Case History: Preferential Weld Corrosion

Preferential weld and heat-affected zone corrosion is directly proportional to the process flow, temperature, pH, location of welds within the piping, and how active the weld metal is electrochemically when coupled to the base metal.

Accelerated decay and possible reasons for this attack are illustrated in this case study.

Preferential weld corrosion (PWC) in stainless steel (SS) construction is not new to the industry, but remains a significant concern. The term describes selective attack of the weld itself rather than of the base plate, and sometimes the heat-affected zone (HAZ). Preferential attack often occurs because the weld material is more active than the base metal. This occurs because differences in the two microstructures make the weld more susceptible to corrosion than the base metal. The influence of the coupling is enhanced by the unfavorable area ratio, a small anodic weld/large cathodic base metal. Selection and approval of compatible and appropriate welds should be done during material selection at the start of the design phase.

In this case, the designers attempted to prevent PWC and HAZ corrosion by enhancing the induction and the integrity of the protective corrosion film. This was done by adding elements such as nickel, chromium, molybdenum, copper, aluminum, vanadium, etc. Unfortunately, these additions may cause the HAZ to be preferentially anodic to the base metal through galvanic action. In addition, precipitation within grains, inter-dendritic regions, and at grain boundaries has a direct effect on the weld's corrosion potential. Thus, grain boundaries and inter-dendritic regions tend to attain a more active corrosion potential than the neighboring grains. For instance, micro-segregation of Cr and Mo in welds of SS will lead to selective pitting corrosion of the weld. Welds are also susceptible to microbiologically influenced corrosion (MIC).

Selection of the proper weld material is the best way to combat PWC. Another method of combating PWC in flowing streams is inhibition. Proper knowledge of inhibitors and their selection is crucial, however, as inhibitors may actually lead to accelerating corrosion rather than inhibiting it.
In some cases, the HAZ may be selectively corroded, leaving behind the weld bead. The HAZ is metallurgically more complex than the base metal and the weld materials. Hence, the HAZ becomes electrochemically more active than the base or weld materials. The relatively smaller size of the HAZ causes it to corrode rapidly, leading to penetration and subsequent leakage.

**Case History**
A pipeline conveying ethylene dichloride (EDC) from a reactor to storage as dry EDC leaked in two places. Both leaks were reported to be at weld areas. The leaks were clamped until replacement with the same pipe materials was made. Many failures of the same nature had occurred in the past. In addition, no history of any previous failures was kept. No failure analysis was ever carried out. The piping material is 6-in. (152-mm) carbon steel (CS). The pressure and temperature are 135 kPA and 50 to 55°C, respectively.

One failure occurred at the weld between a flange and an elbow, and the other at the weld between a flange and straight pipe (Figure 1). The pipes were cut in half to reveal the internal condition. There was excessive corrosion damage
apparent on the inner surface of the pipe, and the weld appeared as if selectively attacked circumferentially (Figure 2). No excessive corrosion deposit was found; no surface cracking was apparent. Cross section samples were taken at each failure. Figure 3 shows a cross section sample containing pipe weld and flange areas.

Metallography and optical microscopic examination revealed the condition of the pipe samples. Figure 4 is an optical microscope photograph showing significant attack at the fusion boundary of the elbow-flange weld. The microstructures show no abnormality or cracking. Figure 5 shows a magnified portion of the most attacked fusion boundary microstructure. In Figure 6, a scanning electron microscopy (SEM) photomicrograph shows elemental analysis of three areas adjacent to a hole where EDC had leaked. All areas showed high content of chlorides. In addition, measurement along the line of fusion also showed high content of chlorides.

Discussion

Dry EDC, in the absence of moisture, is harmless to practically all metals used in the chemical and petrochemical industry. If moisture is present, however, hydrolysis can occur, releasing hydrochloric acid (HCl). When this situation occurs, material selection must be restricted to those materials that resist HCl in the suspected existing concentrations and at the existing temperatures. It is advisable not to select the type 300 series SS if there is the slightest chance that the EDC could be wet, or might become wet. The hydrolysis and resulting HCl formation could lead to chloride stress cracking.

The history of HCl content obtained from the plant personnel showed concentrations were higher than expected. This explains the many repeated failures that had occurred. Acid corrosion at localized weak points thinned the weld. Instead of an even crown, a cross section of the surface weld revealed a cresting wave pattern. The circumferential weld on the lower head appeared to have been degraded by HCl.

Since HCl is part of the process and cannot be eliminated, material replacement is inevitable. Generally, when
chlorinated hydrocarbons hydrolyze, they release HCl in concentrations often <0.5%. Still, SS will be prone to failure in this process. But, HCl concentration may increase with time. Among the many alloys that can be selected for this service, price and availability are controlling factors. Thus, it seems for this service and wide use, Monel™ will be suitable. If CS is selected as the preferred material, then HCl and moisture content must be lowered to the allowable minimum content. According to plant personnel, process HCl can be in the thousands of ppm. Many other EDC manufacturing company brochures mention that their HCl content is no more than 10 to 20 ppm.

In conclusion, in view of the available evidence, the failure was preferential HAZ attack to the EDC line welds because of the high HCl content and moisture in the system.

References
5. Author’s personal experimentations, observations and analysis, to be published.

†Trade name.

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