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On the use of advanced material point methods for problems involving large rotational deformation

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The Material Point Method (MPM) is a quasi Eulerian-Lagrangian approach to solve solid mechanics problems involving large deformations. The standard MPM [1] discretises the physical domain using material points which are advected through a standard finite element background mesh. The method of mapping state variables back and forth between the material points and background mesh nodes in the MPM significantly influences the results. In the standard MPM (sMPM), a material point only influences its parent element (i.e. the background element in which it is located), which can cause spurious stress oscillations when material points cross between elements. The instability is due to the sudden transfer of stiffness between elements. It can also result in some elements having very little stiffness or some internal elements loosing all stiffness. Therefore, several extensions to the sMPM have been proposed, each of which replaces the material point with a deformable particle domain. The most notable of these extensions are the Generalised Interpolation Material Point (GIMP), the Convected Particle Domain Interpolation (CPDI1) and Second-order CPDI (CPDI2) methods [2]. In this paper, the sMPM, CPDI1 and CPDI2 approaches are unified for geometrically non-linear elasto-plastic problems using an implicit solver and their performance investigated for large rotational problems. This type of deformation is common in applications in the area of soil mechanics, for example the vane shear test and, specifically of interest here, the installation of screw piles. Screw piles are currently used as an onshore foundation solution and research being undertaken at Durham, Dundee and Southampton universities is exploring their use in the area of offshore renewables. The numerical modelling using the MPM aims to predict the installation torque and vertical force as well as understanding the “state” of the soil around the screw pile which is critical in understanding the long term performance of the foundation. In the analysis, the pile is assumed to be a rigid body and no-slip boundary condition is used at the pile-soil interface. The boundary condition is imposed using the moving mesh concept within an unstructured mesh fixed to the pile. It will be shown that the CPDI2 approach produces erroneous torque due to particle domain distortion, while the CPDI1 approach and sMPM predict physically realistic mechanical responses.

REFERENCES

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