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Abstract

This paper covers the development of tensile strain design models using a multidisciplinary approach, including fundamental fracture mechanics, small-scale material characterization tests, and large-scale tests of full-size pipes. The tensile strain design models are formulated in a four-level format. The Level 1 procedure provides estimated tensile strain capacity (TSC) in a tabular format for quick initial assessment. The initiation toughness alternatively termed apparent toughness is estimated from upper shelf Charpy impact energy. The Level 2 procedure contains a set of parametric equations based on an initiation-control limit state. The tensile strain capacity can be computed from these equations with the input of a pipe's dimensional and material property parameters. The apparent toughness is estimated from either upper shelf Charpy energy or upper shelf toughness of standard CTOD test specimens. The Level 3 procedure uses the same set of equations as in Level 2 and the toughness values are obtained from low-constraint tests. In the Level 3 procedure, two limit states based on either initiation control or ductile instability can be used. The Level 4 procedure allows the use of direct FEA calculation to develop crack driving force relations. The same limit states as those in Level 3 may be used. The Level 4 procedures should only be used by seasoned experts in special circumstances where lower level procedures are judged inappropriate. The tensile strain design models may be used for the following purposes: (1) The determination of tensile strain capacity for a given set of material properties and flaw size. (2) The determination of acceptable flaw sizes for a given set of material properties and target tensile strain capacity. (3) The selection of material properties to achieve a target strain capacity for a given flaw size. (4) The optimization of the tensile strain capacity by balancing the requirements of material parameters, such as weld strength (thus weld strength mismatch level) versus toughness. The application of the tensile strain design models is given in a companion paper.

Keywords

Pipeline, Strain-based design, Girth weld, Toughness, Tensile strain design