International Journal of Solids and Structures 48 (2011) 2324–2332

Contents lists available at ScienceDirect

International Journal of Solids and Structures

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

Localization in elasto-plastic materials: Influence of an evolving yield surface in biaxial loading conditions

J.L. Dequiedt *

CEA, DAM, DIF, F-91297 Arpajon, France

ARTICLE INFO

Article history:
Received 4 February 2011
Received in revised form 11 April 2011
Available online 22 April 2011

Keywords:
Instability
Shear bands
Plasticity yield surface
Texture evolution

ABSTRACT

The influence of the plasticity yield surface – and of its evolution with plastic deformation – on the development of instabilities in metals is analyzed. Conditions for the activation of slip bands are taken as an instability criterion. They are exhibited in stress states identical to the ones encountered in a flat plate in biaxial tension. The classical bifurcation criterion is replaced by a criterion on the growth of a perturbation at a time scale comparable to the one of the homogeneous solution. This second criterion reveals less severe than the bifurcation one which is reached for the limit case of an infinite growth rate in the perturbation approach. The growth rate is a decreasing function of the biaxiality of the loading which is in agreement with previous studies. The possible destabilizing effect of texture evolution is also exhibited by using an evolving yield surface the curvature of which increases in the neighborhood of the homogeneous solution.

1. Introduction

Localization phenomena are usually observed in plates in tension, in every part where the loading is locally equivalent to uniaxial or even biaxial stretching in the plane of the plate. They take the form of multiple necks or networks of shear bands and generally lead to the fragmentation of the plates. In uniaxial loading, lines perpendicular to the direction of tension are observed on the surface of the plate whereas in equi-biaxial loading the pattern is roughly isotropic.

For instance, the phenomenon has been studied in the last decades in order to evaluate the formability of materials and to display "forming limit diagrams". Localization is usually supposed to be initiated by elasto-plastic instabilities at the macroscopic scale. Since the work of Hill (1952), the initiation and growth of these instabilities is classically analyzed for thin sheets in a plane stress hypothesis. They are represented as bands in the plane of the sheet (which would in fact give a neck in the thickness in the case when the deformation in the plane is not pure shear). In the framework of Hill study, localization is well understood and justified in stress states varying from uniaxial tension (in the plane of the plate) to the one met in plane strain conditions. It is then possible to determine a more favorable orientation for the band.

However, for the classical Von Mises plasticity model, neither the simulations nor the analytical developments display localization in states between plane strain and biaxial tension. The models were later improved in different ways in order to explain localization in such conditions. The first kind of approaches replaces the Von Mises yield surface by a regular one intermediate between the Von Mises and the Tresca surface (Barlat, 1987). Such surfaces are exhibited by poly-crystal plasticity simulations of annealed bcc and fcc isotropic metals. In this case, Barlat (1987) found noticeably lower strains for localization than with the Von Mises surface. The second kind of approaches allows deviation from the normality rule. Among them are the so-called "J2-deformation theory" of plasticity (Storen and Rice, 1975; Needleman and Rice, 1978) and other theories in the same spirit which keep the Von Mises plasticity surface but introduce in the plastic strain rate a component collinear to the time derivative of the stress deviator. Such models are approximations of yield surfaces developing vertices during plastic deformation which are also displayed by poly-crystal models (Hutchinson, 1970). The use of deformation theories also gives localization in biaxial tension (Hutchinson and Neale, 1978).

In a recent work (Dequiedt, 2010), the problem of localization in uniaxial and biaxial stretching was treated in a slightly different formalism, by exhibiting a condition for the development of a band of localization in an infinite tri-dimensional elasto-plastic medium in small strains and quasi-static loading. This medium was submitted to a stress state equivalent to the one met in a flat plate in biaxial tension. The development of the band was treated as a bifurcation from the homogeneous solution corresponding to a simple glide in a thin layer (cf. Rice, 1976).

This criterion linked the strain hardening coefficient to the shape of the plasticity yield surface and the biaxiality rate of the

* Tel.: +33 0 169266964; fax: +33 0 169267097.
E-mail address: jean-lin.dequiedt@cea.fr

0020-7683/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijsolstr.2011.04.004