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A numerical analysis of Saint-Venant torsion in strain-gradient bars

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Abstract

The article addresses the torsion of bars with arbitrary cross sections subject to warping employing the finite element method in the strain-gradient elasticity. Subsequent to extracting the strains and stresses given by the Saint-Venant torsion hypothesis for an infinitesimal deformation, the principle of virtual work is adopted to investigate the weak form of stationary equation. Then, two torsion-warping elements, the former has four nodes and the latter has nine nodes with 6 DoF per node, are constructed for the torsion analysis of bars. To investigate the behaviour of the devised elements, some examples with known cross sections are presented which can be used to examine the accuracy of the developed elements and to study the size-dependent trend in the bars.

Key Words: Strain-gradient Elasticity; Saint-Venant Torsion; Finite Element Method

1. Introduction

The experimental results are evidences for drawbacks of the classical mechanics in small scales (Aifantis, 2003; Fleck et al., 2004). That is, the responses obtained from the experiments are stiffer than the prediction of Cauchy mechanics. In order to simulate the response of solids and structures in small scales, some gradient theories were devised by Mindlin (1964) and Mindlin and Eshel (1968). The main idea of those is the presence of an embedded micro-volume in a macro-volume. The strain-gradient theories developed by Mindlin are capable of modeling the response of bodies in small scales (Lam et al., 2003; Aifantis, 2009). In this category of mechanics, some additional, new material

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