Study on cracking directions and crack initiation criteria in thermal fatigue crazing

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High cycle thermal fatigue crazing, defined as a network of unidirectional or multidirectional small and shallow cracks, was found on the inner surface of the pipes in the mixing zones of the RHRS in pressurized water reactor power plants. The high cycle thermal fatigue crazing is related to nuclear safety and attracts much international concern. However, the phenomenon is still not fully understood.

Different cracking directions were observed in the high cycle thermal fatigue crazing. The cracking directions are related to the orientation of the critical plane defined by the maximum damage. The analytical solutions of the critical plane orientation using Matake's and Fatemi-Socie's criteria, which are both modified for the damage accumulation, are first derived and validated by the computational results obtained from Code_Aster. The critical plane orientation seems not to significantly depend on the frequency, the amplitude and the mean value of the fluid temperature fluctuations, and the heat transfer film coefficient between the fluid and the pipe wall. It seems that the biaxial residual stress has strong effects on the critical plane orientation. The critical plane orientations are used to partially explain the observed cracking directions of the thermal fatigue crazing in the old residual heat removal system of the nuclear power plant.

A consistent crack initiation criterion is essential for the fatigue life estimation. Various crack initiation criteria for the 304L stainless steel under uni-axial and multi-axial fatigue loading conditions are evaluated by using the experimental data obtained from 225 uni-axial, bi-axial tension/torsion and bi-axial tension/compression fatigue tests for the 304L stainless steel. The results show that most criteria are consistent with the experimental data under uni-axial fatigue loading condition. However, very few criteria are consistent with the experimental data under

multi-axial fatigue loading condition. Two modified criteria appear to give better correlations than the existing criteria based on the proposed parameter for evaluation.

Key words: cracking direction; critical plane orientation; crack initiation criteria; multi-axial fatigue