Coupled simulation of elastic wave propagation and failure phenomenon using a particle method

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The failure of brittle materials like glasses and rock masses is commonly observed discontinuous. It is, however, difficult to simulate these phenomena in the conventional numerical simulation methods like FDM (Finite Difference Method) or FEM (Finite Element Method) due to the existence of computational grids or elements artificially given before the simulation. It is, therefore, important for researches of such discontinuous failures in scientific and engineering fields to analyze the phenomena in a seamless manner. This study deals with the coupled simulation of elastic wave propagations and failure phenomena using a MPS (Moving Particle Semi-implicit) method, i.e., one of the particle methods. It is simple to model the objects of analysis since no gridded or lattice structure is necessary in particle methods. In addition, the lack of gridded or lattice structure makes it simple to simulate large deformations and failure phenomena at a time. We first confirm that the validation of MPS code developed in this study functions with any problems after comparing the propagation using MPS and that from FDM (Finite Difference Method). These two different methods gives results in good agreement with each other with respect to the reproducibility of P and S waves in the modeled medium. It is examined that the numerical stability was controlled by the seismic velocity of the media, grid spacing of the model and time interval for the simulation. The grid dispersion problems and absorbing boundary conditions in MPS method are also examined. Finally, we focus our attention to the Hopkinsons effect as an example of the failure induced by the wave propagation. In the application of the MPS, the algorithm is basically the same as the previous calculation except for the introduction of failure criterion. The failure criterion applied in this study is the particle connectivity that is to be disconnected when the distance between the particles exceeds a failure threshold. We found that the implementation of this disconnection or failure condition is very simple and effective. We applied the developed algorithm to a suspended specimen that was modeled as a long bar consisting of particles. A compressional wave in the bar is generated by an abrupt pressure change on one edge. The compressional wave propagates the interior of the specimen and is observed clearly. On the other side of the bar, the spalling of the bar is reproduced numerically, and a broken piece of the bar is formed to fall away from the main body of the bar. Consequently, these results shows that the MPS method is an effective method to reproduce wave propagation and failure phenomena at a time.