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Dynamics of Phase Transformations and Microstructure Evolution in Carbon-Manganese Steel Arc Welds using Time-resolved Synchrotron X-ray Diffraction

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Abstract

Phase transformations that occur in both the heat affected zone (HAZ) and fusion zone (FZ) of a carbon-manganese steel spot weld have been investigated using time resolved x-ray diffraction (TRXRD) with time resolutions down to 50ms. It is found that in both zones, the α(fcc) to β(bcc) transformation on cooling is twice as fast as the forward transformation of α - β upon heating. Profile analysis of the major Bragg reflections recorded in the TRXRD patterns reveals similarities and differences in the microstructural evolution with time in the HAZ and in the FZ. The latter undergoes melting and solidification in addition to solid state transformations. With increasing temperature, the (110) d-spacing of the a-phase prior to and during the transformation and the (111) d-spacing of the g-phase just after the same transformation exhibit a decrease. The observed (and unusual) lattice contraction with temperature rise may be attributed to chemical effects such as carbide precipitation in the a matrix, and/or mechanical effects due to stress relief. In the FZ, the α-Fe that forms has a preferential (200)-texture upon solidification of the liquid, whereas upon cooling in the HAZ, the α-Fe retains largely a (111)-texture induced in the α - β transformation on heating. Upon cooling in the HAZ, the width of the g(111) reflection increases initially, indicative of micro-strain developing in the fcc lattice, but decreases as expected with reduction of thermal disorder upon further cooling all the way to the completion of the α - β transformation. In the FZ, however, the micro-strain in the g-phase increases steadily upon solidification, and more rapidly in the entire duration of the α - β transformation on further cooling. The final microstructure of the FZ is likely to consist of a single a-phase dispersed in two morphological entities, whereas in the HAZ, the a-phase persists in one morphological entity in the final microstructure.