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Prediction of anisotropy and hardening for metallic sheets in tension, simple shear and biaxial tension

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ABSTRACT

The mechanical behavior of mild and dual phase steel sheets is investigated at room temperature in quasi-static conditions under different strain paths: uniaxial tension, simple shear and balanced biaxial tension. The aim is to characterize both the anisotropy and the hardening, in order to identify material parameters of constitutive equations able to reproduce the mechanical behavior. In particular, a good description of flow stress levels in tension and shear as well as plastic anisotropy coefficients is expected. Moreover, the Bauschinger effect is investigated with loading–reloading in the reverse direction shear tests and the balanced biaxial tension test gives insight of the mechanical behavior up to very high equivalent plastic strains. Yoshida–Uemori hardening model associated with Bron–Besson orthotropic yield criterion is used to represent the in-plane mechanical behavior of the two steels. The identification procedure is based on minimization of a cost function defined over the whole database. The presented results show a very good agreement between model predictions and experiments: flow stress during loading and reverse loading as well as plastic anisotropy coefficients are well reproduced; it is shown that the work-hardening stagnation after strain path reversal is well estimated in length but Yoshida–Uemori model underestimates the rate of work-hardening.

1. Introduction

Nowadays, phenomenological models are widely used in finite element analysis of sheet metal forming process, since they present a good compromise between simulation accuracy and computation time. Such models of the elasto-viscoplastic behavior of sheet metals are based on the definition of a yield surface, to describe the initial anisotropy related to the crystallographic texture, and its evolution with plastic strain. Initial orthotropy is a good representation for rolled sheets and is assumed to be kept during strain, by considering a corotation of the anisotropy frame with material rotation. Strain-induced anisotropy, such as Bauschinger effect, is described by the evolution of internal variables with plastic strain. Several experimental tests, like tension-compression [1,2] and simple shear [3], have been performed to characterize the hardening behavior of sheet metals under strain reversal, which refers to the fact that the subsequent loading direction is opposite to that of former loading, and is quite common in sheet metal forming processes; for example, bending–unbending on the die radius and reverse bending–unbending at the punch nose. This behavior under strain reversal, called the Bauschinger effect, is characterized by a lower yield stress under strain reversal, further transient behavior that corresponds to the smooth elastic-plastic transition with a rapid change of strain-hardening rate, and a hardening stagnation, the magnitude of which depends on the prestrain and permanent softening characterized by stress offset.

The prediction of the anisotropy and hardening of metallic sheets depends not only on the constitutive model but also on the accurate material parameter identification which refers both to the type of the experimental tests being used and the identification methods. Tension, simple shear and balanced biaxial tension tests provide relevant information on the shape of the yield surface and its evolution with plastic strain. However, current researches seldom consider all of them to identify the material parameters. The general identification strategy is that the first step is the identification of the initial yield surface, using either the yield stresses or the anisotropy coefficients, or both, and the second step is the hardening behavior, e.g. [4].

In the present study, an alternative procedure is used and the material parameters of both the yield function and the hardening model are identified from the stress–strain curves and both longitudinal and transverse strain in tension at the same time. The constitutive equations are derived from Bron–Besson yield

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