The Response of Buried Pipelines to Ice Gouging in the Uniform and Trenched/backfilled Seabed
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ABSTRACT

Ice gouging is a destructive incident to subsea pipelines in Arctic regions. Trenching and backfilling have been selected as the most efficient way to protect the pipeline. Studies indicate that remolded backfill materials with considerably less stiffness than native soil can significantly complicate soil failure mechanisms and pipe trajectories. In this paper, a numerical model was developed using coupled Eulerian-Lagrangian (CEL) method to investigate the influences of a backfilled trench on the seabed soil failure mechanism and the pipeline response with two model configurations. The study showed that the conventional simplification of assuming homogeneous seabed soil on trenched backfilled pipelines might misinterpret pipeline behavior and soil failure mechanisms.

KEY WORDS: ice gouging; coupled Eulerian-Lagrangian (CEL); ice-soil-pipe interaction; arctic pipelines; backfill effect

INTRODUCTION

Due to the depletion of older oil fields, the oil and gas industry is now paying more attention to new techniques and resources for oil extraction. The Arctic regions represent one of the unexplored hydrocarbon resources, with a high percentage of pristine resources (Gautier et al., 2009). However, some other obstacles and hazards could arise at various stages of exploitation in an ice environment, such as ice gouging (Abdalla et al., 2008). Water currents and winds in shallow areas cause ice gouging, which states the drifting of ice features like icebergs on the seabed. Pipelines are buried into the seabed as a practical and economical approach to protecting pipelines against ice gouging because ice keel-pipeline contact would be destructive to pipeline safety. Nonetheless, the ice gouge exerts multiple substantial stresses on the seabed, leading to soil failure mechanisms such as subgouge displacements, frontal mounds, and side berms (Fig. 1). As a result, the buried pipe will be impacted by the ice gouge and undergo a complicated path of lateral, vertical, and axial stresses and strains.

The most common source of backfilling is the excavated soil. Because of the drilling machine's contact with the excavated soil and mixing with the seawater, the soil is disturbed and has less shear strength.

Fig. 1. The main components and soil failure mechanisms during an event of ice gouging

Several experimental and numerical models are available to comprehend the process of ice gouging. Numerical modeling is frequently used in this field due to the challenges associated with physical simulations of ice gouging under various boundary conditions, loading scenarios, or soil materials. Lagrangian modeling failed to simulate ice gouge under several shortcomings, including mesh distortion and severe node displacement (Lach, 1996; Woodworth-Lynes et al., 1996). Researchers, therefore, used other techniques, including the Coupled Eulerian-Lagrangian (CEL) and the Arbitrary Lagrangian-Eulerian Method (ALE) ((Abdalla et al., 2009; Banneyake et al., 2011; Konuk et al., 2005; Konuk et al., 2009; Konuk & Yu, 2007; Pike & Kenny, 2016).

In this study, the movement of the ice keel traveling over a pipeline is simulated using the CEL method and Abaqus/Explicit. This approach allows for large deformations by modeling the soil environment using the Eulerian formulation. Two initial model configurations (shallowly buried and deeply buried pipelines) were conducted to examine the trenching/backfilling effect on the keel reaction forces, soil failure mechanisms, and the pipeline response. It was concluded that the proposed model is a primary yet robust tool that may be utilized in the daily engineering practice of designing Arctic pipelines against ice gouge.