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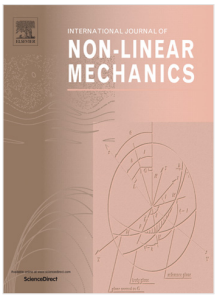

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Nonlinear Dynamic Behavior of Small-Scale Shell-Type Structures Considering Surface Stress Effects: An Isogeometric Analysis

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Abstract

Surface influences on the nonlinear vibrations of micro- and nano-shells are investigated by an efficient numerical approach. The seven-parameter geometrically nonlinear first-order shear deformation shell theory in Lagrangian description is formulated for the bulk part of structure. To consider surface stress effects, the Gurtin-Murdoch surface elasticity theory with considerations proposed by Ru [Continuum Mech. Thermodyn., 2016, 28, 263–273] and Shaat et al. [Int. J. Mech. Sci., 2013, 77, 356-364] is employed. In this regard, two thin inner and outer surface layers are considered, and the corresponding constitutive relations are incorporated into the shell formulations. The stress-strain and strain-displacement relations are represented in a novel matrix-vector form by which the governing equations of motion are derived based on Hamilton's principle. The isogeometric analysis (IGA) is then utilized due to having the capability to construct exact geometries of shells and the associated powerful features. The obtained ordinary differential equations from IGA are finally solved by the periodic grid approach which can be considered as a suitable solution strategy for the analysis of free and harmonically forced vibrations of different structures. The present work contributes to the literature with developing the isogeometric model of size-dependent geometrically nonlinear shells subjected to large-amplitude vibrations.

Keywords: Small-scale shell; Free and forced vibrations, Large deformation; Isogeometric analysis; Surface energy

1. Introduction

Properties and behaviors of shells, as the main parts of several engineering structures, are the focus of interest in many research works [1-3]. Their industrial applications entail comprehensive studies on their mechanical behavior in practical situations, like retention or conveying fluids [4-7]. As an important case, the large elastic deformation of shells has been investigated in numerous works [8-12]. Different shell theories and solution methodologies have been considered in the related studies. In order to determine the

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