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FREE VIBRATION ANALYSIS OF ROTATING STRUCTURES BY CARRERA UNIFIED FORMULATION

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Shafts and blades constitute fundamental parts of airplane engines, helicopters and turbomachinery. A thorough understanding of their dynamic features is therefore needed to assure a correct functioning. The modelling of rotating structures is usually made with beam elements to which some rigid discs may be connected. Despite their evident limitations, classical beam theories were extensively adopted for analysing spinning shafts [1-2] as well as centrifugally stiffened beams [3-4]. Unfortunately, such models are inadequate when the problem becomes complex. For this reason, a number of refined beam theories were proposed [5-8] in order to study the dynamic behaviour of shafts and blades constituted by composite and functionally graded materials. Furthermore, when discs are thin and therefore highly deformable, two- and three dimensional finite elements were used producing a dramatic increase of the computational effort [9-10].
In this paper, Carrera Unified Formulation (CUF) is used for the study of the dynamics of rotating structures [11-12]. CUF provides a procedure to obtain refined structural models merely by enriching the displacement field components [13]. The present formulation includes gyroscopic effects and stiffening due to centrifugal stresses and, as to verify the accuracy of new theories, several analyses are carried out considering composite, thin-walled boxes as well as FGM structures. The good accuracy of the obtained results combined with a low number of degrees of freedom makes CUF an attractive approach to deal with the rotordynamics.

REFERENCES

[1] H.F. Bauer. Vibration of a rotating uniform beam, part 1: Orientation in the axis of rotation. *Journal of Sound and Vibration*, 72:177–189, 1980.

[2] M.L. Chen and Y.S. Liao. Vibrations of pretwisted spinning beams under axial compressive loads with elastic constraints. *Journal of Sound and Vibration*, 147:497–513, 1991.

[3] J.R Banerjee. Free vibration of centrifugally stiffened uniform and tapered beams using the dynamic stiffness method. *Journal of Sound and Vibration*, 233:857–875, 2000.

[4] J.R Banerjee, H. Su, and D.R. Jackson. Free vibration of rotating tapered beams using the dynamic stiffness method. *Journal of Sound and Vibration*, 298:1034–1054, 2006.

[5] O. Song, L. Librescu, and N-H. Jeong. Vibration and stability control of composite rotating shaft via structural tailoring and piezoeletric strain actuation. *Journal of Sound and Vibration*, 257:503–525, 2002.

[6] L. Librescu, S.Y. Oh, and O. Song. Spinning thin-walled beams made of functionally graded materials: modeling, vibration and instability. *European Journal of Mechanics A/Solids*, 23:499–515, 2004.

[7] N.K. Chandiramani, L. Librescu, and C.D. Shete. On the free-vibration of rotating composite beams using a higher-order shear formulation. *Aerospace Science and Technology*, 6:545–561, 2002.

[8] N.K. Chandiramani, L. Librescu, and C.D. Shete. Vibration of higher-order-shearable pretwisted rotating composite blades. *International Journal of Mechanical Sciences*, 45:2017–2041, 2003.

[9] D. Guo, Z. Zheng, and F. Chu. Vibration analysis of spinning cylindrical shells by finite element method. *International Journal of Solids and Structures*, 39:725–739, 2002.

[10] D. Combescure and A. Lazarus. Refined finite element modelling for the vibration analysis of large rotating machines: Application to the gas turbine modular helium reactor power conversion unit. *Journal of Sound and Vibration*, 2008. doi:10.1016/j.jsv.2008.04.025.

[11] E. Carrera and M. Filippi and E. Zappino. Analysis of rotor dynamic by one-dimensional variable kinematic theories. *Journal of Engineering for Gas Turbines and Power*, 2013. doi:10.1115/1.4024381

[12] E. Carrera and M. Filippi and E. Zappino. Free Vibration Analysis of Rotating Composite Blades via Carrera Unified Formulation. *Composite Structures*, 2013. doi: 10.1016/j.compstruct.2013.05.055

[13] E. Carrera, G. Giunta, and M. Petrolo. *Beam Structures. Classical and Advanced Theories.* Wiley, 2011.