International Journal of Plasticity 27 (2011) 823–840

Contents lists available at ScienceDirect

International Journal of Plasticity

journal homepage: www.elsevier.com/locate/ijplas

A numerical modelling of 3D polycrystal-to-polycrystal diffusive phase transformations involving crystal plasticity

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ARTICLE INFO

Article history:
Received 26 April 2010
Received in final revised form 16 September 2010
Available online 26 September 2010

Keywords:
Diffusive transformation
Crystal plasticity
3D polycrystal
Finite elements

ABSTRACT

A FE modelling of the elastoplastic interactions occurring within a 3D polycrystal subjected to diffusive phase transformation is proposed. The parent polycrystal is represented by a Voronoi tessellation, where grains differ in shape, size and crystallographic orientation. Grains of the new phase nucleate at favourable sites of the parent polycrystal then grow isotropically, following specific kinetics. This process can result in various product polycrystal morphologies where grains are distinguished by their morphologies and their crystallographic orientations, and have crystalline properties different from those of the parent grains. Application is performed on the austenite-to-ferrite transformation of a low carbon steel, by analysing different basic cases of transformation history with different constitutive modellings. Microplasticity and its related internal stresses are shown to develop during the phase transformations and to affect significantly the elastoplasticity of the product medium.

1. Introduction

Solid-state phase transformations are commonly involved in polycrystalline material elaboration processes with the aim of controlling the final mechanical properties. Different compacities between the parent and product phases of the transformation can lead to the development of microplasticity at the grain scale. When phase transformations occur in structural applications, this can results in plasticity at the scale of the bulk material, called TRansformation-Induced Plasticity (TRIP).

In any case of occurrence, the factors governing its crystallographic, morphological and thermo-mechanical features are complex combinations of alloy composition, heat treatments and mechanical loadings. This concerns particularly steels: as each phase has its own crystallographic characteristics –including density and strength, mechanical fields form at the vicinity of the interfaces between phases, which can in turn affect the driving forces for nucleation and growth and by extent the evolution of the microstructure. Although the thermodynamic framework has been well established, strong couplings between the involved mechanisms make the complete description of phase transformations in steels a very complex problem.

A large amount of experimental works have been lead to understand and explain phase transformations in a wide range of practical configurations: Lecroisey and Pineau (1972), Olson and Cohen (1975), Denis et al. (1987), Kempen et al. (2002), Offerman et al. (2003), Gourgues (2007), Zhang and Kelly (2009a). The considerable set of experimental data provided by these studies, in conjunction with the continuous expansion of computation capabilities, has contributed in the advent of

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doi:10.1016/j.ijplas.2010.09.008