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Pipeline Risk Assessment in Deep-Sea Furrow Regions

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Abstract

Deep-sea sedimentary furrows have been recently identified as a potentially significant factor for pipeline risk assessment and route selection. Furrow fields are large-scale variations in seafloor topography which, when coupled with high-velocity bottom currents, can present a significant geohazard to pipelines by creating large spans, flow-induced vibration, and other as-yet-unknown hazards. It is therefore necessary to understand the behavior of the furrow fields and the interactions between pipelines and furrows (at various spatial and temporal scales) so that risk may be characterized and pipeline routes efficiently selected. The first component of this study focused on the analyses of various geometrical, morphological, and geophysical data related to Gulf of Mexico (GOM) furrow fields. These data analyses were used to develop qualitative and quantitative insights concerning the hydrodynamics and sediment transport within GOM furrow fields. This work resulted in the development of a conceptual model for GOM furrow fields. The second component of this study used hydrodynamic and sediment transport models to investigate the interactions between a pipeline and deep-sea furrows. The models were used to investigate flow and sediment transport in furrowed areas for a range of conditions: 1) with and without a pipeline; 2) rigid and deflecting pipeline; 3) varying current velocity; 4) varying current direction; and 5) varying width-to-depth (W:D) ratio of a furrow. Model simulations provide a quantitative method for evaluating the interactions between a pipeline and deep-sea furrows; model results may be used to assess pipeline risk within a furrow field.

Introduction

Deep-sea sedimentary furrows, known as furrow fields, have been recently identified as a potentially significant factor for pipeline route selection (Tootill et al. 2003). Furrow fields are large-scale variations in seafloor topography which, when coupled with high-velocity bottom currents, can present a significant geohazard to pipelines by creating large spans and producing flow-induced vibration and other as-yet-unknown hazards. It is therefore necessary to understand the behavior of the furrow fields and the interactions between pipelines and furrows (at various spatial and temporal scales) so that risk to pipeline operations may be characterized, engineering solutions developed, and pipeline routes efficiently selected.

Furrows are longitudinal bed forms formed in cohesive sediments that tend to be aligned parallel to bottom currents. Furrow depths typically vary between 1 and 10 m and widths range from about 5 to 50 m. Furrows have been commonly observed in deep-sea and lake regions with strong bottom currents (Flood 1983). Furrows with the potential to impact pipelines laid across them have been observed in the vicinity of the Sigsbee Escarpment in the Gulf of Mexico (GOM), where current velocities of 90 cm/s and greater have been measured. Additionally, furrows have been observed on the seafloor of the Bahama Outer ridge where currents reach 20 cm/s, the English Channel where currents reach 175 cm/s, and Lake Superior where currents reach 30 cm/s.

Potential pipeline hazards associated with deep-sea furrow fields can be separated into the following four categories: 1) unsupported pipeline spans; 2) pipeline shoulder scour; 3) vortex-induced vibrations (VIV); and 4) large-scale effects (e.g. hydrodynamic forces on a pipeline resulting from multiple unsupported spans across a furrow field in conjunction with strong episodic currents, which may cause lateral instability and pipeline movement). Pipeline shoulder scour, which may increase pipeline risk due to VIV, can be especially problematic in deep-sea furrow fields because of the highly non-linear relationship between the erosion rate of cohesive (muddy) sediment and current velocity. For example, an increase of 25 percent in current velocity can result in the erosion rate increasing by approximately 300 percent.

The focus of this study was to characterize the fundamental risks associated with the placement of a pipeline across a deep-sea furrow field. From an engineering perspective, this study has two primary objectives: 1) develop a methodology for pipeline risk assessment in a furrow field; and 2) conduct a screening-level assessment of pipeline risk in a furrow field. The second objective is intended to provide a demonstration of the utility of the pipeline risk assessment methodology