High-Strength Mooring Chains--Rules and Standards Updates for Improved Usability and Suitability

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ABSTRACT

In recent years it has been reported a number of incidents related to failures of high-strength mooring chains used in mobile offshore units mooring systems.

Different investigations have been carried out resulting in several explanations for why these incidents occur, and several possible measures to counteract them, have been launched.

A data aggregation project resulted in a defined failure mechanism and root causes.

This paper presents a discussion of the mitigation actions implemented across the industry to minimize the occurrence of such failures, taking in consideration the determined failure mechanism and root causes.

KEY WORDS: High-strength; mooring chain; hydrogen sensitivity; HISC; failure; brittle fracture.

NOMENCLATURE

AHV Anchor handling vessel
CP Cathodic protection
CTOD- Crack tip opening displacement
FOW Floating offshore wind
FOWT Floating offshore wind turbines
GOMO Guidelines for Offshore Marine Operations
ICCP Impressed current cathodic protection
HISC Hydrogen induced stress cracking
HV Vickers hardness
Hs Significant wave height
KIEAC Environment assisted cracking stress intensity
MBL Minimum break load
MOU Mobile offshore unit
R5 Mooring chain material grade per DNV-OS-E301
SACP Sacrificial anode cathodic protection
SSRT Slow strain rate testing

INTRODUCTION

In recent years it has been reported a number of incidents related to failures of high-strength mooring chains used in mobile offshore units mooring systems. Those incidents are limited to chain material grade R5. The failures occurred at different chain life cycle stages, corresponding in some cases to very low tension levels. Explanations for why these incidents occur have been published in investigation reports and seminars. Possible measures to counteract such incidents, have been launched by several industry stakeholders according to the information updates available and the entities roles and responsibilities.

In this context, DNV was commissioned by the Petroleum Safety Authority Norway (PSA) to collect and make a comprehensive and critical review of the available material on usability and suitability of high-strength mooring chain for mobile offshore units (MOU).

In this project a hydrogen embrittlement crack growth failure mechanism, caused by locally hardened and brittle surface layer crack initiation, was proposed.

This paper presents a discussion of the mitigation actions implemented across the industry to minimize the occurrence of such failures, taking in consideration the determined failure mechanism and root causes.

FAILURE ROOT CAUSES AND CONTRIBUTING FACTORS

A total of 18 failures on R5 grade mooring chains have been noted to have occurred between 2015 and 2022. None of these failures could be attributed to commonly occurring causes such as overloading or fatigue. There have not been any similar failures reported in chains of lower material grades. From these failures, 13 failure investigation reports were used in this study, due to lack of complete information on the remaining 5 cases.

According to the analysis of the failure reports, the fractures occur in two well defined locations:

- Cracks in the straight area of the chain link initiate from the outer areas of the section and occur both on welded and non-welded side. The location of crack initiation in the straight part coincides with drag wear marks and some cases of observed untempered martensite. Measured hardness at these locations was significantly higher than the hardness of the base material. It is assumed that a layer of untempered martensite was present in the crack initiation phase for more cases of chain failure than what was observed, but that the relatively thin layer was corroded away at the time of the