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Nonequilibrium Phase Selection during Weld Solidification of Fe-C-Mn-Al steels*

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The phase selection phenomena as a function of composition and interface growth velocity were investigated in Fe-0.2C-0.5Mn-Al (wt.%) self-shielded flux cored arc weld metal deposits. Two aluminum concentrations (1.8 and 3.7 wt.%) were investigated to observe different δ-ferrite stabilizing effects on the microstructure. Under normal weld cooling conditions, the primary solidification in these steels occurs by δ-ferrite formation, however, solidification morphology changes at high cooling rates. The changes in weld cooling rates were produced by changes in the arc welding conditions, and it was shown that, above a critical interface velocity, a shift was induced in the primary solidification mode to nonequilibrium austenite. Moreover, the change in primary solidification mode occurred irrespective of aluminum concentration. The above phase selection phenomenon was tracked in-situ using a time-resolved X-ray diffraction technique employing Synchrotron radiation. Using the theoretical treatment of dendritic solidification and phase selection maps advanced by Kurz and his co-workers, the microstructure evolution at high weld solidification rates was evaluated. The dendrite growth theories for multicomponent solidification suggest that phase selection in this alloy system may be closely related to high carbon concentrations in these steels that cannot be trapped in the δ-ferrite phase at high solid-liquid interface velocities. This in-turn leads to enrichment of carbon in the liquid phase and the subsequent change in primary solidification mode from primary δ-ferrite to nonequilibrium austenite.

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