Transverse Flexural Free Vibration Analysis of Rotating Euler–Bernoulli FGM Beams by the p-FEM

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The lifetime and operating temperatures of turbine blades, turbo-engine blades and helicopter blades could be further improved considerably by thermal barrier coatings with functionally graded concept. The functionally graded materials are inhomogeneous composite materials where the properties of the constituents vary gradually and smoothly. In this study, the transverse free flexural vibration of a rotating functionally graded beam is investigated. From Hamilton's principle, the linear partial differential equations based on Euler–Bernoulli beam theory are derived for coupled stretching and bending motion. Here we show that, by neglecting the inertia force in axial direction and the inertial coupling terms between axial and transverse displacement caused by the variation in material properties through the thickness, the uncoupled bending equations of motion can be obtained. A two node beam Fourier p-element is developed and used with 4-dof at each node (longitudinal displacement, transverse displacement, the slope and the curvature). The convergence properties of the rotating beam Fourier p-element is examined, the results are compared with those of the literature. Only one element is used to obtain good modal frequency prediction, leading to a significant decrease in computational effort compared to conventional elements. The Southwell coefficient giving a useful approach between rotating and non-rotating frequencies of rotating beam is investigated, for a given Young's modulus ratio, power-law exponent and hub ratio. Also, the influence of angular speed, Young's modulus ratio and power-law exponent on the natural frequencies and mode shapes is investigated.

Keywords. Rotating functionally graded beam, Fourier *p*-element, Southwell coefficients, centrifugal stiffening, natural frequencies.