Mathematical modeling and vibration analysis of rotating functionally graded porous spacecraft systems reinforced by graphene nanoplatelets

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Abstract

This paper investigates the theoretical modeling and coupled free vibration behaviors of a rotating double-bladed shaft assembly resting on elastic supports in a spacecraft system. According to the Kirchhoff plate theory and the Euler-Bernoulli beam theory, the theoretical model is established. The studied rotor is considered to be made of porous foam metal matrix and graphene nanoplatelet (GPL) reinforcement. Non-uniform distributions of porosity and graphene nanoplatelets (GPLs) are taken into account and lead to functionally graded (FG) structures. The effective material properties of the double-bladed shaft are varying along the radius and thickness direction of the shaft and blade, respectively. Moreover, the rule of mixture, the Halpin-Tsai model, and the open-cell scheme are used to determine its material properties. Considering the gyroscopic effect, the Lagrange equation is utilized to derive the coupled equations of motion. Then the traveling wave frequencies of the double-bladed shaft assembly is obtained by employing the assumed modes method and substructure modal synthesis method. A detailed parametric analysis is conducted to examine the effects of the rotating speed, GPL weight fraction, GPL distribution pattern, GPL length-to-thickness ratio, GPL length-to-width ratio, porosity coefficient, porosity distribution pattern, shaft length-to-radius ratio, blade length-to-thickness ratio, support stiffness and support location on the free vibration behaviors of the double-bladed shaft assembly.

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