A New Technique for Intergranular Crack Formation on Alloy 600 Steam Generator Tubing

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1. Introduction

For the integrity and life management of nuclear steam generators, the detectability and reliability of eddy current test (ECT) are of prime importance. ECT qualification requires a number of cracked mockup specimens, having physical and micro-structural characteristics of intergranular cracks in the field component. Manufacturing of tube specimens with long-and-shallow intergranular cracks that represent field cracks in SG tubes is involved. While it is desired, techniques to control the crack shape during the specimen manufacturing was not established. In our new technology, a radial dent loading was applied on a sensitized Alloy 600 tube, in corrosive environment at room temperature, to introduce axial intergranular cracks with high aspect ratios, in good agreement with prediction by finite element analysis, as shown below.

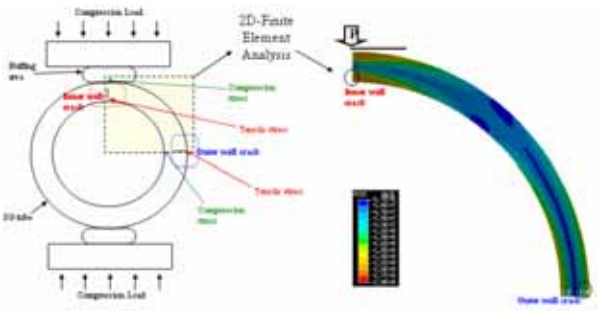

Fig.1. Stress distribution in the tube cross section of a dent loaded tubes

By experiment and hardware development, the radial denting method is shown to be suitable for the production of cracks with controlled aspect ratio. The aspect ratio can be controlled by combined application of this method and traditional internal pressurization method. In order to reduce amount of tube materials and time, direct current potential drop (DCPD) method was installed to monitor crack size and shape online so that the loading can be stopped at desired point. A set of miniaturized array probes was developed for application to the production of ID crack and/or OD crack.

Tube specimens that are cracked at room temperature are then exposed in high temperature water environment in order to produce representative oxide film on all surfaces including crack plank. This is important as electromagnetic ECT response of cracks can vary with different oxide chemistry and thickness that in turn depend on water chemistry. PWR primary or secondary water chemistry with controlled ECP and pH is applied in a refreshed autoclave system.

2. Approach

Methods that were used in earlier studies take significant amount of time and materials because it can produce only a few good specimens starting with a large amount of tube material. This can make significant problem especially for insufficient archive material. In this study, a new efficient manufacturing technique is developed by combining the radial denting with direct current potential drop (DCPD) method. Using DCPD method, crack size can be monitored during crack extension and can be stopped at appropriate crack size. In order to implement DCPD method, radial dent loading provides with additional advantages over the internal pressure loading.

3. Results

In this study, a radial denting method was explored for the production of axial cracks with high aspect ratio. Based on three-dimensional finite element analysis and preliminary experimental work, the method is shown to be more useful than the internal pressurization method for the production of cracks with high aspect ratio. In addition, direct current potential drop (DCPD) method applied with array probes has been developed for use in accurate monitoring and control of crack size and shape.

However it was difficult to grow the axial crack into desired depths exceeding detection threshold of ECT by the method without allowing excessive plastic deformations. Therefore a two-step loading, the radial dent loading followed by an internal expansion loading, has been proposed as a more versatile method for the control of crack aspect ratio and depth.

Finally, to obtain crack shape that is electro-magnetically similar to a natural defect, a completed cracked specimen is further subjected through corrosion film formation process in high temperature coolant condition.

4. Conclusion

In order to produce a library of Laboratory-Degraded SG Tubes (LDT) with intergranular cracks, a radial dent loading method has been explored for generating ID and OD axial crack by three-dimensional finite element analysis and experimental demonstration. It is confirmed that the radial dent loading can lead to long and shallow axial cracks that are more typical of actual degraded tubes in SG's. And From several experiments and finite element analysis, the direct tension loading method introduced to produce circumferential crack is verified a convenient and inexpensive loading method for the production of cracks.

DCPD technique is demonstrated to be applicable with the new radial dent, direct tension, and internal expansion loading method for a two-step loading, and capable for monitoring a crack with a significant depth. For confirmation and supplement of DCPD method, Finite element Analysis simulation was performed, this try give reliability to DCPD results.

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