

Article

Analytical Solutions of Viscoelastic Nonlocal Timoshenko Beams

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Abstract: A consistent nonlocal viscoelastic beam model is proposed in this paper. Specifically, a Timoshenko bending problem, where size- and time-dependent effects cannot be neglected, is investigated. In order to inspect scale phenomena, a stress-driven nonlocal formulation is used, whereas to simulate time-dependent effects, fractional linear viscoelasticity is considered. These two approaches are adopted to develop a new Timoshenko bending model. Analytical solutions and application samples of the proposed formulation are presented. Moreover, in order to show influences of viscoelastic and size effects on mechanical response, parametric analyses are provided. The contributed results can be useful for the design and optimization of small-scale devices exhibiting flexural behaviour.

Keywords: MEMS/NEMS; fractional calculus; stress-driven nonlocality; small-scale beams; size effects



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1. Introduction

Some devices designed at small scales [1–4], such as nano- and micro-sensors, actuators, piezoelectric systems, and AFM indenters can be modeled as beams but require specific stress–strain relations to predict their mechanical behaviour. In this context, the paper proposes a stress–strain relation that is enriched with respect to the classic local elastic one. The presented model is able to model two specific phenomena that occur in the mechanics of several small-scale devices, i.e., size effects and hereditariness.

Size effects can invalidate the hypothesis of the locality of classical continuum mechanical models [5–11]. In this paper, this issue is taken into account and it is overcome with the aid of a nonlocal formulation. Following this approach, the nonlocal strain (or stress) at a continuum point depends on a stress (or strain) field in the whole domain [12,13]. For the problem at hand, the nonlocality is mainly related to the small sizes of the structures and the influences of the stress–strain relation on its space-dependence. Instead, the other considered phenomenon arises when the material that builds the small-sized structure exhibits a time-dependent viscoelastic stress–strain relation [14,15]. Both phenomena are modeled by a stress-driven integral formulation where the nonlocal effect is modeled by a Fredholm integral, in which the kernel is a space attenuation function that weights the long-range mechanical interactions [16], whereas the viscoelastic phenomenon is given by a Boltzmann convolution integral with a time-dependent causal kernel that rules the memory effects [17].

There are various ways to model nonlocalities [18–25], among these approaches the adopted formulation is derived from Eringen's theory [26,27]. In such a model, the nonlocal stress is expressed by the convolution integral between an averaging kernel and the local stress field. However, some paradoxes and mathematical issues appear in the original strain-driven Eringen's formulation for real bounded systems [28–30]. The simplest way to overcome these issues is obtained by the integral stress-driven approach [31,32]. While in the original Eringen's formulation the input is the deformation and the output is the stress, in the stress-driven formulation, nonlocal strain and stress have reversed roles

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Distributed Transfer Function Method Bingen Yang, Kyoungrae Noh, 2023-10-04 The distributed transfer function method DTFM is an analytical method for modeling analysis and control of a class of distributed parameter systems that are governed by partial differential equations and that can be defined over multiple interconnected subregions In this comprehensive reference the authors show how the DTFM delivers highly accurate analytical solutions in both the frequency domain and the time domain while offering a versatile modeling technique for various problems in mechanical civil aerospace electrical chemical biomechanical and vehicle engineering

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