Enhancement of the material point method using isogeometric analysis

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ABSTRACT

Many applications in geotechnical engineering involve large deformations, such as cone penetration testing, pile installation, craters around damaged pipelines and landslides. Solving these types of problems using the Updated Lagrangian Finite Element Method (UL-FEM), as widely used in the geotechnical engineering, can be problematic due to mesh distortion. Some attempts have been made in the past to overcome this limitation by introducing more advanced techniques. One of them is the Material Point Method (MPM) introduced by Sulsky et al. (1994) which can be considered as an extension of the UL-FEM. The method uses a cloud of material or Lagrangian points defined over material of the body and one Eulerian mesh defined on the computational domain. In order to prevent mesh distortion, associated with the Lagrangian method, all computational data including stresses and state variables are mapped from the Lagrangian material points to the Eulerian mesh at the end of each computational step. In the beginning of each step, the stored data in the Eulerian mesh is mapped to the Lagrangian material points and the mesh is reset. In this way, the method benefits from the advantages of both Lagrangian and Eulerian methods, while preventing disadvantages of those methods, i.e. the mesh distortion in the Lagrangian method and the numerical dissipation in the Eulerian method. Although the method has successfully been used in simulation of some geotechnical engineering problems in the past, the classical MPM severely suffers from a number of numerical issues, such as ‘grid crossing’ and quadrature errors, which can strongly influence the simulation of geotechnical problems in which highly nonlinear material models and/or high order elements might be needed. In order to overcome the inherent issues of the classical MPM, a high order version of the method has recently been proposed in [1]. The modified method combines quadratic B-spline basis functions with a reconstruction based quadrature rule, and shows great potential for one-dimensional problems. Wobbes et al. [2] extended the method by using a local Taylor Least Squares approximation which in contrast to standard function reconstruction techniques preserves the fundamental physical properties of the classical MPM. The capability of the new method is examined by a number of one-dimensional problems, such as two phase dynamic consolidation and vibrating bar. The obtained results are promising which open new doors to extend the method to two- and three-dimensional problems in order to be used in practical geotechnical applications.

REFERENCES

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