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Physical Modeling of Current-Induced Seabed Scour around a Vibrating Submarine Pipeline

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ABSTRACT

Most of the existing researches either focus on vortex-induced-vibrations (VIV) of a pipeline near a rigid boundary, or on seabed scour around a fixed pipeline. In the fields, pipeline vibration and seabed scour are actually always coupled. Based on the similarity analysis, a series of tests were conducted with a hydro-elastic facility to investigate the influence of pipe vibration on the local scour and the effects of scour process on the pipeline dynamic responses. Experimental results indicate that, there exist two phases in the process of sand scouring around the pipeline with small embedment, i.e. Phase I: scour beneath pipe without VIV, and Phase II: scour with VIV of pipe. It is also found that the gap-to-diameter ratio (e/D) has much effect upon the scour depth for the fixed pipes. For a given value of e/D, the vibrating pipes with close proximity to seabed may induce a deeper scour hole than the fixed ones. Within the examined gap-to-diameter ratio range ($-0.25 < e/D < 0.75$), the influences of gap-to-diameter ratio on the maximum values of scour-depth for the case of vibrating pipes are not as much as those for the case of fixed pipes.

KEY WORDS: Submarine pipeline; scour; seabed; currents; vortex-induced-vibrations

INTRODUCTION

When a pipeline is constructed on seabed and subjected to currents, there exits a complex interaction between current, pipeline and seabed. If the pipeline is not buried, unsupported spans may exist in some locations, especially at the uneven zones of seabed. Seabed erosion around pipeline may also result in the spanning of pipeline. When exposed to currents or other hydrodynamic loadings, such a suspended pipeline may experience vortex-induced vibrations (VIV), which have been widely recognized as one of the main causes for the fatigue damage to pipeline. Therefore, it is of highly essential to analyze the dynamic responses of a pipeline in vicinity of seabed under ocean environmental loads for the proper design of submarine pipeline.

During recent decades, the dynamic interaction between ocean currents, pipeline and seabed has received wide interests from submarine pipeline designers and researchers. Numerous experiments on vortex-induced-vibrations of pipeline have shown that, when the vortex-shedding frequency brackets the natural frequency of an elastic or elastically mounted rigid cylinder, the cylinder takes control of the shedding frequency in an apparent violation of the Strouhal law. Then the vortex-shedding and pipeline oscillation collapses into a single frequency, which is well known as lock-in phenomenon (Sarpkaya and Isaacson 1981). A few experimental results for cylinders with two degrees of freedom indicated that the amplitudes of in-line vibration are one order less than those of cross-stream vibration (Bryndum et al., 1989). For above reasons, many researchers paid their attentions mostly on the cross-stream vibrations of cylinders, such as the work by Khalak et al. (1999), Govardhan and Williamson (2000). However, the aforementioned researches focus on pipeline vibrations near a rigid boundary or under wall-free conditions, in which the seabed scour was not involved.

Recently, much effort has also been devoted on the seabed scour around fixed pipelines in currents (Hansen et al., 1986; Sumer et al., 1988a; Chiew, 1991). The researches on seabed scour around marine structures including pipelines have been summarized by Sumer and Fredsoe (2002). Nevertheless, most of the previous researches either concentrate on vortex-induced-vibration of a pipeline near rigid boundary, or on seabed scour around fixed pipelines. In the actual situations, pipeline vibration and the seabed scour are always coupled. Till now, the studies on the interaction between vibrating pipe and sand scour are scarce (Sumer et al., 1988b). Thus, it is essential to further investigate the coupling effects between them.

In this paper, the current-induced seabed scour around a vibrating pipeline is simulated experimentally with a new hydro-elastic facility. Based on the similarity analysis, a series of tests were conducted to investigate the influence of pipe vibration on the scour depths and the effects of scour process on the pipeline dynamic responses.

SIMILARITY ANALYSIS AND EXPERIMENTAL METHOD

Similarity Analysis