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Austenite to bainite phase transformation in the heat-affected zone of a high strength low alloy steel

A. Lambert-Perlade [a], A.F. Gourgues [b,*], A. Pineau [b]

[a] IRSID, Arcelor Research and Development, Voie Romaine, 57283 Maizières-lès-Metz cedex, France
[b] Ecole des Mines de Paris, Centre des Matériaux, UMR CNRS 7633, B.P. 87, 91003 Evry cedex, France

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Abstract

The austenite to bainite phase transformation was investigated in a low alloy structural steel after simulated welding heat treatment, by means of light microscopy, electron backscatter diffraction and transmission electron microscopy. Upper bainite packets result from the growth of groups of laths having close crystallographic orientations but highly misoriented habit planes. Self-accommodation of the transformation eigenstrain was evaluated for various bainite configurations using a micromechanical model. The observed pairs of variants seem to help limiting plastic strain in the austenite phase, thus enhancing growth of the bainite phase during cooling.

Keywords: Bainitic steels; Welding; Phase transformation; Electron backscattering diffraction; Mean field analysis

1. Introduction

High strength low alloy steels have been developed for many years and achieve now high tensile properties and good toughness, especially through refinement of the microstructure and by applying efficient welding conditions characterised by high heat inputs. However, significant austenite grain growth may occur in the heat-affected zone of welded joints, leading to bainitic microstructures after completion of the weld. These microstructures are known to be sometimes sensitive to cleavage cracking, especially when some austenite is retained after the bainite transformation, leading to martensite–austenite (M–A) constituents [1–3]. These M–A constituents may be located between bainitic laths as well as at prior austenite grain boundaries. They are intimately related to the incomplete austenite to bainite phase transformation phenomenon.

To combine at best economic welding and safety against brittle failure, it is essential to understand the mechanism of phase transformations in the heat-affected zone and the key effects of the microstructure on the resistance to brittle fracture. The cleavage fracture resistance of bainitic microstructures is closely related to both prior austenite grains and bainite packets [4–6]. The definition of bainite packets is still controversial and optical microscopy may easily give a wrong impression so that sophisticated methods have to be used. Recent results obtained using the electron backscatter diffraction (EBSD) technique help to distinguish between "morphological" packets (as appearing in micrographs) and "crystallographic" packets, (bainite areas delimited by high-angle boundaries) [7]. The relevant microstructural unit controlling cleavage crack propagation is the crystallographic packet [7–9], since only high-angle (misorientation > 40°) bainite packet boundaries can efficiently stop the propagation of brittle cleavage microcracks. The crystallographic packet size strongly depends on the characteristics of the austenite to bainite phase transformation. Up to now, the mechanism of bainite formation in low carbon steels under welding conditions has only scarcely been studied in detail at the

* Corresponding author. Tel.: +33-1-60-76-30-66; fax: +33-1-60-76-31-50.
E-mail address: anne-francoise.gourgues@ensmp.fr (A.F. Gourgues).

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