DAMAGE MECHANISMS AND STATISTICAL METHOD FOR THE FATIGUE LIFE ESTIMATION OF COKE DRUMS

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The Coke drums are vertical pressure vessels used in the delayed coking process in petroleum refineries. They are typically constructed from low alloy carbon steel base plate and clad with stainless steel for resistance to corrosion. During one operational cycle, each location in the drum shell experiences a global temperature change cycle from arbitrary temperature to maximum temperature (450-480° C) and back to arbitrary temperature. Through finite element analysis on a global structural model, it is found that the clad could experience high tensile stress over its yield strength. This is due to mismatch of coefficients of thermal expansion (CTE) between the clad and base materials and relatively small clad thickness. During the quenching stage of the operation cycle, a high rate of quenching water is injected into the vessel to timely extract the solid coke. The water becomes non-uniform and random channeling flows due to the porous structure of coke mass. Therefore, random local hot and cold spots can be formed on the coke drum shell during the quenching stage. The hot/cold spot attacks induce significant local temperature differences and gradients, resulting severe local stresses/strains. Repeated hot/cold spot attacks at the same locations can cause accumulation of ratcheting strain (progressive local bulging). Under such severe global and local thermal-mechanical cyclic loading the coke drums are susceptible to cracking and sometimes associated with bulging deformation after few thousands or even less of operation cycles. To accurately predict the safety lives of coke drums, a statistical fatigue life evaluation method is proposed. To develop this method, thermal-mechanical cyclic fatigue tests of coke drum materials were firstly conducted to obtain strain-life curves, then simplified thermal-elasto-plastic analytical models were developed to calculate maximum equivalent strain amplitudes for global cycling and local hot and cold spot events. Statistical analysis of temperature data on a coke drum shell was also performed to get the probability distributions of the hot and cold spot events. The final statistical fatigue life evaluation model is based on Palmgren-Miner's damage accumulation rule. The fatigue life of a selected coke drum is hereafter estimated according to the maximum equivalent strain amplitudes in both cladding and base plate. The predicted fatigue life of the coke drum is about 5000 operation cycles, which is within the range of operation cycles to the first-through-thickness crack in coke drums, reported by American Petroleum Institute (API) survey. The evaluation methodology developed in this study can be employed to predict the safety lives of coke drums and is expected to be helpful for the design and maintenance of the equipment.