Member report Number: 1072/2016

Industrial Member Report Summary – Key Findings for Industry

Assessment of Limit Loads for Circumferential Embedded Flaws in Pipes

TWI Core Research Programme

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Industrial need

The use of engineering critical assessment (ECA) to derive flaw acceptance criteria for welded joints allows the maximum tolerable size of planar flaws to be determined on a fitness-for-purpose basis. The most commonly used approach to assess metallic structures containing flaws for fracture is the failure assessment diagram (FAD), which involves the calculation of a plastic collapse parameter, L_r, and a fracture parameter (K_r). The plastic collapse parameter characterises the proximity to failure by yielding mechanisms and is defined as either a ratio of the applied load to the limit load, or equivalently, the ratio of the reference stress to the yield strength. The relationship between the parameters L_r and K_r is given by a Failure Assessment Line (FAL).

The work described in this report concerns the calculation of the reference stress (or limit load) for use in FAD-based fracture assessments of circumferential embedded (buried) flaws in pipes. Flaws of this type (caused, for example, by lack of sidewall fusion) are of considerable practical importance in pipeline construction and operation, but their analysis presents particular problems because of anomalies in some of the most widely-used assessment procedures.

Key Findings

The main conclusions of this study are:

- Various engineering approximations have been proposed based on the limit load/reference stress solutions in R6 and BS 7910. These include applying a safety factor (>1.0) to the (R6) global limit load solution, applying an 'enhancement factor' (>1.0) to the BS 7910 reference stress solution (equivalent to applying a safety factor of <1.0 on the limit load solution), or treating the embedded flaw as if it were actually surface-breaking (DNV OS F101). Hitherto, these approximations have not, for the most part, been 'calibrated' against experimental results or numerical analyses.
- An alternative approach to the calculation limit load/reference stress is to use Finite Element (FE) Analysis, adopting either a spreading plastic zone method or a J-based method. The latter requires direct elastic-plastic FE modelling of a flawed component, then forcing a fit between the Option 3 FAD produced by FEA and the Option 1/Option 2 FAD as defined in R6 and BS 7910.
- The re-examination of an earlier study (Cheaitani and Goldthorpe, see below reference) revealed some parametric formulae for limit load to be potentially unsafe, unless a safety factor is applied: these include the R6 global solutions for both fixed-grip and pin-jointed conditions and the DNV-OS-F101 solution. Conversely the BS 7910 solution and R6 local pin-jointed collapse solution were shown to be very conservative.
- By employing J-based limit load calculations for the re-analysis of the embedded flaw in a specimen from the Canadian Pipe Bend trials, some of the conservatism arising from the use of flat plate solutions in R6 and BS 7910 can be removed.

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