Proceedings of The Fifteenth (2005) International Offshore and Polar Engineering Conference
Seoul, Korea, June 19–24, 2005

ISBN 1-880653-64-8 (Set); ISSN 1098-6189 (Set)

Wave-Induced Pipeline On-bottom Stability: Comparisons between Pipe-Soil and Wave-Pipe-Soil Interaction Models

Fuping Gao, Yingxiang Wu
Institute of Mechanics, Chinese Academy of Sciences, Beijing, China
Dong-Sheng Jeng
Department of Civil Engineering, The University of Sydney, Sydney, Australia
Xu Jia
China Offshore Oil Research Center, China National Offshore Oil Company, Beijing, China

ABSTRACT

To have a better insight into the mechanism of wave-induced pipeline on-bottom stability, the pipe-soil interaction model (Wagner et al., 1987) and the wave-pipe-soil interaction model (Gao et al., 2003) are compared intensively in this paper. This includes the comparisons of their experimental setups, procedure of tests, phenomena of pipe losing stability etc. The comparison indicates that the critical lines for the instability of anti-rolling pipeline and freely-laid pipeline in the empirical wave-pipe-soil interaction model overall agree with the design values, based on both simplified and generalized methods in DnV standard, respectively. However, with the increase of Froude number, the generalized method in DnV standard becomes more conservative than the wave-pipe-soil interaction model for the on-bottom stability design of pipeline. Therefore, wave–pipe-soil coupling effects should be taken into account when we analyze the on-bottom stability pipeline under wave loading.

KEY WORDS: Wave-pipe-soil interaction model; submarine pipeline; on-bottom stability; sandy seabed

INTRODUCTION

One of the main problems encountered with the use of the pipeline in offshore engineering is the wave-induced pipeline instability (Herbich, 1985). When a pipeline is installed upon seabed and subjected to wave loading, there exits a complex interaction between wave, pipeline and soil. To avoid the occurrence of pipeline on-bottom instability, the pipeline has to be given a heavy weight of concrete coating or alternatively be anchored/trenched. Both methodologies are expensive and complicated from the aspects of design and construction. Recently, considerable efforts have been devoted into the interaction between pipeline and seabed. Interest in this aspect of problem was spurred by the situation that the physical mechanism of pipeline on-bottom stability is still unrevealed (Lawlor and Flynn, 1991).

The state-of-the-art in pipeline stability design has been changing very rapidly recently. Three major investigations have addressed the problem of pipeline-seabed interaction, which include PIPESTAB project (Wagner et al., 1987), the American Gas Association (AGA) project (Brennodden et al., 1989) and a project at Danish Hydraulic Institute (DHI) (Palmer et al., 1988). The work completed in the above projects includes large-scale model tests and the development of some models to predict pipe on-bottom stability. The PIPESTAB and AGA projects have produced soil resistance models, i.e. the pipe-soil interaction model (Wagner et al., 1987) and the energy-based pipe-soil interaction model (Brennodden et al., 1989). The existing DnV RPE-305 pipeline stability design standard is mainly based on the pipe-soil interaction model, which was drawn from mechanical actuator loading experiments (Det norske Veritas, 1988). However, the pipe-soil interaction model was found to be conservative for determining the weight coating of pipeline (Verley and Reeds, 1989). Unlike the previous experimental studies, Gao et al. (2003) have recently proposed a wave-pipe-soil interaction model for pipeline on-bottom stability, based on the experiments in a U-shaped oscillatory flow tunnel.

In this paper, a comparison between pipe-soil interaction and wave-pipe-soil interaction models is made, including their test facilities, experimental approaches, physical phenomena of pipe losing on-bottom stability etc. Moreover, the design values of the submerged weight of pipeline predicted with the two models are also compared.

COMPARISONS OF THE EXPERIMENTAL APPROACHES FOR PIPELINE ON-BOTTOM STABILITY

Test Facilities

Pipe-Soil Interaction test. The pipe-soil interaction projects, such as PIPESTAB, AGA and DHI projects, have been focused on the description of the soil resistance for an un-trenched pipeline exposed to wave loading. To achieve this goal, full-scale pipe-soil interaction tests were conducted to collect information from various loading histories for pipelines resting on various marine sediments. The test facility, developed as part of the PIPESTAB project, composed test pipes, mechanical rig, soil flume, a computer systems for test control and data acquisition and the equipment for soil reconditioning. The rig used in the PIPESTAB and AGA tests has been described by Brennodden et al. (1986), Wagner et al. (1987) and Brennodden et al. (1989) (see Fig.1(a)).