On the nonlinear dynamics of rotating hybrid nanocomposite blades with matrix crack

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Abstract. For the first time, nonlinear dynamics of rotating pre-twisted hybrid laminated blades composed of a mixture of matrix cracked graphene platelets reinforced composite (GPLRC) layers and perfect FG carbon nanotube reinforced composite (CNTRC) layers is investigated. The material properties of both nanocomposites are predicted by modified Halpin-Tsai model and the modified rule of mixture. The degraded stiffness of the cracked GPLRC lamina is evaluated within the micromechanical framework of the self-consistent model. Based on the FSDT and the Novozhilov nonlinear shell theory, the discretized nonlinear governing equations are established using the element-free IMLS-Ritz approach and solved employing a direct iterative method. Parametric studies are performed systematically to illustrate the impacts of matrix crack density, CNT distribution configuration, ply angle, and number of layers on the frequency-amplitude relations of rotating matrix cracked hybrid nanocomposite blades.

Introduction

Composite blades are important components in various engineering structures, such as steam turbine, gas turbine, and wind turbine. The laminated FG materials reinforced with GPLs and CNTs possess low weight combined with higher stiffness and strength which are in great demand for rotating machines and their elements [1, 2]. The initial matrix cracks in composite laminates may influence the dynamic properties at a certain extent. Thus the dynamics of rotating hybrid nanocomposite blades with matrix crack should be investigated.

Three coordinate systems in Figure 1 (a) are introduced to describe the geometry properties of the blade with a twisting geometrical shape. As illustrated in Figure 1 (b), it is assumed that the perfect bonded laminated blades are composed of a mixture of GPLRC layers and CNTRC layers. All nanocomposite layers have the same matrix to reduce interlaminar stresses. Number of each lamina increases from the bottom of the multilayer blade to its top. NL is the total number of layers and NL ($NL \geq 3$) is an odd number. Notably, the even-layer and the odd-layer belongs to GPLRC layer and CNTRC layer, respectively. As depicted in Figure 1 (c), the GPLs are evenly distributed in each GPLRC layer and the parallel slit matrix cracks considered to be elliptic cylindrical cavities are dispersed in the matrix of GPLRC layers homogeneously. As an example, three types of five-layer hybrid nanocomposite structures, namely Structure-I, Structure-II, and Structure-III are shown in Figure 1 (d), (e), and (f). The CNTRC layers in Structure-I are considered with CNTs arranged in uniform distributions, while Structure-II and Structure-III are arranged with CNTs FG distributions. Five CNT distribution configurations through the thickness in each CNTRC layer including UD, FG-O, FG-X, FG-V, and FG-Λ are covered.

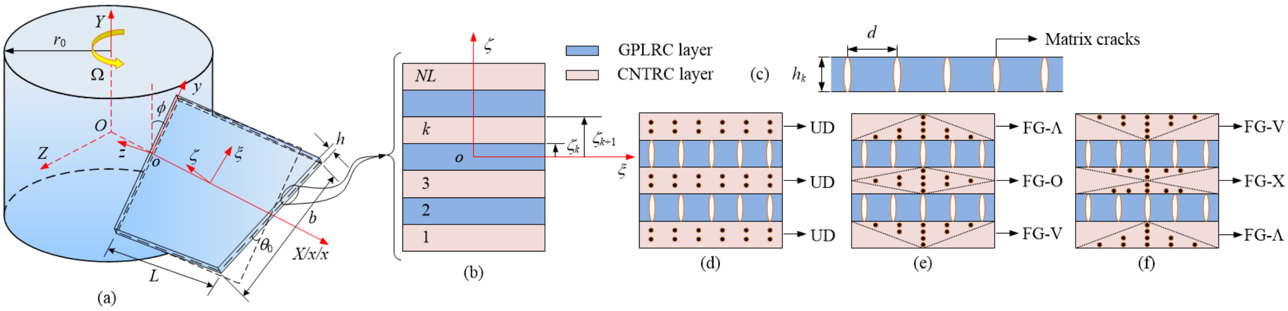

Figure 1: (a) the coordinate system and geometry and (b) the cross-section of rotating pre-twisted perfect bonded laminated hybrid nanocomposite blade; (c) the geometric description of cracks and their distribution in GPLRC layers; the configuration of CNTs in hybrid nanocomposite blade (d) Structure-I, (e) Structure-II, and (f) Structure-III.

Results and discussion

The accuracy and efficiency of the present model are validated in detail by comparing the obtained results with those available in the literature. Parametric studies in the full-length paper are performed systematically to illustrate the impacts of matrix crack density, CNT distribution configuration, GPLs-to-CNTs volume fraction ratio, GPLRC-to-CNTRC layer thickness ratio, ply angle, and a number of layers on nonlinear vibration behaviours of rotating hybrid nanocomposite blades with matrix crack. New insights into the nonlinear dynamics of the considered blades are presented.

References

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