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Case study

Perforated mechanism of a water line outlet tee pipe for an oil well drilling rig

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ABSTRACT

A corroded tee pipe belonging to a 10-in new separator water line outlet installed in an offshore oil well drilling rig was investigated. The configuration of the large corroded pit had the shape of an imperfect horse's hoof with a completely corroded interior and a honeycomb-like cavity. There is a badly corroded pit at the welded seam at the joint connecting the tee pipe and flange. The material strength of the tee pipe meets the requirement of ASTM-A234 Gr. WPR, but its chemical composition does not meet the stipulated requirements. A deformed streamline structure or twin crystal in the ferrite phase can be seen near the surface or sub-surface of the perforated corrosion puncture edge. The micro-hardness is also different from that of the original material. The SEM results show that the puncture appears to have been a mode of quasi-cleavage fractures with secondary cracks along the direction of the crystal grain; thus, the failure has the features of mechanical and chemical corrosion. The corroded surface contains high amounts of O, C, and N, as well as S, Cl, Si, Na, Mg, Al, K, Ti, etc., all of which are corrosion products caused by sea water. The penetrating puncture hole at the turn of the tee pipe is likely the result of cavitation erosion accompanied by chemical/electrochemical corrosion, and the corrosion on the seam connecting the tee pipe and flange is likely the result of electrochemical corrosion.

1. Introduction

Corrosion in oil drilling and transport pipelines is very common [1–7]. The perforated pipe examined in this study is a tee pipe, which is a 10-in new separator water line outlet installed on an offshore oil well-drilling rig, as shown in Fig. 1, where Fig. 1(a) shows its exterior, Fig. 1(b) shows its interior and Fig. 1(c) and (d) shows its corroded areas.

The tested tee pipe was installed on an offshore oil well-drilling rig, and the fluid flowing in the pipe was the oil-containing sewage produced after crude oil has been separated. The pipe was perforated due to corrosion after only 6–12 months of use. The perforation in the pipe is a small-size hole near the pipe joint corner and has a simple shape (arrow 1); the corroded area, however, is relatively large (arrow 2).

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Fig. 1. Interior and exterior of the perforated tee pipe. (a) Exterior; (b) interior; (c) interior of the corroded cavity; (d) interior of location "3" in Fig. 1 (b).

The tee pipe is made of ASTM A234 steel, and the joint flange is made of ASTM A105 steel.

Failure analyses of the perforated failed tee pipe were performed to determine the cause of its failure.

2. Experimental procedure

Based on the analysis requirements and the consignor's demands, test samples were taken from the area around the corroded puncture and from the area where there was no apparent corrosion. The following aspects of the samples were analyzed: metallurgical structure, EM scanning, chemical composition, and mechanical properties (e.g., tension). Chemical composition tests of the materials used to make the tee pipe and joint flange are performed via a photoelectric direct-reading spectrometer DV6E.

All metallographic grinding surfaces were etched by 4% nitric acid-alcohol-mixed liquid to allow observation of their metallographic microstructure. The specimens' microstructures were investigated using optical microscopy (Leica, Germany). The puncture surfaces were ultrasonically cleaned and observed with a scanning electron microscope (SEM, Shimadzu, EPMA1600, Japan) equipped with energy-dispersive X-ray spectroscopy (EDX). The microhardnesses of the pit edge zones and matrix were measured using a Vickers microhardness tester. To confirm the failure mechanism, the corrosion products at the perforation were analyzed by a scanning electron microscope equipped with EDX.