Invited paper to be presented at Calphad XXXII, La Malbaie, Quebec, Canada, May 25-30, 2003

"Calculation of Ferrite Content in Stainless Steel Welds and Castings"

J. M. Vitek and S. S. Babu
Oak Ridge National Laboratory
P. O. Box 2008
Oak Ridge, Tennessee 37831-6096
U. S. A.

Prediction and control of the ferrite content in stainless steel welds and castings is critical because the ferrite content is directly related to mechanical properties and corrosion resistance and it is indirectly related to hot cracking behavior. Traditionally, empirical tools have been used for the prediction of ferrite content as a function of alloy composition. More recently, a neural network model has been developed that includes consideration of cooling rate as well as alloy composition. However, these techniques do not rely on fundamental principles when making predictions. Furthermore, there are numerous areas for potential errors when developing these empirical models based on experimental data. Therefore, a model based on sound metallurgical principles is preferred. Computational thermodynamics (ThermoCalc), coupled with diffusion kinetic modeling (Dictra) have been used to calculate directly the residual ferrite content in stainless steel welds and castings. This method proves to be accurate in predicting the final ferrite content. This approach has been particularly useful in explaining experimental results on cross-sections of chill-cast ingots. The characteristics of the ferrite distribution in such castings do not fit with intuitive estimates based on solidification behavior, including the potential for a change in solidification mode at high cooling rates. The solidification mode was first calculated by coupling interface response function models based on thermodynamic information. These calculations showed that a change in solidification mode from ferrite to austenite for cooling rates typical of chill-cast ingots was unlikely. However, calculations based on computational thermodynamics and kinetics models predicted that the austenite content at room temperature is determined by a combination of cooling rate at the liquidus, which determines the dendrite arm spacing, and the cooling rate at lower temperatures which controls the solid-state ferrite-to-austenite transformation. The predicted results agree with the experimental observations. Furthermore, these models shed light on the critical factors that are most influential in determining the final residual ferrite level and its distribution across the casting.

This research was sponsored by the Division of Materials Sciences and Engineering, U. S. Department of Energy, under contract DE-AC05-00OR22725 with UT-Battelle, LLC.