Self-correcting soil models for numerical simulation of strain rate dependant ice scour in sand

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ABSTRACT

The integrity of subsea pipelines in the Arctic regions are threatened by ice-related subsea geohazard. A common practice for physical protection of the pipelines against the ice loads is to burying them inside the subsea trenches. However, determining the minimum burial depth of the pipeline to minimize the construction cost is a challenging design aspect of Arctic offshore pipelines. This requires an in-depth understanding of the ice-soil-pipe interaction, which in turn is significantly affected by ice-soil interaction. Mohr-Coulomb soil model is conventionally used for continuum modeling of dense sand by adopting the constant friction and dilation angles. However, this approach neglects the pre-peak hardening and the post-peak softening behavior of dense sand. In this study, two smart self-correcting soil models were incorporated into an advanced Coupled Eulerian-Lagrangian (CEL) analysis to automatically update the shear strength parameters by the magnitude of plastic strains. The analysis was conducted using ABAQUS/ Explicit scheme incorporating the soil model that was coded into a user-defined subroutine. The soil strength parameters are self-corrected to model the nonlinear hardening, softening and pressure dependency behavior of dense sand by considering the ice keel bearing pressure and octahedral shear strain. The pre-peak hardening, and post-peak softening behavior of dense sand were captured through a series of free-field ice gouging analysis. The sub gouge soil deformation and ice-soil contact pressure were extracted and compared with the results of the original Mohr-Coulomb model, the existing analytical solutions, and the published test data. The study showed the significance of incorporating the strain rate dependency of dense sand on seabed response to ice gouging. The methodology was found to be a strong but simple framework that can be used in daily engineering analyses. It was observed that the magnitude of the subgouge soil deformation is overestimated by the conventional decoupled methods. Also, the required burial depth was found to be smaller than those recommended by conventional methods, which in turn can significantly reduce the construction effort.