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The Exact Solutions of Tower-Yoke Mooring Systems

Yonghui (Allen) Liu
SOFEC, Inc.
Houston, TX, USA

ABSTRACT

Tower-yoke mooring system, which consists of a tower fixed at the seabed and a mooring yoke assembly connecting a platform with the tower and utilizes pendant linkages to hang a heavy weight from top of the vessel, has been utilized for station-keeping applications in extreme shallow water. This paper will derive the exact solutions of the tower-yoke mooring systems. The motions of the tower-yoke mooring system is described based on the three rotational movements of the pendants and yoke. The exact relations between those rotational motions and the vessel motions are derived. The theoretical solutions of the restoring force characteristics of the tower-yoke mooring system can then be calculated. The model tests have been carried-out for the tower-yoke mooring systems. The excellent agreement between the analytical solutions and the measurements has validated and verified the methodology proposed in the paper.

KEY WORDS: Tower yoke mooring system; mooring system; restoring force; station-keeping; shallow water; exact solutions.

INTRODUCTION

In extreme shallow water, the conventional catenary mooring systems are very difficult to hold vessels on position since the water depth limits the effectiveness of the restoring forces generated by the weights of the mooring components. The very shallow water will also induce significant non-linearity to the cateneary mooring system.

Tower-yoke mooring system, which consists of a tower fixed at the seabed and a mooring yoke assembly connecting the platform with the tower and utilizes a heavy weight hanging from the top of the vessel, has been utilized for the vessel station-keeping applications in shallow water. The mooring yoke assembly attaches the platform to the turntable on the tower and allows the yoke and platform to weathervane around the tower while allowing transfer of the oil and gas from/to the vessels and electric power to the tower. The yoke contains a two-axis joint that allows the vessel to roll and pitch relative to the tower and heavy ballast to provide restoring forces to moor the vessel. The vessels are attached to the yoke with two pendant linkages, which have one double-axis joint on upper end (upper U-joint) and one triple-axis joint on lower end (lower U-Joint). The pendants hang over the vessel bow or stern and are attached to the vessel mooring support structure.

The tower yoke mooring systems have been designed to keep the 165,000 DWT new built FPSO vessel secured at CNOOC QHD 32-6 site in the extreme shallow water of 20 meters in Bohai Bay of China, and the 357,000 DWT converted FSO vessel moored on the ESSO Chad site in 35 meters water offshore West Africa. The QHD 32-6 FPSO and ESSO Chad FSO with the tower yoke mooring systems are illustrated in Figs. 1 and 2.

Fig. 1 Tower-yoke mooring system for CNOOC QHD 32-6 FPSO

However, the complexity of the tower-yoke mooring system make the analysis extreme difficult. Special finite element methods have been utilized to analyze the mooring systems. This paper will derive the exact solutions of the tower-yoke mooring systems. The motions of the tower-yoke mooring system is described based on the three rotational movements of the pendants and yoke. The exact relations between those rotational motions and the vessel motions are derived. The