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A unified Lagrangian formulation for solid and fluid dynamics and its possibility for modelling submarine landslides and their consequences

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Abstract

Consequences of submarine landslides include both their direct impact on offshore infrastructure, such as subsea electric cables and gas/oil pipelines, and their indirect impact via the generated tsunami. The simulation of submarine landslides and their consequences has been a long-standing challenge majorly due to the strong coupling among sliding sediments, seawater and infrastructure as well as the induced extreme material deformation during the complete process. In this paper, we propose a unified finite element formulation for solid and fluid dynamics based on a generalised Hellinger-Reissner variational principle so that the coupling of fluid and solid can be achieved naturally in a monolithic fashion. In order to tackle extreme deformation problems, the resulting formulation is implemented within the framework of the particle finite element method. The correctness and robustness of the proposed unified formulation for single-phase problems (e.g. fluid dynamics problems involving Newtonian/Non-Newtonian flows and solid dynamics problems) as well as for multi-phase problems (e.g. two-phase flows) are verified against benchmarks. Comparisons are carried out against numerical and analytical solutions or experimental data that are available in the literature. Last but not least, the possibility of the proposed approach for modelling submarine landslides and their consequences is demonstrated via a numerical experiment of an underwater slope stability problem. It is shown that the failure and post-