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Study on the Production of the Thermal Fatigue Crack for in-service inspection qualification mock-ups

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1. Introduction

Various series of the plant maintenances are conducted to secure the reliable operation of power plants. Part of the maintenance includes periodically performed non-destructive in-service inspections (ISI). One of the key issues in the in-service inspection qualification is the representativeness of the defects used in the qualification specimens. The best representativeness is achieved with realistic defects. However, present specimen production techniques have some significant weaknesses, such as unrealistic defects or additional alterations induced in the surrounding material [1].

The aim of this study was to fulfil the need by developing an artificial flaw manufacturing method, which would produce realistic flaws. The method would allow production of flaws with controllable size, location and flaw characteristics, accurate production tolerances, reliable reproducibility without any additional disturbances.

2. Background

Thermal fatigue is one of the life-limiting damage mechanisms in the nuclear power plant conditions. A typical component where thermal fatigue cracking occurs is a T-joint where hot and cold fluids meet and mix. The turbulent mixing of fluids of different temperatures induces rapid temperature changes to the pipe wall [2]. The successive thermal transients cause varying cyclic thermal stresses. These cyclic thermal stresses cause fatigue crack nucleation and growth similar to the cyclic mechanical stresses [3].

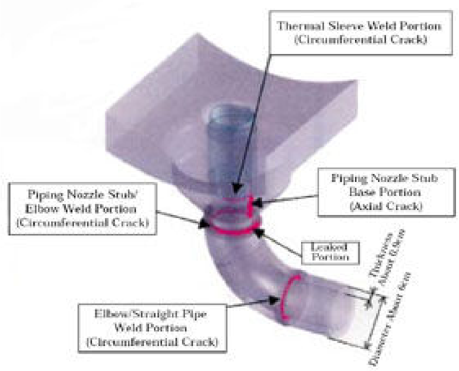


Figure 1. Outlet pipe of shell side of regenerative heat exchanger

For example, Fig. 1 shows thermal fatigue crack from the outlet pipe of shell side of regenerative heat exchanger (Tomari Power Station Unit-2, Japan) [4].

3. Methods and Results

3.1 Experimental Method

3.1.1 Block diagram of thermal fatigue crack producing apparatus

In order to produce thermal fatigue crack, was used a STS 304 tube with 89mm O.D. (t=7.7mm). The producing mechanism of thermal fatigue crack formation is shown Fig. 2.

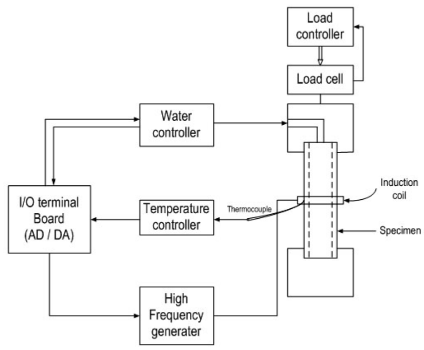
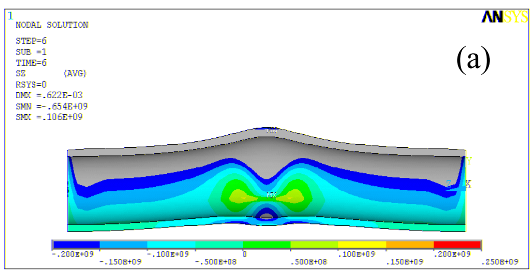


Figure 2. Mechanism of thermal fatigue crack formation

3.2 Experimental results

3.2.1 Thermal stress analysis using FEM

In order to produce thermal fatigue crack similar to realistic crack, successive thermal transients were applied to the specimen. Thermal transient cycles were combined with heating (30sec) and cooling cycle (30sec). In order to prevent intergranular crack by Cr carbide precipitation at the grain boundaries [5], the maximum temperature was restricted to 450℃. Fig. 3 show thermal stress contours at the end of heating and cooling cycle using ANSYS.



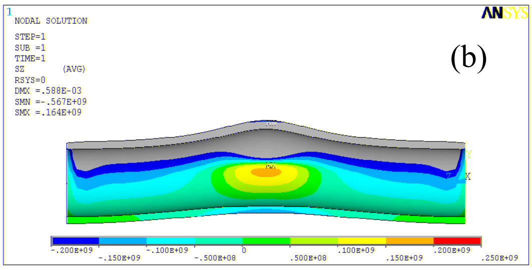


Figure 3. Thermal stress contours at the end of a) heating and b) cooling cycle

These results show that the maximum tension stress was occurred at the middle part of the inner surface at the end of cooling cycle.

3.2.2 Thermal fatigue crack

Fig. 4 shows a thermal fatigue crack (a) and branching of crack (b) which was developed after 25,000cycles. The depth of thermal fatigue crack was approximately 0.8mm.

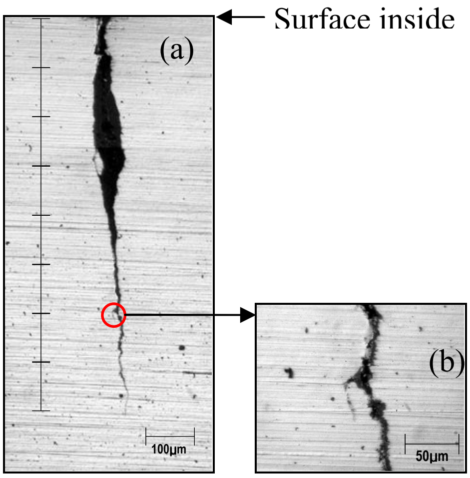


Figure. 4 Cross-sections of thermal fatigue crack

The crack path is tortuous. And the crack shows minor branching, they are narrow and the crack tip radii are small.

3.2.3 Fractographic morphology of fatigue

Fig. 5 shows SEM fractographics of thermal fatigue crack.

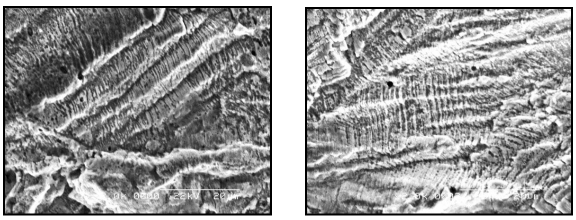


Figure 5. Fracture surface of thermal fatigue crack

Fig.5 shows the SEM micrographs from the fracture surfaces due to the thermal fatigue crack and it's fatigue striations on the fracture surface of thermal fatigue crack. Each fatigue striation represents an incremental advance of the crack front during one load cycle [6].

4. Conclusion

Thermal fatigue crack was artificially produced on STS 304 in order to produce mock-up specimens for the ISI of nuclear power plant components. Thermal fatigue cracks are propagated from inner surface to outer. The depth of thermal fatigue crack was approximately 0.8mm (25,000cycles). If this experiment is rerun a few more times, it will be possible to make perfect the reliability of NDT for nuclear power plants.

5. Acknowledgments

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