Experimental and Numerical Assessments of Fatigue Fracture Phenomenon for Tube-to-Tubesheet Welded Joints of Shell and Tube Heat Exchangers

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A shell and tube heat exchanger (STHE) that performs thermal energy regulation process consists of a number of tubes, tubesheet and shell. The tubes are installed in the tubesheet and fabricated by welding. Then tube-to-tubesheet welded joints are involved in the STHE structural system and become the nominated area of fatigue fracture. In this study, the fatigue fracture characteristics are discussed through experimental and numerical methods of fracture mechanics aspect.

Since the overall STHE structural system is complicated, test specimens are developed based on the target STHE designs. In this study, two kinds of the STHE specimens are employed. The first specimen is the single tube test specimen and uses for the fundamental fracture behaviors. The second one is the multiple tube test specimen and employs for the distinctive fracture behaviors due to the surrounding tubes. The welded joint geometry, the layout of the tubes and material grades are the same with the target STHEs that are made up of advanced steel grades, austenitic and duplex stainless steels.

Fatigue test is carried out using the single and multiple tubes STHE specimens. The cyclic load amplitude is determined based on the operational situation of the target STHE structure. The fatigue fracture is initiated around the welded joint vicinity and crack propagation phenomenon is obtained. Numerical simulations are performed to discuss the fatigue testing results. Stress analysis of the intact model is conducted employing finite element method (FEM). An advanced fracture analysis, crack propagation (CP) simulation, is also performed employing extended finite element method (X-FEM) in Code_Aster. Special fracture modeling techniques such as the irregular-shaped crack representation and the particular CP program are required in this study.

The fracture characteristics are rigorously studied based on the fatigue test observations and numerical simulations. The fracture mechanics parameter is approximated. The fatigue strength is also evaluated based on the fatigue design standards. Finally, a series of experimental and numerical assessments is performed for the fatigue fracture phenomenon of the tube-to-tubesheet welded joints in the austenitic and duplex stainless steel STHEs.

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