Non-local space-fractional model for complex planar bar-type structures analysis

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Modern mechanical systems, widely deployed across diverse engineering and technological applications, increasingly integrate nanoelectromechanical systems (NEMS) and microelectromechanical systems (MEMS). At these characteristic length scales, the inherently discrete and atomistic nature of matter does not fit the classical theories of continuum mechanics, which assume purely local constitutive behavior. They are therefore inadequate for precise modeling and predictive analysis in these applications.

A wide range of nonlocal phenomenological models have been developed to capture size-dependent and scale-related effects, including integral-type theories, general nonlocal theories, strain-gradient theories, and micropolar theories, among others. However, in the present work the analysis is conducted within the framework of the Fractional Continuum Mechanics (FCM) model [1].

The primary objective of the present study is to quantify changes in the global structural response resulting from microstructural modifications in selected members. It has been demonstrated that the microstructure governs the nonlocal behavior of the material [3] modeled using the fractional model. Consequently, the parameters of this model can be adjusted to represent microstructural alterations. In this work, various configurations of fractional order of material α and characteristic length scale ℓ_f for individual structural members are examined, with particular emphasis on their influence on the global response and the emergence of unexpected asymmetry. Additionally, due to the complex and computationally demanding nature of the numerical solution of fractional calculus cite szajek-2019, a multilevel framework is proposed that employs fractional bar reduction as a surrogate model [4].

The proposed procedure was assessed using full-scale models of truss-like structures that explicitly account for local effects. The findings unambiguously demonstrate the impact of microstructural characteristics on the global structural response, including the emergence of asymmetric deformation in geometrically symmetric models under symmetric loading and boundary conditions.

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