CORROSION AND CRACKING IN AIR INJECTION PIPE

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Background

An internal inspection of a blend tank revealed that a support securing an air injection pipe had failed, leaving the pipe to move freely in currents produced by agitation of the tank contents. Impact damage was found on the tank internals in the vicinity of the pipe and on the external surface of the pipe closest to the tank internals. There were also evidence of exfoliation corrosion and cracking on the pipe where some of the impact damage occurred.

A section of the piping containing the elbow and flange pair was made available for examination and the following information was provided:

- The tank contained a slurry of water and PVC fines.
- The piping of interest is 3 inch NPS, schedule 10, 304/316 stainless steel.
- The piping was attached to the baffle at one location near the top of the tank.
- The external surface of the pipe was exposed to atmospheric pressure.
- The internal surface of the pipe was exposed to air at less than 15 psi.
- The operating temperature was around 155ºF.

Assignment

Determine the cause of the exfoliation corrosion and cracking, and recommend procedures to prevent a reoccurrence.

Findings

Visual examination of the sample revealed several areas of cracking and corrosion on the external surface (Figure 1). Markings on the flange indicated that it was 316 stainless steel, while markings on the elbow revealed that it was 304 stainless steel. The visual examination also indicated that the damage occurred in areas where there were signs of surface deformation and denting on the external surface of the pipe (Figure 2). Additionally, there was evidence of heavy dark brown corrosion deposits in the cracks and had expanded, causing the pipe material to delaminate.


Figure 1

Figure 2

Metallurgical examination revealed widespread cracking at the location examined. The cracking appeared to have initiated on the pipe's external surface where the mechanical damage had occurred, and propagated somewhat parallel to the surface of the pipe with many of the cracks spreading completely through the wall of the pipe (Figure 3). Cracks were also found in the flange particularly near the bolt holes.

Metallurgical examination revealed that the majority of the cracks observed exhibited a branched, transgranular morphology typical of chloride stress corrosion cracking (CSCC), while the unbranched, transgranular nature of a few of the cracks suggests that they were initiated by fatigue (Figure 4).

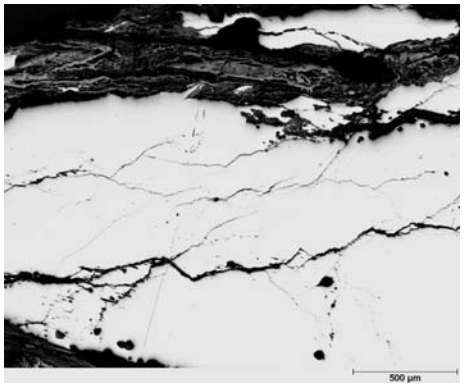

Figure 3

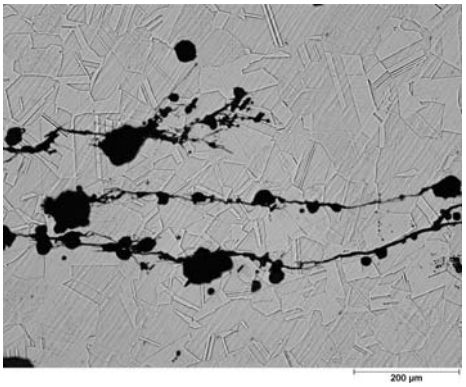

Figure 4

Scanning electron microscope examination of the fracture surface and deposits in the cracks confirmed that chlorides were present on the fracture surface but not on the base metal away from the fracture at the initiation point.

An analysis of the tank fluid showed an oxygen level of 10.5 ppm and an iron level of 0.43 ppm. The measured pH was 4.5 and the chloride content was 0.01 ppm.

Conclusions

Numerous areas of corrosion and cracking were found on the external surface of the pipe. Although it was not possible to determine with certainty whether the cracks were initiated by CSCC or fatigue, the existence of both branched and unbranched cracks suggests that the cracks resulted from both mechanisms. The cracks were caused by tensile stress produced by the pipe repeatedly striking the baffle inside the tank. The increased pipe movement was the result of the retaining bracket failure, which is designed to prevent such motion.

The impact damage resulted in deformation of the pipe surface and caused tensile stresses in the pipe wall. These high local stresses resulted in CSCC which spread through the wall of the pipe. In addition to CSCC, the piping also suffered exfoliation type corrosion - a result of the expansion of the corrosion products that formed inside of the cracks.

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