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Fitness For Service Assessment of Spherical Oxygen Storage Vessel

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ABSTRACT

API Recommended Practice 579 was applied to assess internal surface cracks in the heat-affected-zone of the seam welds in a spherical vessel of oxygen holder made of SA516 Gr. 70 steel. Because of uncertainty in the procedures determining material fracture toughness, welding-induced residual stresses, and the plasticity effect, it was decided to conduct a comparative study on the assessment procedures between API579 and the British Standard BS7910 using a cracked plate model. The purpose of this exercise is to understand the sensitivity of various data assumptions to the assessment results and to verify the results of FEA. This comparative knowledge enables a more realistic interpretation of the assessment results for the distressed vessel.

Level II assessment based on FAD was applied to assess the acceptability of three surface cracks of different sizes (0.18 to 0.56 inches in depth and 0.39 to 3.94 inches in length) and aspect ratios (0.13 to 0.45). Through-thickness, transverse stress distribution and various approaches to estimate the material toughness, including actual test data and ASME UCS66, were included in the sensitivity study. The lower bound K_{mat}-CVN correlations for both lower-shelf and upper-shelf fracture behaviors and the Master Curve were studied to understand their effect on the K_{mat} estimate. The different approaches in determining the plasticity adjustment factors and their sensitivity to the relative plastic zone size resulting from the respective principle load and the secondary residual stresses were also investigated.

The primary source of deviation in the FAD assessment results comes from the K_{mat} estimate and the validity of the CVN data. When the through-thickness residual stress distributions are linearized, the API distribution shows different values of membrane and bending stresses for different crack sizes, while BS distribution shows practically the same for all crack sizes. Such difference causes different estimates in toughness ratios. The cracking conditions existing in the oxygen holder vessel are acceptable if the test CVN data is used in the assessment. However, the cracking conditions are likely to fail if the ASME guideline for K_{mat} is used. Care must be exercised if the test data is unavailable. The surface crack on the oxygen spherical vessel are performed the FEA and based on the API 579 guideline and the results are followed. The result for the deeper point of the crack was identical with API guideline within 6%, but it appears so many differences in the surface and that should be considered when assessment of crack growth is performed. When the assessment considering the residual stress is preformed on the crack, it presented that worst case crack would excess the safety zone of the FAD. This shown that the material is assumed for brittle fracture and if the material shows the mode of ductile fracture then the JR curve measurement and the J-T analysis would be required to be more accurately.

KEY WORDS: Fitness-For-Service (FFS), Failure Assessment Diagram (FAD)

INTRODUCTION

Several application standards specifying requirements for weld flaw acceptance levels based on fitness-for-service (FFS) have been published over the past fifteen years. The assessment is a multi-disciplinary engineering analysis of equipment or structure to determine if it is fit for continued service until the end of a desired period of operation. API Recommended Practice 579(2000) provides a general procedure for assessing FFS of process equipment, such as pressure vessels, piping, and tanks, operating in the petroleum and chemical industry. The British Standard BS 7910(1999) is a more generic FFS guide outlining methods for assessing the acceptability of flaw in all types of structures and components. Both guides utilize a failure assessment diagram (FAD) applied to crack-like flaws. The assessment procedures of both standards are similar using three different assessment levels with reducing conservatism but increasing analysis complexity. The Level I assessment procedure is intended to be conducted primarily by plant inspection personnel. The Level II procedure is to be conducted by plant or corporate engineering personnel. The Level III procedure should be conducted by experienced corporate FFS personnel.

Although the assessment procedures are similar for both guides, there are differences in handling the assessment details, such as evaluation of reference stress, material toughness, residual stresses, plasticity effect, etc. This paper reviews the procedure details of both guides using a cracked plate model and then applies API 579 to assess the flaw conditions in a welded spherical oxygen holder. Three surface cracks of different sizes and aspect ratios (depth-to-length ratio) varying from 0.13 to 0.45 were revealed in the weld heat-affected-zone during a scheduled turnaround inspection. Level II assessment was applied with