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A RATIONAL METHODOLOGY FOR DETERMINATION OF SERVICE LIFE FOR A DELAYED COKER DRUM

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ABSTRACT

Delayed unit coker drums operate in a severe service environment that precludes long term reliability due to excessive shell bulging and cracking of shell joint and shell to skirt welds. Thermal fatigue is recognized as the leading damage mechanism and past work has provided an idealized description of the thermo-mechanical mechanism via local hot and cold spot formation to quantify a lower bound life estimate for shell weld failure.

The present work extends this idealized thermo-mechanical damage model by evaluating actual field data to determine a potential upper bound life estimate. This assessment also provides insight into practical techniques for equipment operators to identify design and operational opportunities to extend the service life of coke drums for their specific service environments.

A modern trend of specifying higher chromium and molybdenum alloy content for drum shell material in order to improve low cycle fatigue strength is seen to be problematic; rather, the use of very low alloy materials that are generally described as fatigue tough materials are better suited for the high strain-low cycle fatigue service environment of coke drums. Materials such as SA 204 C (C – ½ Mo) and SA 302 B (C – Mn – ½ Mo) or SA 302 C (C – Mn – ½ Mo – ½ Ni) are shown to be better candidates for construction in lieu of low chromium alloy steel materials such as SA 387 grades P11 (1¼ Cr – ½ Mo), P12 (1 Cr – ½ Mo), P22 (2¼ Cr – 1 Mo) and P21 (3 Cr – 1 Mo).

INTRODUCTION

Coke drums are relatively large pressure vessels used in delayed coking units [DCU] to thermally crack reduced bitumen for the incremental recovery of hydrocarbon liquid and gas streams. The drums are usually paired, that is, there are two drums to ensure that operation occurs on a batch – continuous basis. Some unit operators use a three drum arrangement and many units operate with 4 to 6 drums and even 8 drums in the DCU. The drums are one of the more costly vessels in an oil sands or conventional refinery facility due to their large size and perceived need for higher alloy materials of construction. Due to the need for corrosion resistance and normal operating temperature sometimes exceeding 482 °C [900 °F], materials range from C – ½ Mo to 3Cr – 1 Mo low alloy ferritic steels with a majority of units fabricated from low alloy selections of 1¼ Cr – ½ Mo and 2¼ Cr – 1 Mo [1]. In addition to the base material, an internal cladding material is provided for essential corrosion protection; this clad material typically consists of TP 405, TP 410 or TP 410S stainless steel of 12 ½ % or 13% Cr. Design loads and practices will determine the shell wall thicknesses which vary between 19 mm to 50 mm [¾" – 2"], for vessel diameters ranging from 6000 mm to 9200 mm [20' to 30'] in diameter and 26 m to 32 m [85' to 105'] in height. The vessel is a thin shelled axisymmetric structure. Past design practice has been to vary drum thickness over the height of a drum to take advantage of reduced hydrostatic loading at upper elevations; some recent practices use a uniform shell thickness and flush joint welds to eliminate geometric discontinuities. The benefit is a reduction in strain / stress concentration factor [SCF] which improves fatigue life. Cladding thickness is typically about 3 mm [0.120"].

Prior work has shown the severity of three thermal stresses that are not routinely accounted for in the usual ASME VIII Division 1 design of coker drum vessels [2, 3], namely, the thermal stresses due to

- the differing coefficients of thermal expansion between base, cladding and weld materials
- the formation of "hot" and "cold" spots on the shell
- the axial temperature gradients during water quench

