Stress Corrosion Crack Growth: Discrepancies with Service History and Impacts on Time to Failure

Gery Wilkowski[1], Heqin Xu[1], and David Rudland[1]

Stress corrosion cracks have occurred in BWR plant piping in the past, as well as more recently in PWR plant piping and CANDU feeder piping. In the earlier BWR pipe cracking days, it was well known that the length of the SCC cracks in pipe butt welds could be significantly underpredicted using typical fracture mechanics techniques and laboratory data. Empirical guidance was suggested by the USNRC's NUREG-0313 Revision 2 guidelines. More recent PWSCC cracking events in the US have also shown that an axial or circumferential SCC in a CRDM nozzle could extend much farther in the length direction than the depth direction. Using laboratory testing crack growth rates with typical fracture mechanics analyses could significantly underpredict the length of the surface flaws. This faster growth rate in the length direction is very important since the potential for break rather than leak behavior is highly driven by the length of the crack. Probabilistic analyses are frequently conducted to assess if such piping is safe to operate and what the inspection intervals should be. Since leak versus break behavior is highly dependant on the length of the flaw, considerations of actual crack growth in the length direction need to be included to give realistic results in probabilistic as well as deterministic analyses.

This paper explores the effect of crack growth shape with the assumptions that there are various degrees of accelerated crack growth along the ends of a surface crack. At the ends of the surface flaw where the material has been at the same temperature and environmental history as the original surface crack location, higher stresses due to the formation of that surface crack are now present. It is hypothesized that small micro-initiation sites can form at the higher stressed ends of the surface flaw and link with the main crack front, giving an effectively higher growth rate. This hypothesis may explain the service history observations.

Simple analyses showing the effect on time to failure for a CRDM nozzle are given in this paper, where a thin layer of material on the surface is given an accelerated crack growth rate and the rest of the growth through the thickness is controlled by the typical unaccelerated crack growth rates. These analyses show the need to refine the evaluations with more detailed K-solutions for complex crack shapes.

[1] Engineering Mechanics Corporation of Columbus, 3518 Riverside Drive – Suite 202, Columbus, OH 43221. gwilkowski@emc-sq.com, (614) 459-3200/6800 phone/fax.