Stress-oriented hydrogen-induced cracking (SOHIC) in H2S environments

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ABSTRACT

Hydrogen damage in wet H_2S environments is classified as Blistering, Hydrogen-induced cracking (HIC), Stress-oriented hydrogen-induced cracking (SOHIC) or Sulfide stress cracking (SSC) in API 571 recommended practice [1] while the assessment of hydrogen damage is performed in accordance with API 579 [2]. While hydrogen blistering and HIC is a frequent problem when steel operates in wet H_2S service, SOHIC is a rather rare phenomenon and when occurring is mostly associated with residual stresses at welds. SOHIC in pipelines and pressure vessels has been thoroughly reviewed by Pargeter [3] and actally most of the case studies reported, associated with SOHIC, are related with SOHIC at welds and concern mostly pipelines. In the present work we report on a SOHIC cracking of a pressure vessel for hydrocarbon/amine processing. The vessel was originally constructed of a HIC-resistant steel. The investigation methodology included metallography, scanning electron microscopy, tensile testing and impact testing.

Figure 1: Characteristic crack path during SOHIC

The results indicated that SOHIC proceeds in two steps: (a) initiation of small HIC cracks lying in the rolling plane and stacked in a direction normal to the applied stress, (b) through thickness linking of HIC cracks (see Figure 1). The propagation of the HIC cracks as well as the through-thickness link cracks is associated to cleavage fracture mechanisms.

The key factors identified in this failure were: (a) short periods of high hydrogen charging conditions as manifested by high H_2S/MDEA ratios and (b) stress triaxiality imposed by the relatively large thickness of the plate. The results indicated that a HIC-resistant steel might not be immune from SOHIC. Under high hydrogen charging conditions HIC cracks can initiate at interfaces other than stringer-type inclusions, such as ferrite/pearlite interfaces in the microstructure of the steel.

References

[1] API RP 571, Damage mechanisms affecting fixed equipment in the refining and petrochemical industries, American Petroleum Institute, Washington, D.C., 2011.

[2] API RP 579, Fittness-for-service, American Petroleum Institute, Washington, D.C., 2007.

[3] R.J. Pargeter, Susceptibility to SOHIC for linepipe and pressure vessel steels – review of current knowledge, NACE Corrosion 2007 conference, 11-15 March Nashville, Tennessee, NACE document 07115