

S. Rapp¹ and Y.-Y. Wang, Low Strain Capacity of X70 Pipeline Girth Welds and its Implications on Linepipe Steels, AIST 2018.

Abstract

There has been a number of in-service girth weld failures of newly constructed pipelines in recent years. Girth weld failures have also been observed during pre-service hydrostatic testing. There were no anomalies exceeding the acceptance limits of industry standards, such as API 1104, in those failed welds. These welds were fabricated, inspected, and accepted per industry acceptance standards. The linepipes met the requirements of industry standards, such as API 5L. The loads on these welds tended to be higher than those on most welds in cross-country pipelines, but still within the expected range for normal pipeline construction and service conditions. In some cases, failures occurred at an applied strain of less than 0.5%. From historical experience, these failures were not expected.

Metallurgical, structural, and fracture mechanics analysis to date indicate the primary contributing factors are: (1) unintentional weld strength undermatching, (2) heat-affected zone (HAZ) softening, (3) weld bevel geometries of manual stick welding processes that favor tensile failure through plastic straining along the softened HAZ, and (4) elevated stresses/strains from normal settlement and other loads.

In examining the history of linepipe steel manufacturing, it is noted that modern control-rolled and microalloyed steels could have very low hardenability, which is a major contributor to HAZ softening. In addition, these steels tend to have low strain hardening and low uniform elongation which can reduce their tolerance to anomalies and deformation. Some of the drivers for the new steel chemistry and processing routes were to increase toughness and to reduce the susceptibility to hydrogen-assisted cracking in the HAZ, while increasing the overall strength of the steels (grade). It appears that these approaches may have led to unintended negative consequences.

This paper starts with a review of recent girth weld incidents. A few key features of a failed weld and their implications are examined. The characteristics of all failures are summarized and the major contributing factors known to date are given. Various ongoing and planned initiatives aimed at remediating these types of failures are briefly summarized. Trends in steel making processes, the resulting changes in steel properties, and the implications of such properties in pipeline service are reviewed. Possible directions for changes in steel making and the testing and qualification requirements of linepipes are provided.

Keywords

Linepipe properties, Strain hardening, Hardenability, Girth weld, HAZ softening, Strain capacity