Dekhane, A., Wang, A., Wang, Y.Y. and Quintana, M., 2016, Application of Thermal Analysis Tool for Girth Welding Procedure Qualification, Proceedings of the 11th International Pipeline Conference, Paper No. IPC2016-64629, September 26-30, 2016, Calgary, AB, Canada.

Abstract

The mechanical properties of welds are governed by the final microstructure that develops as an interaction between the chemical composition and cooling rates produced by welding thermal cycles. For welds in modern microalloyed thermomechanically controlled processed (TMCP) pipeline steels, the microstructure and mechanical properties can be extremely sensitive to cooling rates. The development and qualification of welding procedures to achieve targeted mechanical properties is often an iterative process. Accurate knowledge of welding thermal cycles and cooling rates as a function of welding parameters is valuable for optimization of welding process development.

This paper covers the development, validation, and application of a girth welding thermal analysis tool. The core of the tool is a numerical model that has a two-dimensional, axi-symmetrical finite element procedure to simulate the transient heat transfer processes both in the weld metal and the heat affected zone (HAZ). The tool takes welding parameters, pipe and bevel geometry, and thermal properties as inputs and predicts thermal cycles and cooling rates in weld metal and HAZ. The comparison of thermal cycles between experimental measurements and the model predictions show the tool was robust and accurate.

This tool is particularly effective in understanding the thermal history and resulting microstructure and mechanical properties of welds produced with high-productivity gas metal arc welding (GMAW), such as mechanized dual-torch pulsed gas metal arc welding (DT GMAW-P). The tool was used in optimization of development and qualification of welding procedures of a DT GMAW-P process under a tight time schedule. The actual welds were fabricated according to the optimized welding procedures followed by the mechanical testing of welds. Good agreement was found between the predicted tensile properties and those from experimental tests. The welding procedures were qualified within the tight time schedule by avoiding iterative trials, and reducing the cost associated with the making of trial welds and mechanical testing by approximately 50%. This tool has also been applied in the application of essential welding variables methodology (EWVM) for X80 and X70 linepipe steels [1, 2].

Future applications of the tools include the revamp of the approach to essential variables in welding procedure qualification. In particular, the parameters affecting cooling rates may be “bundled” together towards the one critical factor affecting weld properties, i.e., cooling rate. The individual parameters may be varied beyond the limits in the current codes and standards as long as their combined effects make the cooling rate stay within a narrow band. It is expected that the same framework of approaches to GMAW processes can be extended other welding processes, such as FCAW and SMAW.