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Investigation in Centrifuge of Anchor-pipeline Interaction

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Centrifuge tests have been performed at the Centre for Offshore Foundation Systems in order to investigate the performance of a rock protection poured into a trench to safeguard pipelines against the dragging of vessel anchors. The results provided reliable and useful information about the size and shape of the trench and the grading curve of the rock protection, and this has assisted in the design of a gas pipeline project in China.

INTRODUCTION

Soft soils usually do not make a good anchorage for vessels, and in the presence of a strong current, vessels are likely to drift, dragging their anchors across pipelines. When these are located in areas of shipping movement in shallow water, they are susceptible to the effect of the dragging of vessel anchors, which is characterized by buckling of the pipeline due to lateral anchor-hooking forces. This may lead to significant damage to the pipeline, with risk to safety, environmental pollution, and significant repair costs. One solution is to bury the pipeline into the seabed. Pipelines may be either buried deeply enough to prevent any interaction with anchors, or protected by a specific rock cover to limit lateral displacements. Although this solution is now commonly used, there are no formal rules or guidelines to assist in the design. From a geotechnical point of view, parameters of the design of buried pipelines include notably the depth of burial, the shape and size of the trench, and the characteristics and quantity of the covering material. This design requires a deep understanding of the pipeline soil interaction so all potential issues can be tackled. For instance, although the force required to mobilize lateral displacement becomes much higher for buried pipelines, it may actually lead to higher strains due to a tighter curvature of the pipeline.

In addition to the lack of guidelines, only a very few investigations have been performed to understand the effect of anchor forces. Al-Warthan et al. (1993) investigated the effect of dropping anchors on free-spanning pipelines, while Sriskandarajah and Wilkins (2002) assessed the buckling of pipelines due to lateral load through finite element analysis. While extremely useful, outcomes of these studies are not sufficient to assist in the design. Yasseri and Prager (2005) presented a comprehensive probabilistic method for deciding upon the depth of burial of pipelines, accounting for both the likelihood of various levels of hazards and the uncertainty in the response behavior of the system. However, this method does not provide any insight into the interaction mechanism between the anchor, the chain and the seabed.

Without proper guidelines, investigations on a reduced scale model can provide very useful and valuable information to assist in the design of buried pipelines. BMT Asia Pacific Limited has commissioned the Centre for Offshore Foundation Systems to conduct a series of centrifuge tests in order to assess the efficiency of different trench shapes and sizes, and different grading curves of rock cover, to protect two 18-in gas pipelines linking Shenzhen to Tai Pei in China (Gaudin et al., 2005). This paper presents the methodology adopted and outcomes.

CENTRIFUGE TESTING

Experimental Setup

The experiments investigated the monotonic drag behavior of a 16-ton U.S. Navy stockless anchor (consistent with that carried by some of the largest container ships in the area) through normally consolidated kaolin clay, and the interaction of the chain-anchor configuration with the rock protection covering a buried pipeline. The experiments were performed using the beam geotechnical centrifuge facility housed at the University of Western Australia. It has a swinging platform of 1.8 m with a nominal working radius of 1.60 m, and is rated at 40-g tons. The platform seats standard rectangular strongboxes, whose internal dimensions are $650 \times 390 \times 325$ mm. The centrifuge also allows equipment to be mounted on the strongboxes to perform so-called in-flight events (such as cone penetrometer or anchor dragging). Randolph et al. (1991) provide detailed description of this centrifuge.

The model anchor was constructed from mild steel and modeled accurately (both in shape and dimensions) a 16-ton U.S. Navy stockless anchor at 70 g (Fig. 1). The overall width of the anchor was 39.3 mm (2.75-m prototype) and the height of the flukes was 36.1 mm (2.52-m prototype). For the first test, the anchor was used with the flukes allowed to rotate while the anchor was

Fig. 1 Model anchor

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