Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
International Journal of Plasticity 21 (2005) 493–512
INTERNATIONAL JOURNAL OF Plasticity
www.elsevier.com/locate/ijplas

An improved analytical description of orthotropy in metallic sheets

D. Banabic [a,c,*], H. Aretz [b], D.S. Comsa [a], L. Paraianu [a]

[a] *Department of Mechanical Engineering, Technical University of Cluj-Napoca, Bd. Muncii nr. 103–105, 3400 Cluj-Napoca, Romania*
[b] *Institute of Metal Forming (IBF), RWTH Aachen University, Intzestrasse 10, 52056 Aachen, Germany*
[c] *Institute for Metal Forming Technology (IFU), Stuttgart University, Holzgartenstrasse 17, 70174 Stuttgart, Germany*

Received in final revised form 15 February 2004
Available online 6 May 2004

Abstract

The correct description of initial plastic anisotropy of metallic sheets plays a key role in modelling of sheet forming processes since prediction of material flow, residual stresses and springback as well as wrinkling and limiting strains are significantly affected by the phenomenological yield function applied in the analysis. In the last decades considerable improvement of anisotropic yield criteria has been achieved. Among these, the yield criterion proposed by Paraianu et al. [An improvement of the BBC2000 yield criterion. In: Proceedings of the ESAFORM 2003 Conference] is one of most promising plane stress yield criteria available for orthotropic sheet materials. This work aims to improve this yield criterion with respect to flexibility. The capabilities of the modified yield function will be demonstrated by applications to an anisotropic aluminium alloy sheet material.

Keywords: Sheet metal forming; Plastic anisotropy; Yield function; Plane stress

* Corresponding author. Tel.: +49-711-1214197; fax: +49-711-1213839.
E-mail address: banabic@ifu.uni-stuttgart.de (D. Banabic).

0749-6419/$ - see front matter
doi:10.1016/j.ijplas.2004.04.003

1. Introduction

For computer simulation of sheet metal forming processes a quantitative description of plastic anisotropy is required. Nowadays, there are several possibilities to account for plastic anisotropy which is mainly caused by crystallographic texture and microstructure of the considered material and its evolution during the forming process. Macroscopic plasticity theory is most frequently used due to its simplicity and its relatively low computational effort in numerical analysis. For the case of an isotropic metallic material, the well-known von Mises yield function is often sufficient to describe yielding. This is, however, not true for anisotropic materials, especially sheet metals. In order to take into account anisotropy, von Mises' yield function can be modified by introducing additional parameters. These parameters may be adjusted to a set of experimental data obtained by subjecting the considered material to mechanical tests. Hill's quadratic yield function (Hill, 1948; Hill, 1998) is the most frequently used yield function of this type. The reason lies in the fact that this yield function is very easy to handle in analytical and numerical calculations. One of the major drawbacks of Hill's criterion is its inability to describe the so-called anomalous behavior often observed in aluminium alloy sheets.

Thereafter, several scientists have proposed more and more sophisticated yield functions for anisotropic materials. Hill (1979, 1990) himself improved his criterion. However, it was stated by Hill (1993) that none of existing formulations is able to represent the behavior of a material exhibiting a tensile yield stress almost equal in value along the rolling and transverse direction, while r-values vary strongly with the angle to the rolling direction. To overcome this problem he proposed a new criterion (Hill, 1993).

Another important research direction in the field of yield function development was initiated by Hosford (1972), who, based on the results of polycrystal calculations, introduced a non-quadratic isotropic yield function. Hosford's criterion was later extended by Barlat and collaborators to anisotropic materials including shear stresses (Barlat and Richmond, 1987; Barlat and Lian, 1989; Barlat et al., 1991). Barlat et al. (1991) have developed a six-component yield function which is an extension of Hosford's yield function to anisotropy. Anisotropy was introduced by means of a linear transformation of the stress tensor. Later, this function was extended by Barlat et al. (1997a,b). Karafillis and Boyce (1993) have generalized the idea of linear stress transformation and suggested a yield function consisting of the sum of two convex functions. Banabic et al. (2000a,b) and Paraianu et al. (2003) extended the plane stress yield function introduced by Barlat and Lian (1989). Barlat et al. (2003) extended the concept of linear stress transformation and introduced two linear stress transformations.

During the last two decades, many other yield functions have been developed in order to improve agreement with the experimental results. For instance, Bassani (1977) has introduced a non-quadratic yield criterion; Gotoh (1977) introduced a fourth degree polynomial yield function; Budiansky (1984) proposed a yield function formulated as a parametric expression in polar coordinates which was extended by Tourki et al. (1994); Vegter et al. (1995) proposed a representation of the yield