A Mixed Finite Element Formulation for Functionally Graded Micro-Beam Resting on Two-Parameter Elastic Foundation

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Abstract : Micro-beams are one of the most common components of Nano-Electromechanical Systems (NEMS) and Micro Electromechanical Systems (MEMS). For this reason, static bending, buckling, and free vibration analysis of micro-beams have been the subject of many studies. In addition, micro-beams restrained with elastic type foundations have been of particular interest. In the analysis of microstructures, closed-form solutions are proposed when available, but most of the time solutions are based on numerical methods due to the complex nature of the resulting differential equations. Thus, a robust and efficient solution method has great importance. In this study, a mixed finite element formulation is obtained for a functionally graded Timoshenko micro-beam resting on two-parameter elastic foundation. In the formulation modified couple stress theory is utilized for the micro-scale effects. The equation of motion and boundary conditions are derived according to Hamilton's principle. A functional, derived through a scientific procedure based on Gateaux Differential, is proposed for the bending and buckling analysis which is equivalent to the governing equations and boundary conditions. Most important advantage of the formulation is that the mixed finite element formulation allows usage of C_0 type continuous shape functions. Thus shear-locking is avoided in a built-in manner. Also, element matrices are sparsely populated and can be easily calculated with closed-form integration. In this framework results concerning the effects of micro-scale length parameter, power-law parameter, aspect ratio and coefficients of partially or fully continuous elastic foundation over the static bending, buckling, and free vibration response of FG-micro-beam under various boundary conditions are presented and compared with existing literature. Performance characteristics of the presented formulation were evaluated concerning other numerical methods such as generalized differential quadrature method (GDQM). It is found that with less computational burden similar convergence characteristics were obtained. Moreover, formulation also includes a direct calculation of the micro-scale related contributions to the structural response as well.

Keywords : micro-beam, functionally graded materials, two-paramater elastic foundation, mixed finite element method
Conference Title : ICTCM 2020 : International Conference on Theoretical and Computational Mechanics
Conference Location : Dublin, Ireland
Conference Dates : March 19-20, 2020