Meshfree Method for Stress Driven Beams

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Introduction

Low-dimensional structures with dimensions in the micro-nano range exhibit size-dependent behavior that cannot be captured by local constitutive models. This deviation occurs because local models assume material point interactions are local, whereas size-dependent behavior arises from long-range interactions. While Eringen's strain-driven nonlocal model has been widely used, it often results in ill-posed governing equations and paradoxical results for beam bending. The stress-driven nonlocal approach has emerged as a mathematically consistent and well-posed substitute. This research develops the Element-Free Galerkin (EFG) method for a stress-driven one-dimensional Bernoulli-Euler beam, utilizing its inherent nonlocal solution approximation to accurately simulate size effects.

Theoretical Formulation and Methodology

The formulation begins with the stress-driven integral model, where nonlocal bending curvatures are defined by the spatial convolution of a kernel function and the bending interaction. This approach leads to a sixth-order governing differential equation for the transverse displacement field. Unlike traditional finite element methods that rely on predefined meshes, the EFG method utilizes scattered nodes and Moving Least Square (MLS) approximations for constructing shape functions. To satisfy the requirements for higher-order continuity needed to approximate bending moments and shear forces in a stress-driven setting, a 6th-order spline weighting function is employed

Normalized displacement of clamped-clamped beam

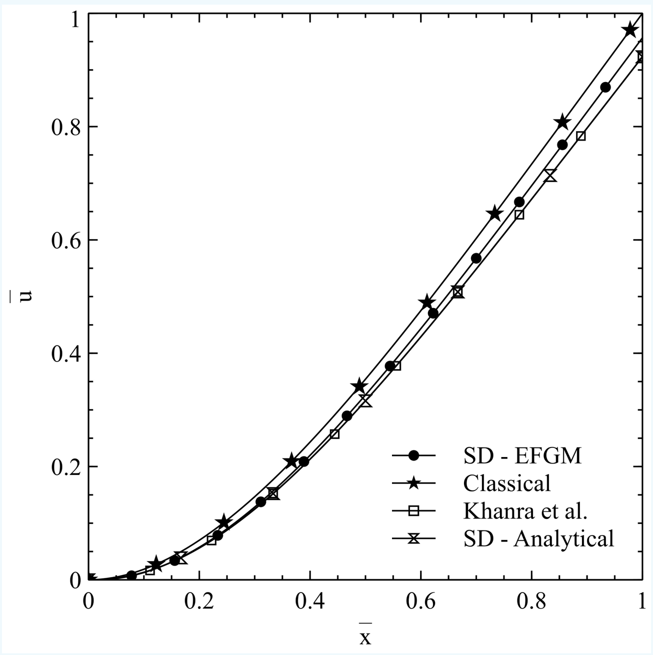

Figure 1. Normalized displacemnt of cantilever beam

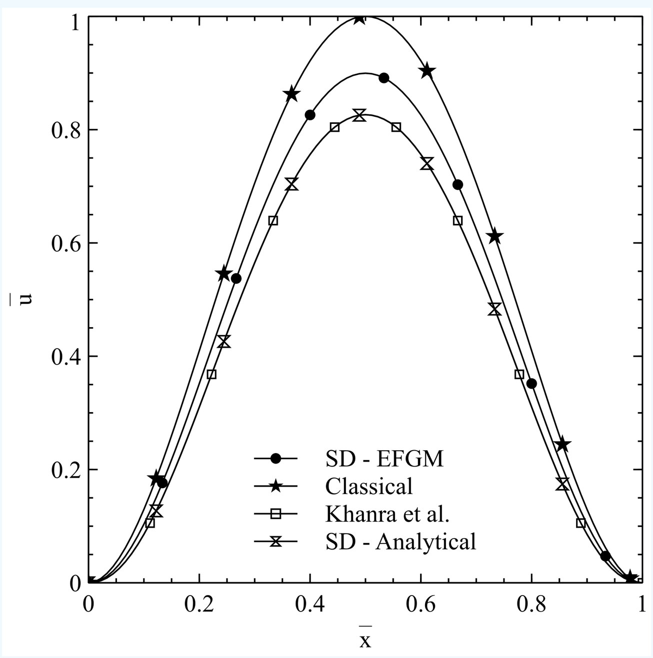

Figure 2. Domain and boundary conditions of the numerical model

Normalized displacement of clamped-clamped beam

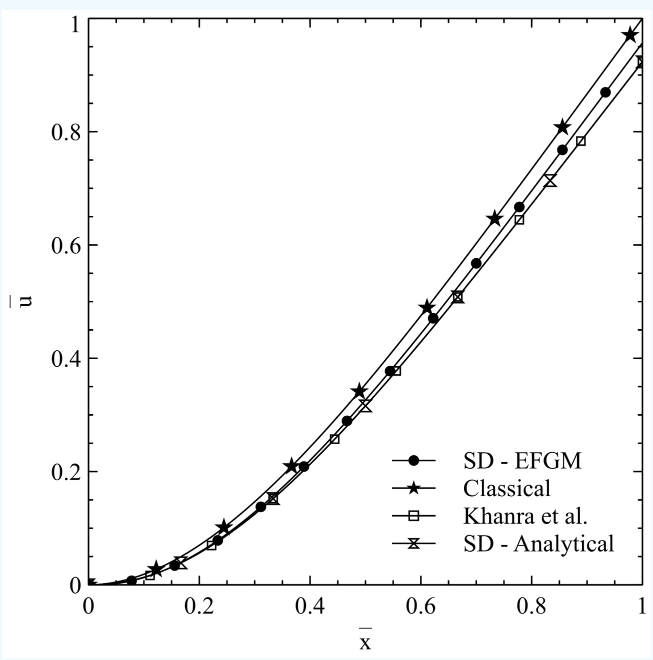

Figure 3. Normalized displacemnt of cantilever beam

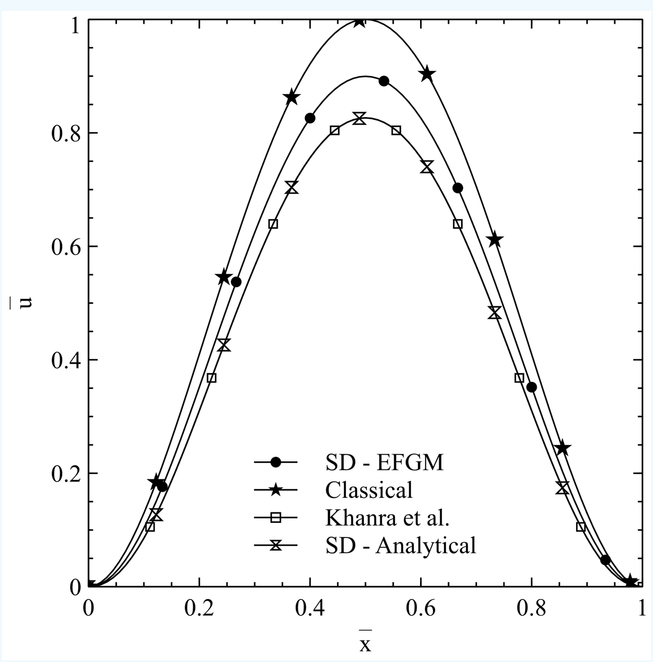

Figure 4. Domain and boundary conditions of the numerical model

Normalized displacement of clamped-clamped beam

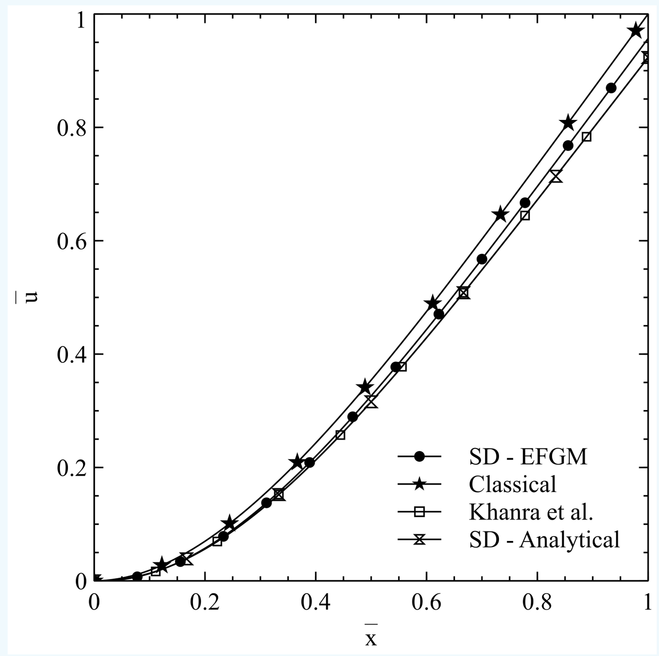

Figure 5. Normalized displacemnt of cantilever beam

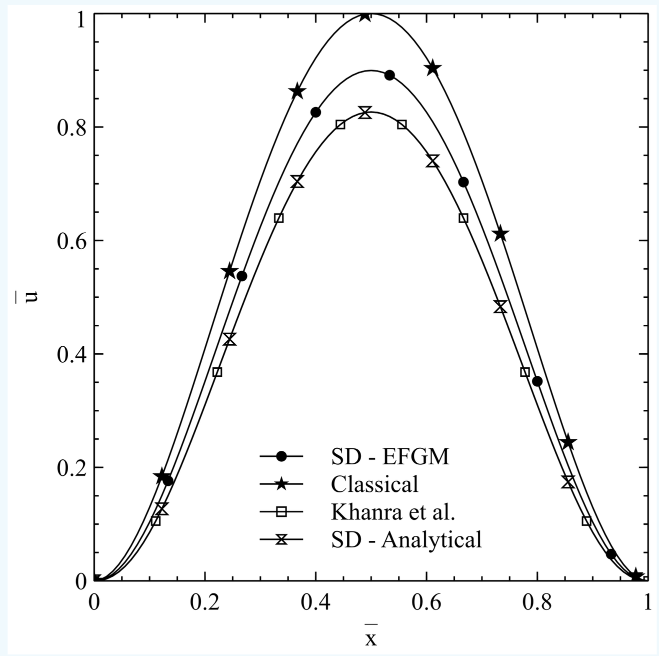

Figure 6. Domain and boundary conditions of the numerical model

Normalized displacement of clamped-clamped beam

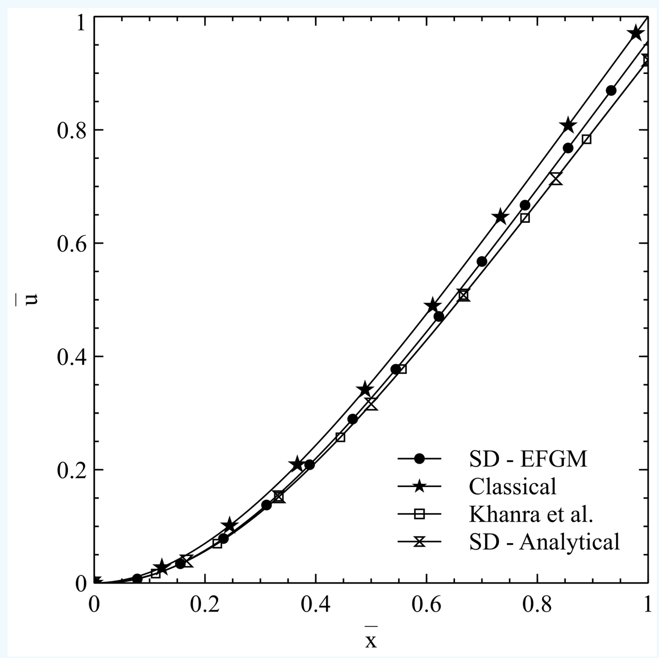

Figure 7. Normalized displacemnt of cantilever beam

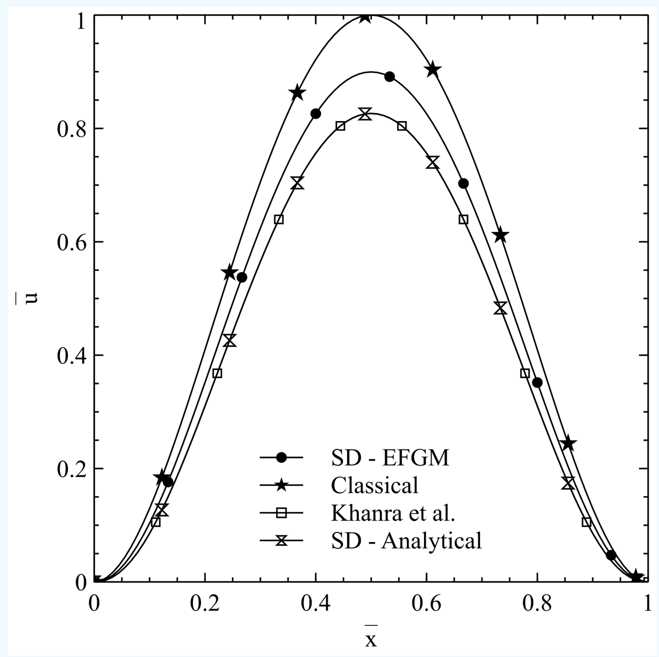

Figure 8. Domain and boundary conditions of the numerical model

References

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