Accepted Manuscript

Variational formulations and isogeometric analysis for the dynamics of anisotropic gradient-elastic Euler-Bernoulli and shear-deformable beams

Saba Tahaei Yaghoubi, Viacheslav Balobanov, S. Mahmoud Mousavi, Jarkko Niiranen

PII: S0997-7538(17)30476-X
DOI: 10.1016/j.euromechsol.2017.11.012
Reference: EJMSOL 3518

To appear in: *European Journal of Mechanics / A Solids*

Received Date: 16 June 2017
Revised Date: 22 October 2017
Accepted Date: 28 November 2017

Please cite this article as: Yaghoubi, S.T., Balobanov, V., Mousavi, S.M., Niiranen, J., Variational formulations and isogeometric analysis for the dynamics of anisotropic gradient-elastic Euler-Bernoulli and shear-deformable beams, *European Journal of Mechanics / A Solids* (2018), doi: 10.1016/j.euromechsol.2017.11.012.

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

ACCEPTED MANUSCRIPT

Variational formulations and isogeometric analysis for the dynamics of anisotropic gradient-elastic Euler-Bernoulli and shear-deformable beams

Saba Tahaei Yaghoubi[a,*], Viacheslav Balobanov[a], S. Mahmoud Mousavi[b], Jarkko Niiranen[a]

[a]*Department of Civil Engineering, Aalto University, P.O.Box 12100, FI-00076 Aalto, Finland*
[b]*Department of Engineering and Physics, Karlstad University, 65188 Karlstad, Sweden*

Abstract

A strain and velocity gradient framework is formulated for centrosymmetric anisotropic Euler-Bernoulli and third-order shear-deformable (TSD) beam models, reducible to Timoshenko beams. The governing equations and boundary conditions are obtained by using variational approach. The strain energy is generalized to include strain gradients and the tensor of anisotropic static length scale parameters. The kinetic energy includes velocity gradients and a tensor of anisotropic length scale parameters and hence the static and kinetic quantities of centrosymmetric anisotropic materials are distinguished in micro- and macroscales. Furthermore, the external work is written in the corresponding general form. Free vibration of simply supported centrosymmetric anisotropic TSD beams is studied by using analytical solution as well as an isogeometric numerical method verified with respect to convergence.

Keywords: anisotropic strain and velocity gradient, shear-deformable beam, centrosymmetric, isogeometric analysis

1. Introduction

Recent developments in nanotechnology necessitate the analysis of structural elements in ultra-small scales. Micro and nanobeams are frequently used in micro- and nano-sized systems and devices such as sensors (Takamatsu et al., 2014; Shaat and Abdelkefi, 2015), resonators (Kacem et al., 2009; Chen et al., 2011) or actuators (Tian et al., 2016) and the accurate prediction of their behavior in micro/nano scales is of utmost importance. However, it is well-known that the classical theories of continuum mechanics fail to describe the behavior of micro- or nano-sized structures. The reason for this problem is that the equations of the standard elasticity theories do not include parameters characterising the underlying microstructure, named as the internal length scale parameters. In order to improve this deficiency, higher-order continuum theories such as the couple stress theory (Mindlin and Tiersten, 1962; Toupin, 1964), non-local elasticity theory (Eringen, 1972, 1983) and gradient elasticity theory (Mindlin, 1964) were developed. In these size-dependent continuum theories, one or more internal length scale parameters appear in the constitutive equations and make the interpretation of the size-effect in the behavior of the structures possible. In this paper, the focus is on the gradient theory proposed by Mindlin (1964). The static length scale appears in the constitutive law relating stress and double stress tensors to strain and its gradient. Additionally, the dynamic length scale appears in the constitutive law relating momentum and double momentum tensors to velocity and its gradient.

The classical Euler-Bernoulli beam theory provides inaccurate interpretation of the statical and dynamical behavior of beams when their thickness-to-length ratio is relatively large. This deficiency was first demonstrated by Timoshenko (1921). Since in the Timoshenko beam theory the transverse shear strain and

*Corresponding author
Email address: saba.tahaei@outlook.com (Saba Tahaei Yaghoubi)

دریافت فوری ← متن کامل مقاله

ISIArticles
مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات