Some comments on modelling failure with peridynamics

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Peridynamics have been widely developed over the past twenty years following the pioneering work of Silling (2000). Because conservation equations do not involve the derivatives of the displacements (i.e. strains), it is a convenient framework for modelling fracture. The theory captures very easily the initiation and propagation of discontinuities of displacements in a structure. This convenient property, however, is counterbalanced by the difficulties at handling Dirichlet or Neuman boundary conditions. This aspect of peridynamics is well known and it has been discussed in detail.

Peridynamics is a nonlocal theory that accounts for long range interactions, as inspired by molecular simulations. The mechanical response at each material point results from an average of interaction forces taken over a domain called "horizon". So far, the horizon has been considered to be a numerical parameter. This paper intends to demonstrate that it should not be the case. In the present contribution, we shall consider bond-based interactions only.

We illustrate the argument on a simple, one-dimensional, problem of propagation of waves and their interaction. We look at the failure of the bar triggered by the interaction between two constant strain waves at the center of the bar. When the waves meet, the strain is multiplied by two and failure is initiated. Two interaction models are considered. An elastic perfectly brittle interaction and a damage model with linear softening after the peak force has been reached. In the first model, the parameters are the micro-stiffness and the critical stretch, the softening slope is added in the second.

The profiles of strain and damage upon fracture are obtained. The width of the strain profile is found to increase linearly with the horizon size, similar to what is observed in continuum based nonlocal models for fracture. The horizon has the same role as the internal length and therefore should bear the same status. According to a continuum model, material parameters are the elastic constant, the tensile strength, and the fracture energy. Usually, in peridynamics, the horizon is defined arbitrarily and the peridynamics parameters are adjusted to fit these parameters. We show that such a fit is not possible unless the horizon becomes a material parameter, useful for the calibration of the fracture energy. Without this, the tensile strength corresponding to the correct fracture energy for a given horizon size becomes unrealistic.