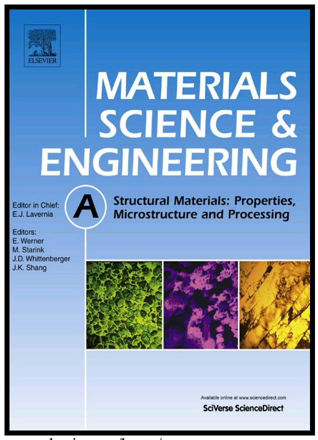
Author's Accepted Manuscript



www.elsevier.com/locate/msea

Impact of the heating rate on the annealing behavior and resulting mechanical properties of UFG HSLA steel

J. Niehuesbernd, E. Bruder, C. Müller

PII: S0921-5093(17)31467-3
DOI: https://doi.org/10.1016/j.msea.2017.11.018
Reference: MSA35733

To appear in: *Materials Science & Engineering A*

Received date: 4 August 2017
Revised date: 6 November 2017
Accepted date: 7 November 2017

Cite this article as: J. Niehuesbernd, E. Bruder and C. Müller, Impact of the heating rate on the annealing behavior and resulting mechanical properties of UFG HSLA steel, *Materials Science & Engineering A,* https://doi.org/10.1016/j.msea.2017.11.018

Impact of the heating rate on the annealing behavior and resulting mechanical properties of UFG HSLA steel

J. Niehuesbernd[1], E. Bruder*[1], C. Müller[1]

1 *Physical Metallurgy Division, Materials Science Department, TU Darmstadt, Alarich-Weiß-Straße 2, 64287 Darmstadt - Germany*

* Corresponding author: e.bruder@phm.tu-darmstadt.de

Abstract

The formability of materials with ultrafine grained (UFG) microstructures produced by severe plastic deformation processes is often limited due to low strain hardening capabilities and strain localizations. Most commonly, heat treatments are used to regain the formability. However, conventional furnace heat treatments can lead to grain growth and significant losses in strength. One approach to address this issue is to increase the heating and cooling rates of the heat treatments. The present work focuses on the heating rate dependencies of the microstructure evolution and resulting mechanical properties of a UFG high strength low alloy (HSLA) steel. Electron backscatter diffraction (EBSD) measurements are used to characterize the microstructure and texture. Bending tests and uniaxial tensile tests are conducted to provide insight into the mechanical properties that are related to the obtained microstructures, with an emphasis on the tendency for strain localizations. The investigations reveal a distinct effect of the heating rate on the annealing behavior, i.e., continuous vs. discontinuous growth. Thus, resulting microstructures and mechanical properties are not only a function of time and temperature but also depend on the heating rate. In this context, the application of laser annealing is shown to be a suitable approach to impede strain localizations in the form of shear bands without sacrificing much of the strength of the UFG material obtained by severe plastic deformation.

1. Introduction

Ultrafine grained (UFG) metals produced by severe plastic deformation (SPD) techniques such as equal channel angular pressing (ECAP), high pressure torsion (HPT) or accumulative roll bonding (ARB) have been subject of numerous investigations during the last decades due to the possible gains in strength, which, however, are accompanied by a reduction in ductility [1-3]. By definition SPD techniques only generate semi-finished parts that often require subsequent shape forming processes. In this context, bulk or sheet forming processes are typically more economical in terms of material usage than machining processes. The low formability of UFG materials, however, represents a considerable limitation. As a result of low strain hardening capabilities, nanocrystalline and UFG microstructures are prone to localized deformation, such as necking or shear band formation [4, 5]. This behavior appears to be an inherent characteristic of these materials, linked to the small grain size [6-8]. A distinct transition to a more ductile behavior with a significant improvement in uniform elongation is generally observed at grain sizes around 1 µm [2].

A prime example for an SPD-like manufacturing process for which those limitations in formability are of technological relevance is linear flow splitting (LFS) [9-16]. The process is designed to produce bifurcations (flanges) through severe plastic deformation of sheet metal,