Case Study of Stress Corrosion Cracking of Glass Fibers in a FRP Vessel

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One client of UTComp Inc is a large mineral processing facility that requires storage of hydrochloric acid (HCL)at concentrations from 5% to 33% as part of the production process. The subject of this article stores 18% HCL at 200°F. The 35 foot diameter storage vessel is made from FRP using bisphenol-A epoxy vinyl ester resin and E-glass reinforcement with capacity of 200,000 gallons. Vessel design including calculations and manufacturing details was in accordance with the rules of ASME RTP-1 for filament winding (Type X in RTP-1). The vessel was made using a hoop-axial lamination sequence. The RTP-1 stamp was not applied to the vessel. At the time of manufacture, physical properties testing of the shell laminate verified the thickness, strength and glass content to match the lamination design and calculations. At this writing, the vessels are15 years old.

As part of an ongoing reliability program, the Owner completes annual inspections including internal, external and ultrasonic evaluation of the FRP using the UTComp® System. Structural evaluation by the UTComp® System of the FRP in the vessel shells has revealed that the strength of the FRP has declined to an average of 60% of the original values. A cutout from a new access placed in the tank shell has been destructively tested to verify the UTComp® results. The corrosion barriers have maintained excellent hardness, gloss and thickness with no visible evidence of permeation of vessel contents to the structural layers.

Work done by a number of researchers including the Swedish Corrosion Institute and Owens-Corning has shown that E-type glass fibers can experience weakening when the glass is exposed to hydrochloric acid and this shows up as Stress Corrosion Cracking (SCC) of the fibers. The strain rate associated with fiber failure in laminates such as these, with highly oriented fibers is reported to be 0.2% after as little as 1 month of exposure. The design strain rate specified in RTP-1 for Type X FRP laminates is 0.1%, less than the critical strain for SCC when the FRP is new.

For the strength determined by the UTComp® System, it was determined that the average strain rate in the shells was 0.17%, near the critical rate of 0.2%. The Owner was advised that SCC failure of glass fibers may pose a risk if the glass fibers in the structural FRP are exposed to the hydrochloric acid in the vessels.

During an external inspection in 2011, a small leak was found near a 6" nozzle near the bottom of the vessel. Further investigation found that the leak started from an internal seal bond in the nozzle and found its way into the structural layers and under the reinforcing pad for the nozzle. The bond of the nozzle repad to the vessel shell was found to be poor, causing additional strain in the shell - analysis showed that the strain exceeded 0.2%. A crack developed in the shell along the axial direction starting at the top of the nozzle cutout. The crack had not progressed through the shell thickness. There was no sign of the crack in the corrosion barrier.

The vessel was repaired and returned to service. The section of shell with the crack was removed for analysis. Only the structural laminate was affected by the crack. Chemical and microscopic analysis was completed by Owens-Corning. The analysis concluded that SCC had occurred to the glass fibers.

Although the repair was unplanned, the following lessons from it are being used by the Owner to improve its maintenance plans.

- The Owner has instituted new standards for nozzle installation, glass materials, and corrosion barrier veils with plans to upgrade all vessels with new corrosion barriers, nozzle and repad replacements
- UTComp® System evaluation has been expanded to evaluate bonding of nozzle repads in addition to strength monitoring. The UTComp® System is being used to determine the how well the repad is bonded to the shell to reduce stress concentrations in the shell. As well, variations can be identified and tracked to provide early warning of developing risks.