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# Free vibration of four-parameter functionally graded spherical and parabolic shells of revolution with arbitrary boundary conditions

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## Abstract

The objective of this work is to present a Haar Wavelet Differential Quadrature (HWDQ) method-based solution approach for the free vibration analysis of functionally graded (FG) spherical and parabolic shells of revolution with arbitrary boundary conditions. The first-order shear deformation theory is adopted to account for the transverse shear effect and rotary inertia of the shell structures. Haar wavelet and their integral and Fourier series are selected as the basis functions for the variables and their derivatives in the meridional and circumferential directions, respectively. The constants appearing in the integrating process are determined by boundary conditions, and thus the equations of motion as well as the boundary condition equations are transformed into a set of algebraic equations. The proposed approach directly deals with nodal values and does not require special formula for evaluating system matrices. Also, the convenience of the approach is shown in handling general boundary conditions. Numerical examples are given for the free vibrations of FG shells with different combinations of classical and elastic boundary conditions. Effects of spring stiffness values and the material power-law distributions on the natural frequencies of shells are also discussed. Some new results for the considered shell structures are presented, which may serve as benchmark solutions.

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