Selective oxidation of Mn alloyed steels during annealing prior to galvanizing

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Advanced high strength steels (AHSS) are widely used in automotive industries to reduce the weight of car bodies and thereby reducing fuel consumption and CO_2 emissions. To protect AHSS against corrosion, a zinc coating is usually applied to the surface by hot-dip galvanizing. During the hot-dip galvanizing process, the steel strip passes through continuous annealing furnaces before entering the zinc bath. The final annealing atmosphere is usually a gas mixture of N_2 and H_2 with some water vapor. However, the alloying elements in AHSS, such as Mn, Si, Cr, Al etc., can form stable oxides during this annealing process prior to galvanizing. These alloying element oxides at the steel surface reduce the zinc wettability and hence impair the quality of the galvanized steel product. Therefore, understanding the behavior of selective oxidation of AHSS can benefit the steel industry in terms of designing new steel grades and optimizing annealing process.

In order to predict the type of oxides formed during annealing of the selected AHSS, the Fe-Mn, Fe-Mn-Cr and Fe-Mn-Cr-Si phase diagrams for oxidizing environment are computed with the thermodynamic tool FactSage. The oxide phases formed during annealing are predicted as a function of alloy composition, temperature and oxygen partial pressure of the annealing atmosphere. To validate these phase diagrams, Fe-Mn steels with different concentrations of Cr and Si were annealed at 950 °C in a gas mixture of Ar with 5 vol.% H2 and dew points ranging from -45 to 10 °C. The identified oxide species after annealing match with those predicted based on the phase diagrams.

The dependence of oxide composition on oxygen partial pressure can also be well predicted for Fe-Mn steel alloys. The composition of oxide precipitates as a function of depth can be computed with the thermodynamic tool as long as the local oxygen activity is known. As an example, the Fe concentration dissolved in the internal $(Mn_x,Fe_{1-x})O$ as a function of depth was measured after annealing a Mn alloyed steel. This measured composition depth profile of internal $(Mn_x,Fe_{1-x})O$ precipitates matches the composition profile as predicted. This indicates that local thermodynamic equilibrium is established during annealing of Mn alloyed steels. Thus, the thermodynamic tool FactSage can be applied for numerical simulation of internal oxidation behaviour of AHSS.