturally results in the variations of natural frequencies and damping ratios. In addition, these structures usually operate under the complex environment such as aerodynamic force and hygrothermal environment. The temperature and moisture concentration can alter their elasticity and the thermoplastic properties, and aerodynamic force can affect their vibration characteristics. vibration characteristics analysis of such structural systems is essential to acquire the desired accuracy and efficiency.

There exists a great deal of previous researches related to vibration characteristics of the rotating composite structures. For example, in Ref.[3] the numerical model of a rotating composite beam with embedded carbon nanotubes (CNT) was established using the Euler-Bernoulli beam equation. The effects of the beam geometry parameters, angular speed, and CNT damping values on the dynamic response and vibration settling time of a rotating composite beam were examined through the finite element method (FEM). Ozdemir and Kaya[4] investigated the vibration of a rotating piezolaminated composite Timoshenko beam. Effects of the rotational speed, hub radius, applied voltage and ply orientation on natural frequencies and tip deflection were studied. Yoo et al.[5] proposed a modeling method to analyze the modal characteristics of the rotating multi-layered composite beams using Timoshenko beam theory. Lee et al.[6] estimated the variations of natural frequencies and modal shapes of the rotating cantilever beam. The influences of the fiber orientation angle, angular velocity and hub radius of the rotating beam on the variations were investigated. Tolga and Metin[7] examined the vibration of rotating composite beams using different beam theories including Euler–Bernoulli,

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