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Long-term inter-link wear of model mooring chains

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ABSTRACT

Chains usually form the upper part of moorings systems used for maritime structures such as floating production storage and off-loading (FPSO) vessels, increasingly employed in the offshore oil and gas industry particularly in very deep waters. Current design rules do not differentiate between corrosion and inter-link wear. Laboratory experiments are described to determine the rate of wear of model (i.e. small-scale) mooring chains for up to 200,000 wear cycles. Various axial loadings and specific angular displacement were used with testing under either dry or wet conditions and for un-corroded and corroded chain. The results show that tensile force has a significant but non-linear effect on the inter-link wear. The amount of wear is similar for un-corroded and for corroded chains and is lower in wet conditions.

1. Introduction

The floating production storage and off-loading (FPSO) vessels increasingly being used in oil and gas exploration and production in waters up to 3 km or more in depth require safe station-keeping under a variety of sea-states and weather conditions. Typically FPSOs (and other similar vessels) are moored using some 8–12 mooring lines, fastened at the upper ends to the vessel using large sized chains connected at a specially designed turret at the bow or through a similar system amid-ships. The most common size of chain currently is 76 mm nominal metal diameter but increasingly larger chains are being used, currently up to 190 mm metal diameter. Typically the links in the chains are stud-less. Most

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of the remaining part of the mooring lines is large diameter wire or polyester, sometimes with additional buoyancy provided under water (Fig. 1). The lower end of mooring lines typically is a long length of chain lying on the sea floor.

The main function of the mooring line system is to keep the FPSO in place within acceptable limits such that various components such as the risers transferring oil from the reservoir to the FPSO can operate safely. The mooring lines are subject to very considerable tensile forces as a result of the not inconsiderable weight of the chain and wire rope self-weight both of which act continuously on the chain. In operational practice, additional tensile forces are generated by wind and current loads acting on the exposed areas of the FPSO. These loads are a function of the FPSO size and shape and of wind, water and wave velocity on the structure as well as resulting from dynamics effects under various sea-states.

Failure of the mooring system could result in oil spills with the potential to cause significant environmental consequences. This may incur high direct costs (riser rupture, production shutdown and cost of repair) as well as consequential damages. The FPSO industry has experienced a number of mooring line failures and cases of damage to mooring lines. Nine were multiple-line failures but most involved only one mooring line. In the 10 year period to 2011 some 21 mooring failures were reported [1]. This relatively high rate is the main reason for attracting industry attention. For example, Shoup and Mueller [2] reported a case in which failure occurred at the junction between the fixed stopper link (i.e. at the turret) and the first free link in the chain catenary, as a result of loadings imposed by a typhoon, even though it was lower in severity than the design storm for the system. In general, fatigue, corrosion and mechanical issues (including wear) are the main causes of failure for mooring lines. Of course, the ultimate criterion for a mooring line is the reliability with which it can maintain its tensile capacity [3].

Inter-link wear, which is the wear of the contact zones between links, particularly for the upper chain links, under the large tensile force acting on the mooring line has been identified as an important factor in the loss of strength of mooring lines and therefore a potential contributor to mooring line failure. It has been proposed that both inter-link wear and impulsive tensile loads and thus the risk of mooring line failure could be reduced by the use of elastic chains [4]. Another approach to risk reduction is application of risk-based inspection to mooring chains [5], using information from mooring line inspections to update the failure probability. A further possibility is to consider alternative mooring line systems and their comparative dynamic behaviour to reduce risk of failure [6].

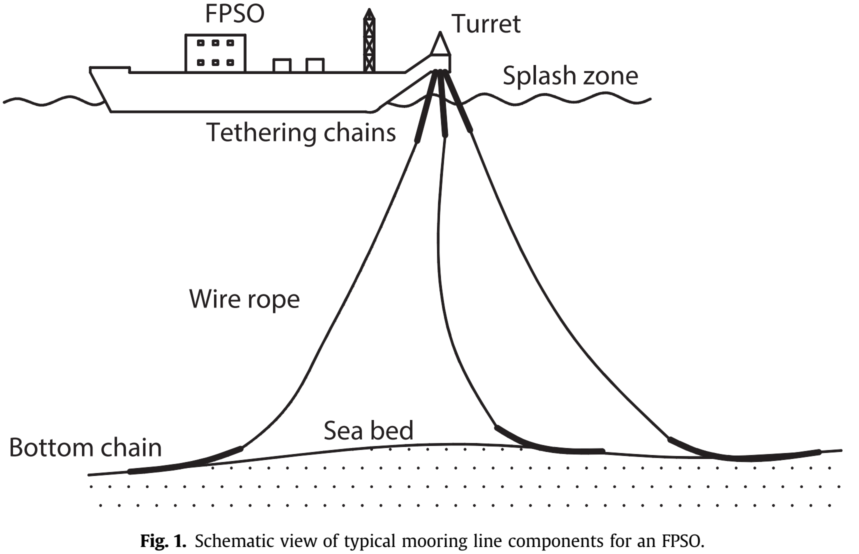

Fig. 1. Schematic view of typical mooring line components for an FPSO.