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Finite element analysis of micromorphic elastic media

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Generalized continuum theories such as the micromorphic or strain gradient theories have been recently in the focus of research communities to reduce the computational costs of numerical structural simulations [1,2]. The micromorphic theory proposes a full-scale generalized continuum model to capture either the size-effect in microstructures [3] or the microarchitecture-effect in cellular metamaterials [1,4]. Unlike the range of applications of the micromorphic theory in structural mechanics, the literature on this topic is still fairly limited mainly due to the complexities in theoretical formulations and challenges in developing appropriate solution methods, although reduced versions of this theory have been recently noticed. Hence, the main objective of this research is to present a theoretical formulation for 2D elastic media based on the micromorphic theory and to develop an efficient computational solution method using higher-order finite element analysis. The corresponding governing equations are given under the kinematic relations of the 2D elasticity model along with Mindlin's micromorphic theory [5] and represented in a matrix form which is efficient from the computational point of view. Then, a quadratic quadrilateral finite element is implemented to solve static and dynamic problems of in-plane external loads. Some numerical examples for elastic media with complex domains are presented to highlight the accuracy and efficiency of the proposed model in capturing the size or/and microarchitecture effects in structural analysis. It is demonstrated that the developed numerical framework can be effectively used to accurately predict the structural mechanics following the micromorphic theory.

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