A Neural Network-based Approach for Strain Gradient Nanoplates

C.A. Yan, R. Vescovini, N. Fantuzzi

Over the past years, a growing interest has been devoted to the field of nanomaterials and nanostructures. The applications are manifold and include microelectromechanical (MEMS) and nanoelectromechanical (NEMS) systems, widely employed in the mechanical, aerospace and electronic fields. Accordingly, the number of studies on theories and methods for the analysis of nanoplates has seen a drastic surge in the recent scientific literature. On one hand, different models have been proposed for capturing the long-range effects that characterize the structural response at nano level – early works on strain gradient theory can be found in [1,2]. On the other hand, solutions based on analytical methods [3] – Navier, Levy – and numerical ones [4] – Finite Element, meshless – have been proposed to derive reference results, investigate the effects of the model's parameters and assess the structural response.

Aside of this, an emerging trend regards the application of Physics Informed Neural Networks (PINNs) as an effective mean for solving differential problems, including those of structural mechanics. PINNs are an inherently meshless strategy relying upon the powerful framework offered by modern neural networks. Recently, the authors have proposed the application of PINNs to study composite structures at macro scale level [5]. In this work, the PINN framework is extended and applied, for the first time, to the static analysis of nanoplates. Specifically, the differential equations based on nonlocal strain gradient theory are solved by means of PINNs. Training is conducted under the paradigm of Extreme Learning Machine (ELM). The study illustrates the potential of this new meshless approach to handle nanoplate problems. Insights are provided into the features of the method, including the effect of different hyperparameters and network architectures.

References

1. E.C. Aifantis, On the role of gradients in the localization of deformation and fracture, 1992, International Journal of Engineering Science, 30(10), 1279-1299.
2. A.C. Eringen, On differential equations of nonlocal elasticity and solutions of screw dislocation and surface waves, 1983, Journal of Applied Physics, 54(9), 4703-4710.
3. B. Babu, B.P. Patel, Analytical solution for strain gradient elastic Kirchhoff rectangular plates under transverse static loading, 2019, European Journal of Mechanics-A/Solids, 73, 101-111.
4. M. Bacciocchi, N. Fantuzzi, A.J.M. Ferreira, Conforming and nonconforming laminated finite element Kirchhoff nanoplates in bending using strain gradient theory, 2020, Computers & Structures, 239, 106322.
5. C.A. Yan, R. Vescovini and L. Dozio, A framework based on physics-informed neural networks and extreme learning for the analysis of composite structures, 2022, Computers & Structures, 265, 106761.