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Analysis and Monitoring Methodology for Rolling Bearing Faults in the Hinge of a Soft Yoke Mooring System

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Due to the complexity of the loading and motions of vessels in marine environments, many uncertainties are involved in the design of mooring systems. A soft yoke mooring system (SYMS) has been applied to moor the floating production, storage, and offloading (FPSO) vessel in the shallow water of Bohai Bay, China. The SYMS has 6 hinge points that are composed of 13 sliding bearings and rolling bearings. The bearings may be damaged as a result of long-term use, improper maintenance, and harsh ocean environmental conditions. The faults of the bearings will affect the function of the yoke and even drag the tower platform down. Thus, any faults in the bearings need to be addressed. Information inside the bearings cannot be measured directly; therefore, an indirect monitoring method was proposed, and a real project was presented. The real project monitored the rotation angle of the problematic rolling bearing, the strain responses, and the displacement variations in the hinges' axes. Furthermore, both sides of the yoke legs were monitored continuously, and the variation tendency of the problematic rolling bearing was evaluated by comparing the difference between the two legs. The results showed the feasibility of the present monitoring system in safety assessments of the SYMS, but more information is needed for a comprehensive evaluation. For example, vibration diagnostic techniques may be a better method because they have been widely used in the fault diagnosis of rotating machines.

INTRODUCTION

Single-point mooring systems are used worldwide (Wichers, 1988). The soft yoke mooring system (SYMS), one of the best single-point mooring systems, has been applied to moor the floating production, storage, and offloading (FPSO) vessel in the shallow water of Bohai Bay, China (Wang et al., 2011, 2012). The SYMS is deployed in shallow water at depths below 50 m and consists of a support structure, two mooring legs, two counterweight ballasts, an A-frame structure (yoke), and a tower platform (Li et al., 2006; Xiao et al., 2008), as shown in Fig. 1. The SYMS is so complex that many researchers have performed considerable work on its design, implementation, analysis, and monitoring (Wu et al., 2016; Fan et al., 2015; Yang et al., 2014). Furthermore, the SYMS has 6 hinges, which can relieve the 3 degrees of freedom of the hull during wave frequency motions (roll, pitch, and heave), and only restricts the hull during low-frequency motions (surge, sway, and yaw), so that the hull could be fixed in a certain area.

The working principles of the SYMS are listed in Table 1, which presents the motion-released states of all the hinges marked X1 to X4, where x, y, and z are the translational degrees of freedom and R1, R2, and R3 are the rotational degrees of freedom. X1, X2, X3, and X4 are the four hinges of the mooring system, as shown in Fig. 1. X1 is a universal hinge that consists

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