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Experimental Study of Pipeline Stability on Sandy Seabed under the Influence of Ocean Currents

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ABSTRACT

Ocean-current-induced pipeline stability on sandy seabed was simulated physically in a flow flume. The process of pipeline losing on-bottom stability in currents was recorded and analyzed. Experimental data show that, for a pipeline directly laid on sandy seabed, there exists a linear relationship between the dimensionless submerged weight of pipeline and Froude number, in which the current-pipe-soil coupling effects are reflected. The sand-particle size effects on pipeline on-bottom stability are further discussed. The new established empirical relationship may provide a guide for the engineering practice of current-induced on-bottom stability design of a submarine pipeline.

KEY WORDS: Submarine pipeline, ocean currents, on-bottom stability, sandy seabed, current-pipe-soil interaction

INTRODUCTION

When a submarine pipeline is installed upon sandy seabed, there exists a complex interaction between pipeline, seabed and ocean environmental loads. To keep the pipeline stable on the seabed, the soil must provide enough resistance to balance the hydrodynamic forces. Otherwise, the pipeline will breakout from its original site, i.e. pipeline on-bottom instability occurs.

In the practice of submarine pipeline stability design, the submerged weight of pipeline is a key factor for influencing the soil resistance. To get a heavier pipeline, thickness of cover layer has usually to be increased. Nevertheless, a slight increase of submerged weight will bring a larger laying cost, and sometimes will make the existing laying barges unworkable. Therefore, an appropriate criterion for pipeline stability is highly desired for the determination of pipeline's submerged weight.

In the past few decades, the dynamics interactions between wave/ current-pipeline-seabed have attracted much interest from pipeline researchers and designers. In the 1980's, the pipeline on-bottom stability has been investigated mainly by physical modeling in a few large projects, such as the PIPESTAB project (Wagner et al., 1987), the AGA project (Brennodden et al., 1989) and a project at DHI (Palmer et al., 1988). On the basis of their test data, a few pipe-soil interaction models have been proposed for predicting pipeline stability on sand or on clay (e.g. see Wagner et al., 1987; Brenodden et al., 1989). Recently, a series of centrifuge tests were conducted on the pipe-soil interaction for shallowly embedded pipeline in calcareous sand. A non-associated bounding surface model was also constructed to simulate the soil responses around pipeline under combined (vertical and horizontal) monotonic loading (Zhang et al., 2002). In above experimental investigations, mechanical actuators were employed in the tests for the simulation of hydrodynamic wave loads upon pipe sections. Thus only the wave forces upon pipe were simulated, however the wave loads upon seabed were ignored in these pipe-soil interaction tests. It should be noted that, in the actual situations, the wave or current not only exerts loads upon the pipeline, but also upon seabed. That is, the pipeline on-bottom stability in ocean environments is actually an interaction between wave/current, pipe and seabed.

Different from the previously mentioned mechanical actuator loading methods, a hydrodynamic loading method with a unique U-shaped oscillatory flow tunnel was adopted by Gao (2001), for physical modeling of wave-induced pipeline on-bottom stability. Based on the established wave-pipe-soil interaction model (Gao et al., 2003), an improved analysis method for wave-induced pipeline on-bottom stability on sandy seabed has been proposed by Gao et al. (2006). However, in most of the previous studies, ocean wave is the main concern of the environmental loads.

In certain ocean zones in shallow waters and most locations in deep waters, current may be the dominant environmental load. Till now, however, the work specifically focused on pipeline on-bottom stability in currents is scarce (Jones, 1978). An appropriate model for accurate estimations of pipeline on-bottom stability in the ocean currents is still desired, although currents sound less complex than waves. Therefore, it is needed to carry out further investigations on the currents induced pipeline stability.

In this paper, similarity analysis is made on ocean currents induced pipeline stability on sandy seabed under the influence of ocean currents. According to the similarity relationships, a series tests have been