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Accurate free vibration analysis of Euler functionally graded beams by the weak form quadrature element method

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Abstract

Based on the classical beam theory (CBT) and differential quadrature (DQ) rule, an *N*-node novel weak form quadrature functionally graded (FG) beam element is established. Both Young's modulus and mass density of the beam materials vary exponentially through the thickness. The element node points can be different from the integration points. Either Gauss-Lobatto-Legendre (GLL) quadrature or Gauss quadrature can be used to obtain the element stiffness matrix and mass matrix. Detailed formulations are given. Convergence study is performed. For verification, results are compared with available solutions in literature. It is shown that the proposed thin beam element can yield very accurate frequencies with relatively small number of nodal points. New accurate results are presented for functionally graded beams with nine different boundary conditions. The tabulated results will be a reference with which other researchers can compare their results during developing new numerical method.

Keywords: Weak form quadrature thin beam element; functionally graded beam; free vibration; classical beam theory

1. Introduction

The functionally graded materials (FGMs), originated in 1984, are seeing increasing use in aerospace, aircraft, automobile and defense industrial applications due to their ability of mitigating the problem caused by the sudden change of thermo-mechanical properties as in the case of

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