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Analysis of corrosion of hot-rolled X70 steel plate during storage

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ABSTRACT

In this work, analysis was performed to investigate the reason resulting in corrosion, especially pitting corrosion, of a stock of hot-rolled X70 steel plates after 4 months of storage in a warehouse. Results demonstrated that corrosion and pitting corrosion of X70 steel plate during storage is attributed to the remnant and concentration of cooling water on the top surface of the plate. Pitting corrosion occurs locally at defects on surface deposit that is generated during corrosion of the steel. The small anode vs. big cathode geometry enhances the pitting corrosion process. Chloride ions enter the pits to maintain the charge-neutrality, while ferrous ions that are generated during corrosion diffuse out of the pits to result in corrosion product layer at pit mouth.

1. Introduction

API X70 steel has been extensively used is a line pipe material in petroleum and pipeline industries for oil/gas transmission. The pipeline integrity is maintained by both coating and cathodic protection (CP). However, corrosion, especially pitting corrosion, of pipeline steel usually occurs under disbanded coating due to coating failures and incompatibility of CP with the applied coating [1–4]. To date, there has been limited report about pitting corrosion of X70 steel occurring in storage.

A stock of hot-rolled X70 steel plates, which was stored in the warehouse, was found to corrode after 4 months of storage. The steel plate was manufactured under rough rolling and precise rolling routes, where controlled rolling and cooling techniques were applied. The cooling water was sprinkled to the steel plates during rolling to decrease temperature. The schematic description of the cooling process is shown in Fig. 1, and the chemical composition of cooling water is given in Table 1.

In this work, a detailed analysis was conducted to understand the mechanism and process of corrosion, especially pitting corrosion, of X70 steel plate during storage through various surface characterization (optical microscopy, scanning electron microscopy (SEM) and electronic probe micro-analysis) and electrochemical measurement techniques.

2. Identification of corrosion

2.1. Visual observation

Visual examination of the surface of corroded X70 steel plate showed that a significant number of corrosion pits existed on the up-surface of the plates, as shown in Fig. 2. However, there was no obvious corrosion pits visible on the down-surface (Fig. 3).

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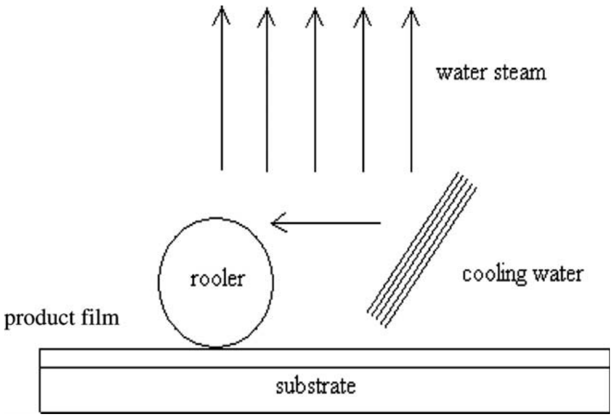

Fig. 1. Schematic diagram of rolling process of X70 steel plate.

Table 1
Chemical composition of cooling water.

Main parameter	Results
pH	8
Electrical conductivity	975 μs/cm
HCO_3^-	146 mg/L
CO_3^{2-}	9.01 mg/L
SO_4^{2-}	189 mg/L
Cl^-	137 mg/L
NO_3^-	4.47 mg/L
K^+	20.4 mg/L
Ca^{2+}	96.4 mg/L
Na^+	67.8 mg/L
Mg^{2+}	35.9 mg/L

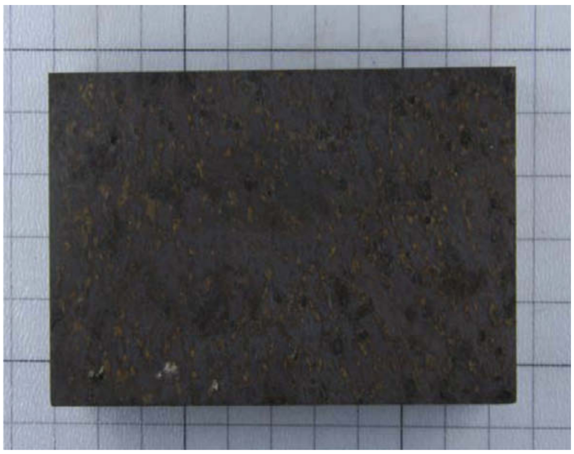

Fig. 2. Optical view showing the up-surface with corrosion and corrosion pits.

2.2. SEM morphological characterization

The surface of corroded X70 steel plate was observed by a JSM-6480LV SEM in Fig. 4. It is apparent that corrosion pits were associated with corrosion product covering the pit mouth. Moreover, corrosion pits looked like mushroom, with a small hole in the center. After remove corrosion product, it is seen in Fig. 5 that the pit mouth was circular, and there was no corrosion product inside pit.

The cross-sectional view of corrosion product on X70 steel plate is shown in Fig. 6. It is seen that corrosion product had a laminar structure, and micro-cracks existed inside the product.