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Soil Impact on Non-Stationary Anchor Performance

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Abstract

This paper discusses predictive models of penetration depth and load capacity of non-stationary anchor, an issue which affects the overall design and reliability of mooring systems in deep water. Anchors under consideration in this paper include drag embedment anchors (DEA's), vertically loaded anchors (VLA's), and spring-shank anchors. This paper presents examples of the performance of predictive models for anchor trajectory and capacity for given sets of soil conditions. The implications of uncertainties in anchor trajectory and capacity on the overall reliability and design of mooring systems is then assessed. DEA's and VLA's are an attractive option for moorings in deep water, particularly mobile offshore drilling units. A chief concern in the usage of such anchors is the uncertainty in their load capacity, uncertainty which is largely associated the difficulty in predicting their depth of penetration. More reliable design tools for predicting the trajectory and capacity of these types of anchors can lead to more economical and reliable mooring system designs for these units. Improved reliability of design tools for predicting the capacity of non-stationary anchors can also aid in gaining acceptance of this type of anchor for permanent mooring systems. Reliable predictions of anchor performance are critical to designing economical and reliable mooring systems. This topic is relevant to the design of mooring systems for hydrocarbon exploration platforms currently in use. Looking forward, reliable mooring systems are also likely to be relevant to the design of various renewable energy source production systems such as wind and current power.

Introduction

Drag anchors are extensively used for moorings in deep water, particularly for mobile offshore drilling units (MODU's), due to their relatively low installation cost, their relatively high holding capacities, and the potential for removal and re-use on other projects. Prediction of the anchor load capacity requires an estimate of the anchor trajectory during drag embedment, difficulty in predicting this trajectory being a major source of uncertainty in the prediction of load capacity. Due to the complex nature of the embedment process as well as the complex conditions of anchor loading, the offshore industry has largely relied on empirical methods to predict anchor penetration depth and load capacity (e.g., Naval Civil Engineering Laboratory, 1987). While empirical investigations will undoubtedly continue to play a prominent role in predicting anchor performance, the problem remains of extrapolating a relatively small database of empirical measurements to the mulitpliicty of soil and loading conditions that may occur in practice. Accordingly, an analytical framework for understanding and predicting anchor performance is needed. The introduction of limit equilibrium analyses (Stewart, 1992; Neubecker & Randolph, 1996; and Dahlberg, 1998), plasticity theory supported by finite element studies of soil-anchor interactions (O'Neill et al., 2003), and analytical formulations for anchor line response (Vivatrat et al., 1982; Neubecker & Randolph, 1995) represent significant advances in the development of such a framework.

Historically, drag embedment anchors (DEA's) were designed for use in catenary mooring systems in which the anchor is subjected to a predominantly horizontal load. More recently, taut mooring systems are being increasingly deployed, which subject the anchor to a substantial component of vertical loading. Vertically loaded anchors (VLA's) were developed in response to this trend. With a VLA, the angle between fluke and shank is opened after an initial phase of embedment to enhance the capacity of the anchor to resist vertical loads. Opening of the shank alters both the load capacity and the trajectory of the anchor, adding an additional layer of complexity to the analysis. The predicted model discussed herein considers both DEA's and VLA's.

Prediction of Anchor Performance

Figure 1 shows a schematic of the anchor system under consideration. The anchor fluke has a length L_f, thickness w_f, and width w_f. A shank of length L_s is attached to the fluke at a distance L_j from the trailing edge of the fluke. In cases of non-