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UTComp® System Used in Preventing Failure

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This case study describes how UTComp® System analysis of a Fiberglass Reinforced Plastic (FRP) tank identified risks to the vessels and detected damage that could result in failure. From this work, other recommendations are made to increase the reliability of FRP fabrications.

This case took place at a large mineral processing facility that uses hydrochloric acid (HCL) at concentrations from 5% to 33% as part of the production process. The subject tank of this article stores 18% HCL at 95°C. The 10.7m diameter storage vessel is made from FRP using bisphenol-A epoxy vinyl ester resin and E-glass reinforcement with nominal capacity of 800 cubic meters. 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. The vessel had been in service for 15 years at the time of this case.

The vessel is insulated on the outer surface and the outer shell is not accessible for UTComp® System testing. Where insulation is not applied, the cladding for the insulation is poorly bonded to the out surface, and preventing ultrasonic signal penetration to the shell.

The tank Owner uses a reliability and asset management program for all FRP fixed assets. The program uses the combined results of frequent external inspections and annual internal, external and UTComp® System evaluation of the FRP. The Owner cleans the tank of accumulated process residue every year in conjunction with the internal evaluations. Figure 1 shows a view of the internal UTComp® System data collection from the shell and the internal surface near a nozzle.

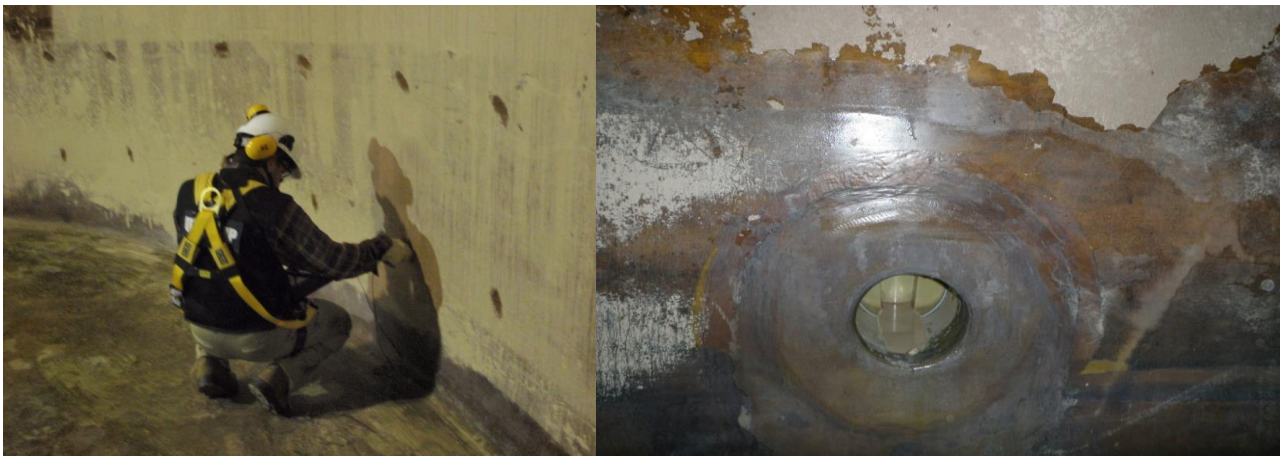

Figure 1 - Data Collection and CB Appearance

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Structural evaluation by the UTComp® System of the FRP in the vessel shells has revealed that the average strength of the FRP has declined to an average of 60% of the original values. In some locations, such as near the nozzle shown in the right photo of Figure 1, the strength is at 50% of the original value. As part of the ongoing verification process of the UTComp® System, the cutout from a new access placed in the tank shell has been destructively tested to verify the UTComp® results.

Although darkened by process temperatures, the corrosion barriers have maintained excellent hardness, gloss and thickness with no visible evidence of permeation of vessel contents to the structural layers. Dynamic Mechanical Analysis (DMA) of the shell has shown almost no change to the resin properties. Barcol hardness of the inner surface is higher than the manufacturer`s published value. There were no visible indications of damage to the vessel.

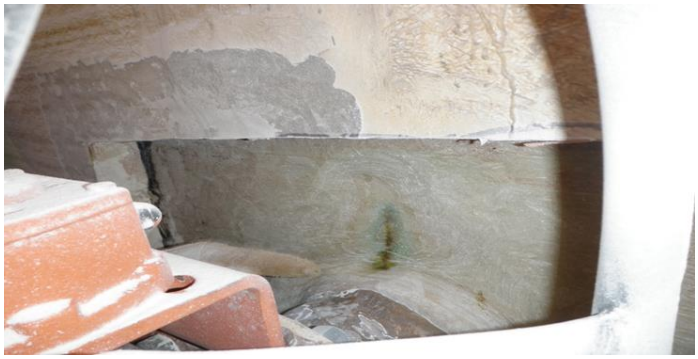
Work done by a number of researchers including the Swedish Corrosion Institute and Owens-Corning has shown that E-type glass fibers can experience weakening when the glass is exposed to hydrochloric acid and this shows up as Stress Corrosion Cracking (SCC) of the fibers. The strain rate associated with 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 shell was 0.17% to 0.2% - in the critical strain region. 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.

As a result of experience with several failures that have occurred at nozzles - where the shell stresses are increased by the presence of the hole - it is Standard Practice for UTComp to take ultrasonic readings through nozzle reinforcing pads (repads) to determine whether the repad is attached all around. At the nozzle shown in Figure 1, several significant anomalies were identified where the repad was not bonded. At these anomalies, the strain in the shell was determined to exceed 0.2%.

External inspection at the nozzle found a vertical crack that extended from under the repad, but was hidden by the cladding. The crack had HCL from the vessel in it, showing that there was a leak in the tank. Further investigation found that the leak started from the internal seal bond in the nozzle and found its way into the structural layers and under the reinforcing pad for the nozzle A crack developed in the shell along the axial direction starting at the top of the nozzle penetration. The crack had not progressed through the shell thickness. There was no sign of the crack in the corrosion barrier. The appearance of the crack in the outer surface, after removal of the cladding layers and some of the repad is shown in Figure 2.

Figure 2 - Crack



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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 and the depth of the crack was about 25% of the shell thickness. Chemical and microscopic analysis was completed by Owens-Corning. The analysis concluded that SCC had occurred to the glass fibers and they failed at the operating strains. Undetected, this could have led to failure of the tank and significant losses for the Owner.

As a result of this experience, UTComp makes the following recommendations:

- Wherever possible, all nozzles of size DN200 (8 inch) and smaller should use penetrating-type installation to improve bonding,
- Use UTComp® System for structural evaluation of all key sections of FRP equipment to optimize reliability.