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Case study

Failure analysis of dissimilar weld in heat exchanger

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ABSTRACT

The failure analysis of a dissimilar weld in a heat exchanger has been conducted. Within hours of being placed in service, the circumferential weld joining the carbon steel shell to the duplex stainless steel tubesheet experienced partial cracking as H_2S was being introduced into the exchanger. The cracking of the weld was determined to be associated with sulfide-stress corrosion cracking facilitated by high weld hardness levels and local dilution of chemistry in the weld.

1. Introduction

Dissimilar welds occur in applications when different materials are combined to improve product performance. A typical example is the use of ferritic and austenitic stainless steels in power plant applications, which can be traced back to the 1940s [1]. Other examples which started later, are the use of ferritic and duplex stainless steels in applications that take advantage of the improved mechanical and corrosion properties of duplex stainless steels [2,3]. However, due to their complexity, dissimilar welds can be susceptible to unanticipated failures. The present case study documents the failure of a duplex and carbon steel weld.

The heat exchanger experienced partial cracking of the circumferential V-groove weld joining the carbon steel shell (SA-106 pipe) and 2205 duplex stainless steel tubesheet (SA-182-F51/F60). The filler metal used for the weld is AWS A5.9 ER2209. The failure occurred within a few hours of being placed into service. The crack was identified as H_2S was being introduced into the heat exchanger. The procedure used subjected the vessel to an ambient temperature H_2S line running at nearly atmospheric pressure without any heat load. Pressure was being equalized through the H_2S system. Prior to this operation, the heat exchanger was successfully pressure tested using N_2. The exchanger was rated for a maximum allowable working pressure of 550 psi at 330 °F.

The duplex stainless steel tubesheet was selected to mitigate pitting corrosion of the 316L stainless steel tubes and tubesheet of the previous exchanger. Duplex has a higher pitting resistance than 316L [3]. The use of the carbon steel shell was primarily for cost savings. A section of the weld containing the crack was extracted from the heat exchanger to conduct this failure analysis.

2. Visual damage assessment

The as received sample extracted from the heat exchanger for this analysis, exposed crack fracture surfaces after sectioning, and illustration of crack location are shown in Fig. 1. The through thickness crack extended approximately 5 in. circumferentially near the top side of the exchanger. The crack initiated and propagated mostly along the weld metal side of the fusion line with the carbon steel except near the OD, where it propagated into the weld metal away from the fusion line. The discoloration seen in Fig. 1(b) appears to be consequential oxidation after the failure, especially on the carbon steel side of the fracture surface. Note that at this location, the weld was approximately 0.1″ thinner than the rest of the weld. No evidence of initial weld defects such as incomplete fusion and lack of penetration were observed.

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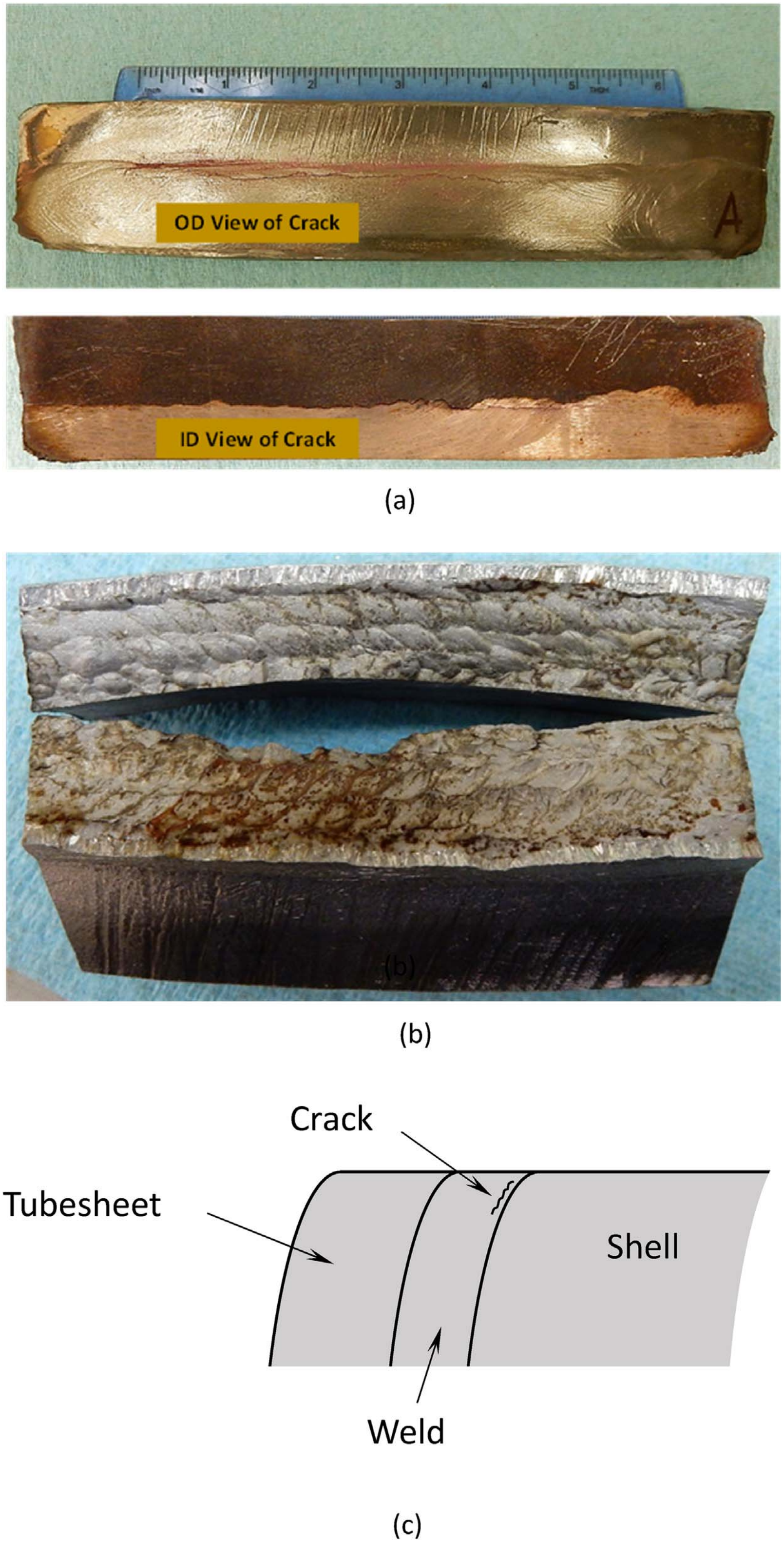

Fig. 1. Circumferential crack in the dissimilar metal weld: (a) as received sample extracted for failure analysis (~8-in. long, 1.75-in. wide, and 0.5-in. thick); (b) exposed crack fracture surfaces after sectioning; (c) illustration of crack location.