Technical Bulletin

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CORROSION PROTECTION BY DESIGN AND SELECTION OF MATERIALS OF CONSTRUCTION

Case: Stress corrosion cracking in a high pressure condenser of a fertilizer plant

In a fertilizer plant, gaseous process stream is condensed in a high-pressure condenser at a pressure of 140 bar and a temperature of approximately 170°C.
The condensate solution is highly corrosive, the most aggressive component being the ammoniacal form of carbamic acid which must be considered as a strong acid in the concerning circumstances. Consequently, materials of construction to be used here must meet high standards in terms of composition and quality. Awareness of the important factors in material selection, equipment design, manufacture and inspection, technological design and proper plant operations, together with periodic corrosion inspections, are the key factors for safe operation for many years. Materials of construction used at the process side of the high pressure condenser are austenitic stainless steels like X2CrNiMo17-13-2 (AISI 316L) and X2CrNiMoN25-22-2.
The heat released during condensation of the gaseous process stream is used for the production of 4.5 bar steam (150°C).
Any chlorides entering the shell side of the high-pressure condenser are likely to initiate stress corrosion cracking of the austenitic stainless steel tubes, starting from the outside surface of the tubes. Numerous cases of stress corrosion cracking are on record. Cracking has been observed in both AISI 316L and X2CrNiMoN25-22-2 tubes.

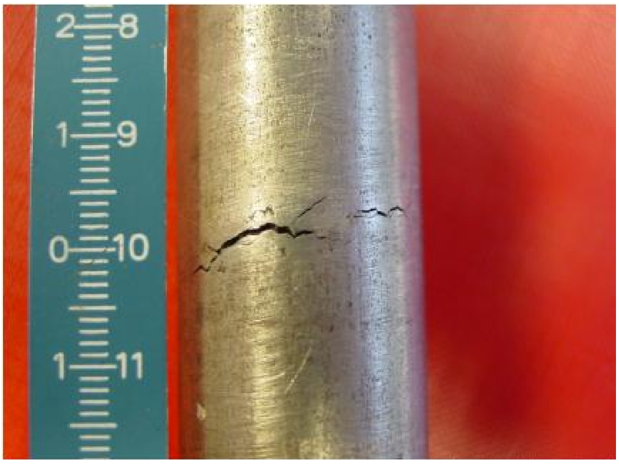

Photo 1: External stress corrosion cracking of austenitic stainless steel type AISI 316L of high pressure condenser tube (Ø25x20mm)

An example of stress corrosion cracking in an AISI 316L condenser tube is shown in Photo 1. Photo 2 shows a microphoto of the typical branched cracking of a stress corrosion crack in the austenitic structure of AISI 316L. The location of the cracks is indicated in Figure 1, for welded-and-expanded tubes, as well as for just welded tubes. It is not allowed to expand the tubes in the tubesheet because this would render the leak detection system inoperative. Leakage may result from pinholes in the tube joints. In case of leakage of the aggressive process solution, severe corrosion of the carbon steel tubesheet may occur without any indication.
In most cases cracking merely occurred in or near the top tubesheet. In some cases also cracking was found in the bottom tubesheet area. The locations have been found to depend on the origin of the chloride contamination.

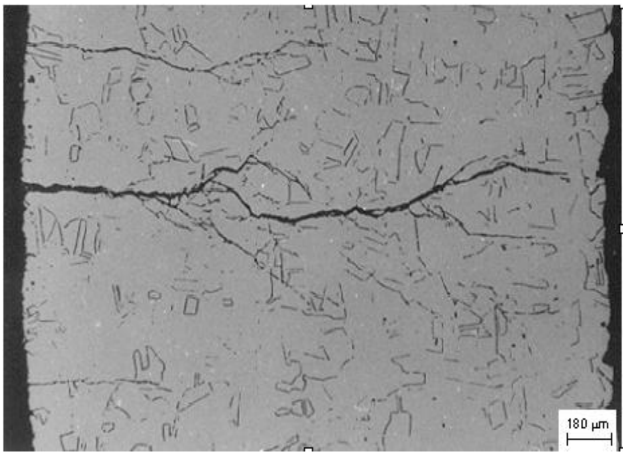

Photo 2: Microphoto of stress corrosion cracking in austenitic stainless steel tube; Etching: oxalic acid

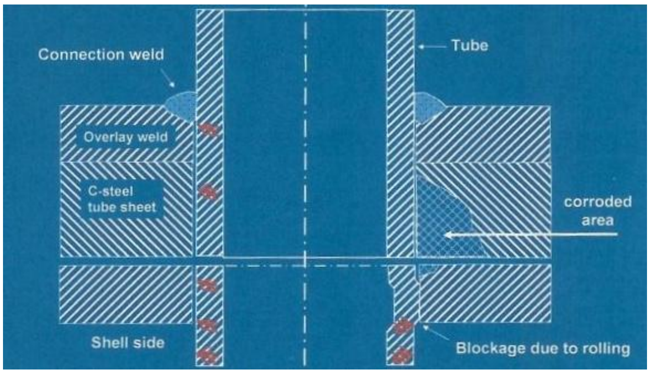

Figure 1: The location of cracks in high pressure condenser tubes; at process side the carbon steel tubesheet is overlay welded with austenitic stainless steel.

The following causes of stress corrosion cracking in high-pressure condensers have been identified:

- Chloride contamination of water used for hydrostatic testing, cleaning or flushing. Cleaning of the shell side of this high pressure condenser must be performed very carefully. Chloride containing solutions and acidic compounds are not allowed.
- Chloride contamination due to transport and storage in a chloride-containing (maritime) atmosphere (infiltration as a result of ''breathing'' due to cyclic temperature changes).
- Chloride contamination of boiler feed water (e.g. leakage of vent condenser in steam condensate tank). In case of a chloride containing cooling water a leakage of the vent condenser in the top of the steam condensate tank will result in contamination of the steam condensate. Via the 4.5 bar steam drum these chlorides will enter the high pressure condenser.

Due to presence of the gap between the tubes and the tubesheet accumulation of chlorides in these gaps is likely to occur, which increases the risk of stress corrosion cracking dramatically.

Stress corrosion cracking in high-pressure condensers can be prevented by avoiding entrance of chlorides, by changing the corrosive environment (inhibition), by using a material that is more resistant to chloride SCC or by changing the design:

- The chloride content of water used for hydrostatic testing, flushing or cleaning should be less than 1 ppm. As an additional precaution it is advised to inhibit the water with 2% TSP (trisodium phosphate).
- During transport and storage in a chloride-containing atmosphere, the equipment should be inerted with nitrogen (0.3-0.5 bar gauge).
- The chloride content of the blow-down should be less than 0.2 ppm. The oxygen content should be zero; this will be the case when the blow-down contains excess oxygen scavenger (0.1-0.5 ppm). If chloride contamination cannot be avoided, continuous inhibition with tri-sodium phosphate (TSP) should be considered.
- Application of more SCC resistant materials like type X2CrNiMN22-5-3 or even better a higher alloyed duplex stainless steel like X2CrNiMoN28-6-2. For existing high pressure condensers the remedies were focused on changing the environment but for new equipment the use of duplex stainless steels was considered. We have gained ample experience with such steels in terms of stress corrosion cracking resistance.
- Designing the high-pressure condenser with internal bore welding results in a tube to tubesheet connection without gaps and as a consequence with a minor risk of stress corrosion cracking.

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