

Nonlocal Mechanics of Solids via Continuum-Kinematics-Inspired Peridynamics (CPD)

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ABSTRACT

Continuum-kinematics-inspired peridynamics (CPD) [1, 2] is a nonlocal formulation of continuum mechanics that is also variationally consistent. Unlike the original formulation of peridynamics (PD), CPD can accurately capture the Poisson effect [3]. Due to its geometrically exact nature, CPD does not suffer from zero-energy modes or displacement oscillations. We distinguish between one-neighbor, two-neighbor, and three-neighbor interactions. While one-neighbor interactions recover the bond-based PD formalism, two- and three-neighbor interactions emerge inherently to preserve the basic elements of continuum kinematics. Through material frame indifference, we provide the appropriate set of arguments for the interactions. Moving forward, we elaborate on thermodynamic restrictions and derive thermodynamically-consistent constitutive laws through a Coleman–Noll-like procedure resulting in nonlocal Fourier-like conduction equations [4].

For three-dimensional elasticity, CPD builds upon three types of interactions that altogether preserve the basic notions of length, area, and volume. The isotropic three-dimensional CPD formulation of non-local elasticity, therefore, involves three material constants associated with length, area, and volume. Through localization and linearization, we rigorously establish relationships between the material parameters of CPD and isotropic linear elasticity. It is shown that the three material parameters of CPD reduce to two independent parameters that can be expressed in terms of any pair of isotropic linear elasticity constants, see [5, 6] for two- and three-dimensional analysis. A remarkable finding is that CPD material parameters can result in the volume-preserving limit (incompressibility) corresponding to Poisson’s ratio of 0.5 and the length-preserving limit associated with Poisson’s ratio of 0.25. In this presentation, we explain key aspects of material modeling in CPD and establish relationships between the nonlocal energy densities of CPD and the local models of classical continuum mechanics at large deformations. Several key features of CPD are demonstrated via computational examples and comparisons to the local elasticity of classical continuum mechanics.

REFERENCES

- [1] A. Javili, A. McBride, P. Steinmann, “Continuum-kinematics-inspired peridynamics. Mechanical Problems”, *J. Mech. Phys. Solids*. 131: 125–146 (2019).
- [2] A. Javili, S. Firooz, A. McBride, P. Steinmann, “The computational framework for continuum-kinematics-inspired peridynamics”, *Comp. Mech.* 66: 795–824 (2020).
- [3] E. Ekiz, A. Javili, “The variational explanation of Poisson’s ratio in bond-based peridynamics and extension to nonlinear Poisson’s ratio”, *J. Peridyn. Nonlocal Model.* 5:121–132 (2023).
- [4] A. Javili, E. Ekiz, A. McBride, P. Steinmann, “Continuum-kinematics-inspired peridynamics: Thermo-mechanical problems”, *Contin. Mech. Thermodyn.* 33: 2039–2063 (2021).
- [5] E. Ekiz, P. Steinmann, A. Javili, “Relationships between the material parameters of CPD and isotropic linear elasticity for two-dimensional problems”, *Int. J. Solids Struct.* 238: 111366 (2022).
- [6] E. Ekiz, P. Steinmann, A. Javili, “From two- to three-dimensional CPD: More than just another dimension”, *Mech. Mater.* 173: 104417 (2022).