Proceedings of the Ninth (2010) ISOPE Pacific/Asia Offshore Mechanics Symposium
Busan, Korea, November 14-17, 2010

ISBN 978-1-880653-79-1: ISSN 1946-004X. www.isope.org

Experimental Study on VIV of a Flexible Pipe with Soil Support

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ABSTRACT

Although there are many studies dedicated to the problem of vortex-induced vibration (VIV) of submarine pipeline spans, VIV experiments considering the effect of soil at the span shoulders are very rare. To investigate the effect of the soil on the VIV of submarine pipeline spans, a pipe model, 16mm in diameter, 2.6m in length and with mass ratios (mass/displaced mass) of 4.30 was tested in a current tank. The pipe was laid horizontally on the soil, and had a free span in length of 2.138m. The tests in still water and in a current were conducted. The flow velocity was in the range of 0-0.57m/s. The response of the model was measured using fiber optic strain gauges. The frequency responses and the time-domain tracing of cross-flow strain responses are presented and analyzed. The experimental results exhibit several valuable features: the natural frequency of the model has a fuzzy property, but the response frequency in a current has not and increases with the increase of flow velocity; the strain amplitude for the sandy soil case is larger than that for the clay soil case.

KEY WORDS: vortex induced vibrations; span; soil support.

INTRODUCTION

Vortex shedding from a submarine pipeline span may occur when a fluid flows past the pipeline, and induces fluctuating hydrodynamic forces. When the frequency of vortex shedding approaches the natural frequency of the structure, the span will be excited into a resonant state and undergo a large amplitude vibration. Vortex-induced vibration (VIV) is of practical importance for the pipeline spans. Large responses give rise to oscillatory stress, which can cause unacceptable fatigue in pipeline.

The VIV of submarine pipeline span is a complicated problem involving both the fluid structure interaction and the pipe-seabed-interaction. The VIV of circular cylinders had been investigated in the last three decades by many researchers. For investigation of VIV of the submarine pipeline span, some experimental studies were performed.. Yang et al. (2006, 2009); Raghavan et al. (2009) performed rigid cylinder tests where the cylinder had one or two degrees of freedom. Furthermore, some flexible pipe tests were performed. Tsahalis and Jones (1981) curried out model tests to determine the effect of the proximity of a plane boundary on the vortex-induced vibrations of a flexible pipe exposed to steady current. Later, Tsahalis (1987) experimentally studied the VIV of a flexible pipe either isolated or in close proximity to a plane boundary exposed simultaneously to steady currents and waves. Also, some studies on the reduction of vortex induced vibration were performed. Chung and Whitney (1993, 1994) devised a vortex-suppression technique to mitigate vortex-shedding-induced vibration and potential flow-induced detorquing of the pipe. Simantiras and Willis (1999) carried out a reduced scale model experimental program to determine both the VIV response and the helical strakes effectiveness at very high incidence angles. The mechanism of VIV mitigation using helical strakes is further investigated by Razali et al (2010). Zhang et al (2010) summarized the key experiments reported in the literature for straked pipes.

Although some work has been done for the VIV of pipeline span, a systemic study considering the effect of soil at the span shoulders has rarely been carried out. The boundary condition for a free span is very important due to a relatively little aspect ratio (length to diameter ratio). The soil at the span shoulders has a significant effect on the natural frequency and dynamic response of the span. Larsen et al. (2002, 2004) presented an approach for VIV analysis of free span pipelines based on the combination of a linear frequency VIV model and a time domain structural model with non-linear boundary conditions at the span shoulders. Ai et al. (2009) investigated the effect of soil non-linearity on VIV by using a wake oscillator model.

However, VIV experiments considering the effect of soil at the span shoulders have not been performed before. In order to investigate the effect of soil support on VIV, a pipe model, 16mm in diameter, 2.6m in length and with mass ratios (mass/displaced mass) of 4.30 was tested in a current tank. The pipe was laid horizontally on the soil, and had a free span in length of 2.138m. The tests in still water and in a current were conducted. The flow velocity was in the range of 0-0.57m/s. The response of the model was measured using fiber optic strain gauges.

EXPERIMENTAL SETUP

Experiments were performed in the current tank located at the State