Modeling of Deformation Responses Using Meshless Local Petrov-Galerkin (MLPG) Approach Based on Strain Gradient Elasticity

Boris Jalusic*, Tomislav Jarak, Jurica Soric

Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb
Ivana Lucica 5, 10002 Zagreb, Croatia
{boris.jalusic,tomislav.jarak,jurica.soric}@fsb.hr

ABSTRACT

Nowadays, a variety of research topics are dedicated to the use of non-classical theories in order to properly capture a number of effects such as the strain localization and material softening phenomena in continuum [1]. The numerical solution of fourth-order elliptic problems arising in non-classical gradient theories of material behavior requires a high order of interpolation functions. Therefore, displacement-based Finite Element Method (FEM) formulations for solving this type of problems involve very complicated shape functions which require large number of nodal degrees of freedom. Hence, the mentioned formulations are often considered as numerically inefficient [2]. In comparison to FEM the shape functions in meshless methods can easily be formulated with any order of continuity and with less number of unknowns per node [3]. Thus, the meshless discretization approach is considered to be a good alternative to FEM procedures when modeling deformation responses using higher-order continuum theories. In this contribution, the Meshless Local Petrov Galerkin (MLPG) collocation method [3] is utilized for the modeling of structures based on a strain gradient elasticity formulation. Herein, the Aifantis theory with only one unknown microstructural parameter is used [1]. Furthermore, the fourth-order equilibrium equations are solved as an uncoupled sequence of two sets of second-order differential equations (operator-split method) [4]. In order to improve the efficiency and lower the continuity requirements on the interpolation meshless functions, the mixed approach was utilized [5]. The advantages of the used formulation are shown in a few numerical examples.

Acknowledgement: This work has been supported in part by Croatian Science Foundation under the project Multiscale Numerical Modeling of Material Deformation Responses from Macro- to Nanolevel (2516). The investigations are also part of the project Multiscale Modeling of Heterogeneous Structures supported by Alexander von Humboldt Foundation, Germany.

References

[1] H. Askes, E.C. Aifantis, Gradient elasticity in statics and dynamics: An overview of formulations, length scale identification procedures, finite element implementations and new results, International Journal of Solids and Structures, 48 (2011) 1962-1990.
[2] S.-A. Papanicolopulos, A. Zervos, I. Vardoulakis, A three-dimensional C1 finite element for gradient elasticity, International Journal for Numerical Methods in Engineering, 77 (2009) 1396-1415.
[3] S.N. Atluri, The Meshless Method (MLPG) for Domain & BIE Discretization, Tech Science Press, Forsyth, USA, 2004.
[4] C.Q. Ru, E.C. Aifantis, A simple approach to solve boundary-value problems ingradient elasticity, Acta Mechanica, 101 (1993) 59-68.
[5] J. Soric, T. Jarak, Mixed meshless formulation for analysis of shell-like structures, Computer Methods in Applied Mechanics and Engineering, 199 (2010) 1153-1164.