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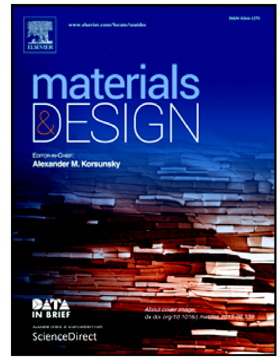

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Frank Niessen, Niels S. Tiedje, John Hald

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Kinetics modeling of delta-ferrite formation and retainment during casting of supermartensitic stainless steel

Frank Niessen[1*], Niels S. Tiedje[2] and John Hald[3]

[1]Technical University of Denmark (DTU), Danish Hydrocarbon Research and Technology Centre (DHRTC), Elektrovej building 375, 2800 Kgs. Lyngby, Denmark; frannie@dtu.dk

[2]Technical University of Denmark (DTU), Department of Mechanical Engineering, Produktionstorvet building 427, 2800 Kgs. Lyngby, Denmark; nsti@mek.dtu.dk

[3]Technical University of Denmark (DTU), Department of Mechanical Engineering, Produktionstorvet building 425, 2800 Kgs. Lyngby, Denmark; jhald@mek.dtu.dk

*Corresponding author

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Abstract

The kinetics model for multi-component diffusion DICTRA was applied to analyze the formation and retainment of δ-ferrite during solidification and cooling of GX4-CrNiMo-16-5-1 cast supermartensitic stainless steel. The obtained results were compared with results from the Schaeffler diagram, equilibrium calculations and the Scheil model in Thermo-Calc, and validated by using microscopy and Energy Dispersive X-ray Spectroscopy for chemical analysis on a cast ingot. The kinetics model showed that micro-segregation from solidification homogenizes within 2 - 3 s (70 °C) of cooling, and that retained δ-ferrite originates from the incomplete transformation to austenite. The kinetics model predicted the measured amount of δ-ferrite and the partitioning of Cr and Ni reasonably well. Further, it showed that slower cooling for the investigated alloy leads to less retained δ-ferrite, which is in excellent agreement with experimental results.

1 Introduction

Since the 1960s, when supermartensitic stainless steels were developed, this type of alloys has found increasing use in many industries [1,2]. Specifically in the offshore oil and gas industry such alloy grades were introduced in the 1990s [3]. Supermartensitic stainless steels combine high strength, good toughness as well as reasonable weldability, and they achieve good corrosion performance with relatively low alloy content [4,5].

The optimal properties of the material, extensively described in Refs. [2,6,7], are obtained by normalizing, leading to martensite transformation, followed by tempering in the inter-critical temperature region, in which both austenite (γ) and ferrite (α) are thermodynamically stable. The tempering treatment leads to formation of reversed austenite in a finely dispersed lamellar morphology on grain boundaries of lath martensite. This is accompanied by diffusion of austenite stabilizing elements into austenite, which stabilize this phase to room temperature [8–13]. Since the good