FAILURE MECHANISMS AND STATISTICAL METHOD FOR THE FATIGUE LIFE PREDICTION OF COKE DRUMS

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Abstract

Coke drums are major pressure vessels used 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, the drum shell experiences a global temperature change cycle from arbitrary temperature to maximum temperature about 480°C. Through finite element analysis on a global structural model, it is found that the clad could experience high tensile stress that over its yield strength. During the quenching stage of the operation cycle, a high rate of cold quenching water is injected into the vessel. 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 gradients, resulting severe local stresses/strains. Under such severe global and local thermal-mechanical cyclic loading the coke drums are susceptible to bulging deformation and cracking after thousands or even less of operation cycles as shown in Fig. 1.

Fig. 1 Bulging and Cracking in Coke Drums

To accurately predict the safety lives of coke drums, a statistical fatigue life evaluation method is proposed: Thermal-mechanical cyclic fatigue tests of coke drum materials were firstly conducted to obtain strain-life curves, then simplified thermal-elastoplastic 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 lives for three different combinations of base/clad materials are then estimated according to the maximum equivalent strain amplitudes in both cladding and base plates. The material combinations in case 1 and 2 are currently most commonly used coke drum materaials. The combination in case 3 is an optional combination we suggested for future new coke drums. The predicted fatigue lives of the

case 1 and 2 are in consistence with the survey data by the American Petroleum Institute (API). It can be seen that the suggested optional base/clad material combination would greatly extend the fatigue life of coke drums.

Table 1. Fatigue Life Comparison of three different combinations of base/clad materials

Fatigue Lives	Case 1 SA387/TP410S	Case 2 SA204C/TP410S	Case 3 SA302B/N06625
Clad	5.24E+03	6.27E+03	2.62E+04
Base	4.82E+03	8.47E+04	3.71E+04

The new evaluation methodology developed 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.