Accepted Manuscript

Small-Scale Timoshenko Beam Element

R. Ansari, M. Faghih Shojaei, H. Rouhi

PII: S0997-7538(15)00018-2

DOI: 10.1016/j.euromechsol.2015.02.005

Reference: EJMSOL 3166

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

Received Date: 16 January 2014

Accepted Date: 17 February 2015

Please cite this article as: Ansari, R., Shojaei, M.F., Rouhi, H., Small-Scale Timoshenko Beam Element, *European Journal of Mechanics / A Solids* (2015), doi: 10.1016/j.euromechsol.2015.02.005.

Small-Scale Timoshenko Beam Element

R. Ansari*, M. Faghih Shojaei, H. Rouhi

Department of Mechanical Engineering, University of Guilan, P.O. Box 3756, Rasht, Iran

Abstract

Higher-order gradient continuum mechanics theories are of critical importance as they can afford to describe the size-dependent mechanical behavior of micro-scale structures. In this article, based on the most general form of strain gradient elasticity theory, a new extended Timoshenko beam element capable of accommodating size effects is introduced. To this end, the higher-order tensors of energy pairs in the energy functional are vectorized and represented in the quadratic form first. This gives way to realize the stiffness and mass matrices of the newly proposed element. Compared to the standard Timoshenko beam element, the new element requires two additional nodal degrees of freedom (d.o.f.) consisting of derivatives of lateral translation and rotation, which means a total of 4 d.o.f. per node. Therefore, the Hermite functions are employed to construct the shape functions of this new element. The proposed element is indicated to exhibit stiffer character, making it desirable when dealing with the problems at the microscale. Also, the standard Timoshenko beam element is recovered when the small scale factor tends to zero. Using this new element, the free vibration and bending of Timoshenko microbeams are investigated. The results are compared with those available in the literature and excellent agreement is achieved.

Keywords: Finite element method; Strain gradient theory; Small-scale effect; Timoshenko beam theory

1. Introduction

Microbeams, as the main building blocks of microelectromechanical systems (MEMS), are widely used in many applications [1-4]. Accordingly, the mechanical characteristics of these

*Corresponding author. Tel. /fax: +98 131 6690276.
E-mail address: r_ansari@guilan.ac.ir (R. Ansari).