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Failure of materials embedding inclusions : a numerical study using a peridynamic approach

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We rely on a peridynamic approach to investigate the evolution of macroscopic mechanical properties of samples composed with spherical particles embedded in a matrix. Both particles and matrix are linear elastic phases with brittle behaviour. Crack growth in heterogeneous materials has been extensively studied using various numerical approaches among which fusible elements method, deformable lattice methods, finite elements method, cohesive elements... More recently, the peridynamic approach appears to be a promising alternative to classical continuum mechanics based on integral equations instead of partial differential equations. In other words, peridynamics is built upon long-range forces instead of locally defined interactions [1]. Major benefits are its ability to account for highly heterogeneous distribution of mechanical properties, to avoid singularities close to discontinuities such as local failures and to limit the influence of the discretization upon crack pattern. In this study, we use a “bond-based” approach [2] where the sample is assimilated to a mass-spring system and the stress tensor is derived at each node from a long-range neighbourhood. The mechanical tests consist in applying successive steps of displacement to the boundary nodes. At each step the total potential energy of the system is minimized using an adaptive time-step relaxation algorithm [3] leading to a quasi-static evolution until failure.

We performed a parametric study of the evolution of the macroscopic elastic modulus and yield stress in tension for an extensive set of numerical samples. We rely on dense granular packings computed by Molecular Dynamics method to determine the centres of the particles inclusions. The volume fraction of particles is varied from very dense to diluted suspensions by applying the same shrinkage factor to all particles. In order to closely follow the transition from hard to void-like inclusions we also vary the toughness ratio between particles and matrix.

As the computational procedure requires extensive numerical resources we developed a parallel algorithm based on domain decomposition using Message Passing Interface (MPI). A particular effort has been necessary to carry out series of numerical tests automatically for broad parameter sets. Finally we consider the evolution of the pdf of stresses into the samples and the cracking patterns for different values of the parameters.

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