Parametric Study on PML-Based Absorbing Boundary Conditions for Wave Propagation Modeling in Material Point Method

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Abstract

In recent years, mesh-based methods, such as the finite element method (FEM), have been proven to accurately model materials under small deformations in solid mechanics. However, when dealing with large deformations, these methods introduce errors due to mesh entanglement, which often require remeshing and remapping processes. To address this limitation, the Material Point Method (MPM), which combines the strengths of mesh-based and mesh-free methods, has gained popularity. However, MPM also faces a few challenges, particularly related to dynamic boundary conditions. Unlike mesh-based approaches, MPM requires special treatments of nonconforming boundary conditions as the material boundaries, most of the time, do not align with the background grid boundaries. Our resent study [1] focuses on solving the numerical challenges of imposing absorbing boundary conditions for dynamic simulations in the MPM. To attenuate elastic waves leaving the computational domain, the resent work integrates the Perfectly Matched Layer (PML) theory into the implicit MPM framework. The proposed approach introduces absorbing particles surrounding the computational domain that efficiently absorb outgoing waves and reduce reflections, allowing for accurate modeling of wave propagation and its further impact on geotechnical slope stability analysis. In this follow-up study, we conduct a parametric analysis to investigate the sensitivity of the PML-MPM method's performance to both the thickness of the PML domain and the discretization mesh size. We systematically vary the PML thickness and the mesh size and evaluate their influence on the wave absorption effectiveness and overall solution accuracy.

Keywords

Material point method, Perfectly matched layer, Absorbing boundary, Dynamic analysis, Slope stability, Earthquake-induced landslides

References

[1] Kurima, J., Chandra, B., & Soga, K. (2024). Absorbing boundary conditions in material point method adopting perfectly matched layer theory. arXiv preprint arXiv:2407.02790.