Metallurgical Reactions in Flame Reheated High Performance Steels
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Thermal cycles associated with welding and flame straightening produce heat affected zones with properties predictable using physical simulations. The governing solid-state phase transformations were found to be dependent on the processing history of the steels

ABSTRACT

As High Performance Weathering steels with 70 ksi minimum yield strength (HPS 70W) have gained more acceptance in the bridge building industry, there has been a need to increase productivity using welding processes such as the recently approved Narrow Gap Improved Electroslag Welding. Flame straightening and curving (cambering) are also routinely used during bridge fabrication and repair on High Performance steels. However, the overall effect on the microstructure and properties of the heat affected zone (HAZs) of these two special thermal processing types have not yet been established.

Actual welding and flame reheating experiments were combined with physical simulations using the Gleeble 1500 systems to characterize the HAZ solid-state transformations. The effects of peak temperature, holding time and cooling rates were studied on two types of steel having the same chemical composition: Quenched-and-Tempered (Q&T) and Thermal Mechanical Control Processed (TMCP) versions of HPS 70W. The potential effects on the HAZ of excess carbon or oxygen caused by unadjusted oxyacetylene flame were also measured. Tensile and impact toughness were measured and optic and electron microscopy were used for post simulation metallographic analysis.

It was found that the metallurgical signature of the steel thermal-mechanical history was erased in the Coarse Grained HAZ of high heat input welds because both types of steels have essentially the same chemistry and undergo complete re-austenitization. The HAZ toughness decreased with heat input as the amount of grain boundary ferrite increased in both steel types. However, at intercritically reheated peak temperatures, the Q&T and TMCP behaved differently. In the TMCP samples partial recrystallization along the banded microstructure and subsequent variation in through-thickness properties caused larger scatter in toughness than seen in the Q&T product. Hardness measurements, which are typically used to verify whether excessive flame reheating temperatures were used, did not reflect these changes. Indeed, the ultimate tensile strength did not vary with peak temperature, but the yield strength and toughness dropped significantly after exceeding the recommended maximum flame reheating temperature.

Cooling rates also changed the yield strength in the HAZ, while holding times at high temperature did not seem to have any effect on the microstructure and properties. Repeated thermal cycles had a negative effect on the flame reheated areas, while both excess carbon and oxygen in these regions increased hardness, reduced ductility and toughness.

It was concluded that a series of simulative test should be performed for flame straightening/curving for each batch of plate steels received, preferably before manufacturing, to ensure compliance with minimum mechanical properties requirements. The information developed will be useful for welded HPS steel users such as bridge builders.