P6 In Situ Weld Metal Continue Cooling Transformation Diagrams

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Continuous cooling transformation (CCT) diagrams illustrate the evolution of microstructure in welded joints as a function of the weld cooling rate. These diagrams allow the welding engineer to select the range of cooling rates, and the respective operational window of heat inputs, that provides optimal combination of microstructural constituents in the heat affected zone (HAZ) and weld metal. Thus the CCT diagrams serve as a valuable tool in controlling the final microstructure and mechanical properties of welded joints.

The CCT diagrams are typically constructed by simulating weld thermal histories over laboratory scale specimens. This approach is limited in depicting the actual heating/cooling rates and thermal gradients, and utilizes expensive, specialized equipment. It is not applicable for investigating the weld metal solidification and solid-state phase transformations, and respectively for constructing weld metal CCT diagrams.

A novel single sensor differential thermal analysis (SS DTA) technique for in situ investigation of phase transformations in welded joints has been recently developed at the Welding Engineering Laboratory of The Ohio State University. Compared to the available techniques for in situ thermal and differential thermal analysis, the SS DTA has superior sensitivity to the heat effects of phase transformations and higher accuracy for determining the phase transformation temperatures.

The capability of the SS DTA technique for investigating the solidification range and solid–state phase transformations under actual welding conditions is demonstrated in the present work by constructing a weld metal CCT diagram. This CCT diagram covers the phase transformations of weld metal produced using an E6010 consumable in the $t_{8/5}$ range between 2 and 10 seconds and is supplemented by photomicrographs.

The weld metal microstructure is analyzed and the measured phase transformation thermal effects are related to the respective microstructural constituents. Valuable information is provided about the microstructure evolution of E6010 weld metal in the typical range of cooling rates for SMAW. The presented investigation proves that the SS DTA technique has tremendous application potential in development of welding consumables and development/testing of welding procedures.