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An FEA-Based Methodology for Assessing the Residual Strength of Degraded Mooring Chains

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In this paper, the authors present a finite element analysis (FEA)-based methodology for estimating the residual strength of degraded mooring chains. The paper presents work investigating FEA modeling parameter sensitivities and selection of appropriate parameters for FEA modeling. In addition, validation against break testing of full-scale chains is presented.

INTRODUCTION

A typical offshore (e.g., floating production storage and offloading (FPSO)) mooring system may contain multiple components: chain stopper, fairlead or bending shoe, chain segments, wire rope, polyester rope, sockets, thimbles, anchors, and connectors or jewelry of various types. Because of its robust nature, chain is usually used at locations along the mooring line that are prone to the highest damage, such as at the top under high tension and in the touchdown or “thrash zone.” Two types of chain may be considered for mooring systems: studded and studless. Studded chains have a stud, or brace, placed between the bars in the midsection of the chain to prevent flexure and aid in fatigue endurance. Studless chains do not contain a bracing stud.

During the design process, an allowance is added to the diameter of chain segments to accommodate for potential material loss due to in-service corrosion and wear. Typically, a design code (e.g., API RP 2SK; API, 2005) or a company-specific practice provides a recommendation or requirement relating an allowed annual corrosion/wear rate. This rate is multiplied by the target design life of the mooring system to reach the total material loss allowance for the mooring chains.

Recent industry experiences have shown that the material losses on chains due to corrosion and wear may be higher than those specified in the design allowance for certain regions of the world. Material losses will result in a reduction in chain strength. If the material loss is more than the design allowance, the mooring systems may not be able to meet design life (typically 20–25 years). For example, chains in West Africa have been found to have higher cross-sectional area loss due to corrosion than the design allowance recommended by API RP 2SK (API, 2005; Fontaine et al., 2014; Rosen et al., 2015). Recent underwater mooring inspections from West African assets also found unexpected line dynamics near the seabed under a typical swell environment causing abrasion of the chain cross section (Bhattacharjee et al., 2014). It is critical to determine if a degraded mooring system is fit for service and to estimate the remaining strength before an intervention is required. Furthermore, the risks associated with continued operation of an asset with degraded mooring chains must be understood.

This paper provides details pertinent to the construction of a finite element analysis (FEA) model of a mooring chain for strength assessment. First, a framework for assessing the fitness for service (FFS) of mooring chains is presented. Next, guidance is provided for how to model degraded mooring chains using FEA. The modeling discussion includes obtaining the chain geometry, number of links, boundary conditions, link alignment, element type and mesh convergence, friction coefficients, and material properties. A summary table of modeling guidance is provided with the paper conclusions. Finally, results of eight full-scale validation tests are compared with FEA, showing excellent agreement. A companion paper (Crapps et al., 2017) provides guidelines for conducting FFS assessments of degraded mooring chains.

FFS METHODOLOGY

Figure 1 illustrates the components involved in the FFS methodology for assessment of degraded mooring chains (Crapps et al., 2017). Obtaining degraded chain geometry and selecting FEA modeling parameters are required for building a robust model capable of predicting residual chain strength. FEA model validation is required to assess the efficacy of the models. The next component is understanding the projected impact of the degradation using simplified geometries. This step involves understanding key geometric characteristics of the chain degradation modes and generating simplified CAD models that are used to understand the chain strength as the degradation progresses. A strength assessment curve is generated using finite element (FE) models with simplified degradation geometries. This curve can be used in conjunction with mooring design loads calculated from

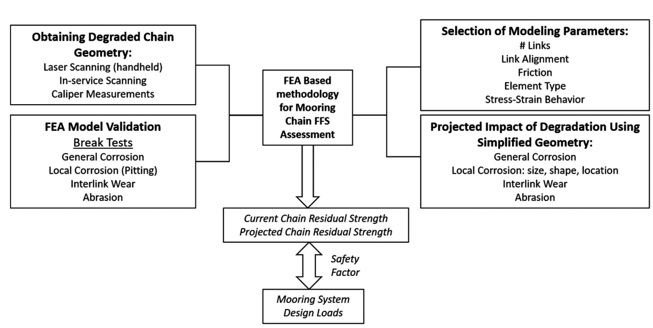

Fig. 1 Elements of FFS methodology

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