Accepted Manuscript

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PII: S0749-6419(17)30056-6

DOI: 10.1016/j.ijplas.2017.02.001

Reference: INTPLA 2151

To appear in: *International Journal of Plasticity*

Received Date: 8 August 2016

Revised Date: 15 January 2017

Accepted Date: 1 February 2017

Please cite this article as: Akpama, H.K., Ben Bettaieb, M., Abed-Meraim, F., Localized necking predictions based on rate-independent self-consistent polycrystal plasticity: Bifurcation analysis versus imperfection approach, *International Journal of Plasticity* (2017), doi: 10.1016/j.ijplas.2017.02.001.

Localized necking predictions based on rate-independent self-consistent polycrystal plasticity: Bifurcation analysis versus imperfection approach

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Abstract

The present study focuses on the development of a relevant numerical tool for predicting the onset of localized necking in polycrystalline aggregates. The latter are assumed to be representative of thin metal sheets. In this tool, a micromechanical model, based on the rate-independent self-consistent multi-scale scheme, is developed to accurately describe the mechanical behavior of polycrystalline aggregates from that of their single crystal constituents. In the current paper, the constitutive framework at the single crystal scale follows a finite strain formulation of the rate-independent theory of crystal elasto-plasticity. To predict the occurrence of localized necking in polycrystalline aggregates, this micromechanical modeling is combined with two main strain localization approaches: the bifurcation analysis and the initial imperfection method. The formulation of both strain localization indicators takes into consideration the plane stress conditions to which thin metal sheets are subjected during deformation. From a numerical point of view, strain localization analysis with this crystal plasticity approach can be viewed as a strongly non-linear problem. Hence, several numerical algorithms and techniques are developed and implemented in the aim of efficiently solving this non-linear problem. Various simulation results obtained by the application of the developed numerical tool are presented and extensively discussed. It is demonstrated from these results that the predictions obtained with the Marciniak–Kuczynski procedure tend towards those yielded by the bifurcation theory, when the initial imperfection ratio tends towards zero. Furthermore, the above result is shown to be valid for both scale-transition schemes, namely the full-constraint Taylor model and self-consistent scheme.

Keywords: rate-independent behavior, crystal plasticity, self-consistent multi-scale model, localized necking, bifurcation theory, imperfection analysis.