Abstract

A weld quality control approach developed for the welding of high-strength pipeline steels has demonstrated its effectiveness in achieving reliability and consistency in the mechanical performance of girth welds. Using a predictive tool that can relate cooling times of welding thermal cycles with welding parameters and with the knowledge of microstructure responses of both pipe materials and weld metals to welding thermal cycles, the approach can evaluate the effects of welding parameters on weld properties and identify the essential welding variables. As a result, the essential welding variable approach can be used to optimize and help shorten the process of welding procedure development.

The current paper presents the application of the essential welding variable approach to the girth welding of X80 pipeline steels.

The application started with the selection of pipe materials, welding consumables, and candidate welding procedures. The selection of actual weld procedures and a welding matrix were made after the candidate welding procedures were analyzed in terms of cooling times. Girth welds for two X80 pipes of different chemical compositions, outside diameters, and wall thicknesses were made with single and dual torch GMAW-P processes and a range of welding consumables. The welding parameters were monitored and recorded for all welds; and the thermal cycles of selected welds were measured by thermocouples.

Small-scale testing, including all-weld-metal tensile test, Charpy impact toughness and CTOD fracture toughness tests, were evaluated and correlated with microstructures formed in the HAZ of the girth welds. The material responses of heat-affected zone (HAZ) to thermal cycles of typical GMAW-P single and dual torch processes were experimentally simulated (Gleeble®). Detailed welding thermal cycle analyses were conducted based on the measured welding parameters. Cooling times of welding thermal cycles for the girth welds were calculated and correlated with the material responses, of X80 pipe steels to welding thermal cycles. The correlation demonstrated very good consistency between the cooling times, the results of the Gleeble simulation, and the mechanical properties of the girth welds. The dependency of the weld properties on welding parameters was analyzed in terms of cooling times, and the optimization strategy for development of welding procedures that offer more balanced welding properties between strength and toughness was evaluated by adjusting the essential welding variables. In summary, the process of applying the essential welding variable approach and the results from the tests and the analyses showed that the approach is capable of evaluating the effects of welding parameters on weld properties, identifying the essential welding variables, and ultimately optimizing welding procedures.