Liu, B., Wang, Y.-Y., Chen, X., Warman, D., 2020, Effects of Biaxial Loading on the Tensile Strain Capacity of Girth Welds with Weld Strength Undermatching and HAZ Softening, Proceedings of the 13th International Pipeline Conference, Paper No. IPC2020-9663, September 28- October 1, 2020, Calgary, AB, Canada.

Abstract

The ability to accurately estimate the tensile strain capacity (TSC) of a girth weld is critical to performing strain-based assessment (SBA). A wide range of geometry, material, and loading factors can affect the TSC of a girth weld. Among the influencing factors, the internal pressure level has been shown to exhibit a relatively simple relation with TSC: at low pressure levels, increasing internal pressure roughly proportionally reduces the TSC; at pressure factors beyond 0.5 – 0.6, the TSC becomes insensitive to internal pressure. The pressure factor is defined as the ratio of the nominal hoop stress induced by pressure to the yield strength (YS) of the pipe material.

The overall influence of internal pressure is usually quantified by a TSC reduction factor, defined as the ratio of the TSC at zero pressure to the lowest TSC typically attained at pressure factors around 0.5 – 0.6. A number of numeric and experiment studies have reported a TSC reduction factor of 1.5 – 2.5. These studies generally focused on strain-based designed pipelines with evenmatching or overmatching weld, minimum heat affected zone (HAZ) softening, and a surface breaking flaw at the weld centerline or the fusion boundary.

This paper examines the effects of pipe internal pressure on the TSC of girth welds under the premise of weld strength undermatching and HAZ softening. The interaction of biaxial loading and the local stress concentration at the girth weld region was quantified using full-pipe finite element analysis (FEA). The relationship between TSC and the internal pressure level was obtained under several combinations of weld strength mismatch and HAZ softening. Results from the FEA show that the effects of pipe internal pressure on the TSC are highly sensitive to the material attributes in the girth weld region, and the traditionally assumed reduction factor or 1.5 – 2.5 may not be accurate under less favorable weld strength undermatching and HAZ softening conditions. Further, the location of tensile failure is found to depend on both the weld material attributes and the internal pressure. It is possible for the failure location to shift from pipe body at zero internal pressure to the girth weld at elevated internal pressure levels. The implications of the results on both girth weld qualification and integrity assessment are discussed.

Keywords

Engineering assessments, HAZ softening, integrity management, properties of girth welds, strain based design, tensile strain capacity, weld qualification