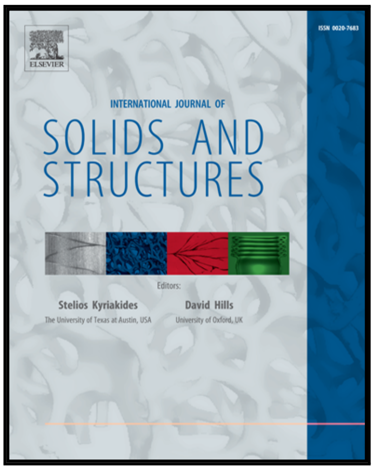
Accepted Manuscript



Geometric-Material analogy for multiscale modelling of twisted plates

A. Kordolemis, P.M. Weaver

PII: S0020-7683(17)30060-4
DOI: 10.1016/j.ijsolstr.2017.02.006
Reference: SAS 9464

To appear in: *International Journal of Solids and Structures*

Received date: 14 June 2016
Revised date: 16 November 2016
Accepted date: 6 February 2017

Please cite this article as: A. Kordolemis, P.M. Weaver, Geometric-Material analogy for multiscale modelling of twisted plates, *International Journal of Solids and Structures* (2017), doi: 10.1016/j.ijsolstr.2017.02.006

Geometric-Material analogy for multiscale modelling of twisted plates

A.Kordolemis*[1] and P.M.Weaver[1,2]

[1]Advanced Composites Centre for Innovation and Science, University of Bristol, Queen's Building, University Walk, Bristol BS8 1TR, UK.

[2]Bernal Institute, University of Ireland, Limerick.

Abstract

It is well known that the macroscopic behavior of many engineering materials is strongly affected by the role of underlying microstructure. Currently though, mathematical expressions linking behavior of large scale structures to the geometry of their microscopic structure are largely lacking. In this respect, establishing quantitative links across different material lengthscales may offer new pathways for engineering design. In the present work an analogy between cross sectional geometrical properties, representing macrostructure, and a material length parameter, representing microstructure, is presented. The analogy is established through the study of a thin plate subject to axial loading undergoing finite displacements from two alternative perspectives. First, we consider a thin elastic plate with a pretwist about the loading axis where a warping term is introduced accounting for the out-of-plane deformation of the cross section. The coupled governing differential equations and the corresponding coupled boundary conditions are explicitly derived employing a classical structural mechanics approach utilising an energy variational statement. Secondly, an axially loaded thin flat plate (i.e. with no pretwist) is studied with strain gradient elasticity theory incorporating only one material length parameter representing the microstructure, in addition to the two classical Lamé stiffness constants. The ensuing analogy emerges by comparison of the governing equations of the two formulations which shows a mathematical expression can be identified, which incorporates both geometric and material length variables, that formalises the link between microscale and macroscale. This mathematical expression, which constitutes the kernel of the proposed multiscale approach, admits a twofold interpretation depending on the assumed independent variable. On the one hand, the proposed multiscale modelling approach suggests that a plate with complex global geometry can be substituted by a structurally - equivalent, flat plate with constitutive relations given by a non - local, strain gradient theory. On the other hand, the material length parameter can be interpreted on a physical basis because for the first time it has been identified as a known function of geometrical features of the structure through simple algebraic relationships for various cross sectional profiles.

Keywords: *warping deformation, pretwist, strain gradient elasticity, variational principle, Helmholtz equation*

1 Introduction

It is well known that twisted structural elements can be found in many practical engineering applications including, rotor machinery components (i.e. rotor blades, helicopter blades, wind turbines), impellers, drilling devices used

*corresponding author, email: alexis.kordolemis@bristol.ac.uk.