On a Linear Constitutive Model in Peridynamics

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ABSTRACT

Constitutive modeling within the peridynamic theory considers the collective deformation at each time of all the material within a δ-neighborhood of any point of a peridynamic body. The difference displacement field quotient in this neighborhood, rather than the extension scalar field, is used to generate a three dimensional state-based linearly elastic peridynamic theory. This yields an enhanced interpretation of the kinematics between bonds that includes both length and relative angle changes. A strain energy function for a linearly elastic isotropic peridynamic material which contains four material constants is proposed as a model, and it is used to obtain the force vector state and the associated modulus state for this material. These states are analogous to, respectively, the stress field and the fourth-order elasticity tensor in the classical linear theory. In the limit of small horizon, we find that only three of the four peridynamic material constants are related to the classical elastic coefficients of an isotropic linear elastic material, with one of the three constants being arbitrary. The fourth peridynamic material constant, which accounts for the coupling effect of both bond length and relative angle change, has no effect in the limit, but remains a part of the peridynamic model. It is a matter of concern that, in spite of the fact that the peridynamic model is isotropic and reproduces the classical elasticity model in the limit of small horizon, two peridynamic constants are left undetermined. The determination of these two constants is the subject of future investigation. Peridynamic models proposed elsewhere in the literature depend on the deformation state through its dilatational and deviatoric parts and contain only two peridynamic material constants, in analogy to the classical linear elasticity theory. Even though these models are called linear peridynamic solid models, they depend nonlinearly on the difference displacement field quotient. Observe from above that our model depends on both length and relative angle changes, as in the classical linear theory, but, otherwise, is not limited to having only two material constants and depends linearly on infinitesimal strain states. If two of the four peridynamic constants vanish and if a certain weighting function is considered to be radial, then, for small strain states, the linear peridynamic solid model found elsewhere can be seen as a particular case of our model.

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