The Material Point Method in Offshore Geotechnical Engineering

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ABSTRACT

We present a newly developed material point method (MPM) that uses second-order finite element shape functions. The method employs a fully implicit Newmark time discretisation scheme for solving time-dependent problems. The use of second-order finite element shape functions improves the accuracy of the numerical solution and reduces the oscillation of stresses being caused by material points crossing cell interfaces. To reduce stress oscillations even further, we employ a Dual Domain Material Point (DDMP) Method formulation that has been incorporated into our implicit second-order formulation. To make the DDMP formulation applicable on all common shapes of elements, e.g., quadrilaterals, hexahedra, triangles, and tetrahedra, a new, more general formula for the smoothing of the gradient of a shape function has been derived.

In addition, we have developed a natural coupling between MPM and FEM such that only regions, where large deformations are expected, have to be discretised by MPM. In regions with only moderate deformations, a standard finite element discretisation is being used. This approach improves the performance of the material point method significantly. In addition to this natural FEM-MPM coupling, we also have developed an augmented Lagrangian level-set contact formulation that allows for frictional contact between a penetrating structure - being discretised by FEM - and the soil which is being discretised by MPM.

The applicability to realistic applications in offshore geotechnical engineering is presented at hand of the numerical simulation of typical engineering processes, such as underwater slope collapses, spudcan installation and extraction, and monopile installation.