Analysis on the Acoustic Emission Signals in the Crack Evolution of Steam Generator Tube

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1. Introduction

The evolution of a defect in steam generator (SG) tube during plant operation can be classified into the stages of initiation and propagation. However, the detection and discrimination of these two stages are difficult, and the real time monitoring of the defect evolution in plant operation is impossible. Moreover, it was generally known that the commercial non-destructive examination techniques such as eddy current test(ECT) can detect the defect already grown up to the size of more than 40% in tube wall thickness[1]. Therefore, the scope of the present study is to develop the fundamental technology for monitoring the degradation process from the initiation stage to the subsequent propagation stage by acoustic emission (AE) signal measurement.

2. Experiment

The degradation process was traced by monitoring AE signal emitted by crack initiation and propagation using the AE monitoring system in the course of manufacturing laboratory natural circumferential cracks on the outer surface of high temperature mill annealed (HTMA) Alloy 600 tubes, which were same as those used in the SG of OPR 1000 nuclear power plants[2,3]. The AE signals emitted during the development of circumferential crack from outer surface of tube were collected through piezoelectric AE sensors with measurement frequencies of 150 and 500 kHz, which were attached on the tube surface via wave guides. The AE events of hit, count, and energy were continuously recorded using the personal computer. After the occurrence of large energy in the AE signal, the crack manufacturing process was stopped and the fracture surface was carefully analyzed in order to scrutinize the relationship between the features of crack evolution and the corresponding AE events.

3. Results and Discussion

3.1. AE Signals and Crack Evolution

The AE signal evolved during the development of circumferential crack was monitored. Fig. 1 shows the variation of hits and energy of acoustic emission signal in the process of crack propagation, and the fractograph of the corresponding cracked specimen. Fig. 1-a represents the accumulated numbers of hits in the acoustic emission signal generated from the formation of new crack surfaces with time. It was found from the figure that the crack was initiated in the very early stage and the crack grew and propagated discontinuously with time. This observation can be confirmed by comparing the fractograph of Fig. 1-b. The results showed that the evolution of the cracks were divided by sequential process, that was, initiation of multiple micro-crack, coalescence to a single crack, through-wall penetration of a single crack and circumferential growth of a through-wall crack. Large acoustic energy was emitted when the crack penetrated through-wall, and it could be considered that the separation of the crack initiation stage from the crack propagation stage using the acoustic emission monitoring can be possible.

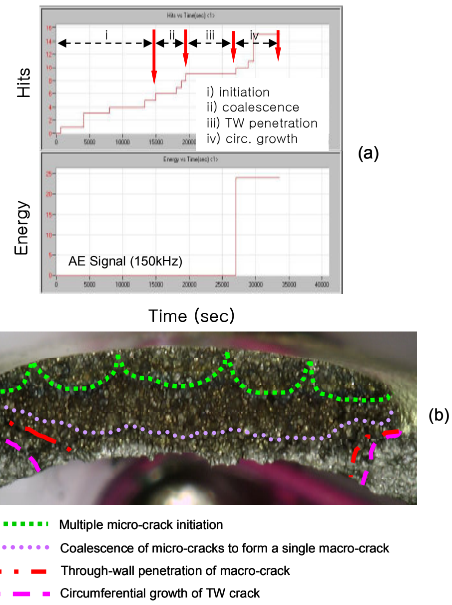

Figure 1. AE signal events(a) and corresponding fracture surface(b) in the evolution of a circumferential OD crack

3.2. Evaluation of Crack Propagation Rate

The possibility of the crack propagation rate measurement by monitoring acoustic emission events was evaluated under the condition of two different levels of applied stresses in the fabrication process of circumferential cracks. Fig. 2-a and 2-b are the results of acoustic emission signal monitoring in the evolution of cracks under the axial applied stresses of 245 and 236 MPa, respectively. The accumulated number of hits for two cases were counted to be 10 for the stress level of 245 MPa and 76 for the stress level of 236 MPa, and the average values of crack increment across the tube wall depth from the initiation to the through-wall penetration were calculated to be 107 ㎛/hit and 14 ㎛/hit, respectively. These results reflect that the frequency and total number of acoustic emission from the beginning to the through-wall penetration depend strongly on the magnitude of the applied stress, and the changes in the magnitude of crack increment depend upon the stress level and material characteristics. Therefore, it can be concluded that the in-situ measurement of the absolute crack propagation rate is difficult, but the average crack propagation rate across the tube wall can be quantified limitedly through the detection of crack initiation and through-wall penetration.

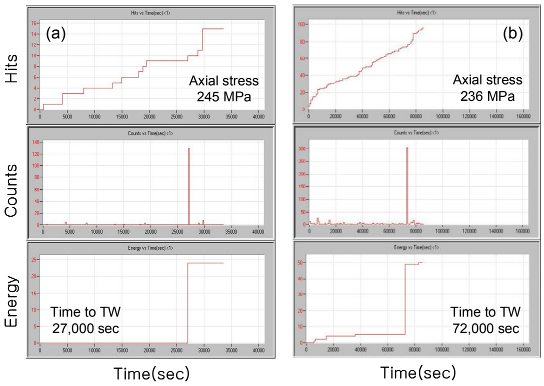

Figure 2. History of AE signal events in the evolution of circumferential OD cracks under the different axial stress

4. Conclusion

From this study, it was found that the separation of the crack initiation stage from the crack propagation stage using the acoustic emission monitoring could be possible. Even though the measurement of the absolute crack propagation rate by AE monitoring is difficult but the average crack propagation rate across the tube wall can be quantified limitedly through the detection of crack initiation and through-wall penetration.

Acknowledgement

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