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ScienceDirect

Procedia Engineering 207 (2017) 125–130

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on the Technology of Plasticity, ICTP 2017, 17-22 September 2017, Cambridge, United Kingdom

Identification of advanced constitutive model parameters through global optimization approach for DP780 steel sheet

Yongfeng Li[a,b], Ji He[a,b], Bin Gu[a,b], Shuhui Li[a,b,*]

[a]*State Key Laboratory of Mechanical System and Vibration, Shanghai Jiao Tong University, Shanghai 200240, China*
[b]*Shanghai Key Laboratory of Digital Manufacture for Thin-walled Structures, Shanghai Jiao Tong University, Shanghai 200240, China*

Abstract

In recent years, in order to improve the precision of the springback prediction, many advanced material constitutive models have been developed to describe the complex material behavior of sheet metal upon load reversals. The Yoshida-Uemori (Y-U) and the homogeneous yield function-based anisotropic hardening (HAH) models are typical models which are able to predict the Bauschinger effect, transient hardening and permanent softening phenomena. The heavy identification efforts raise to be one main chanllenge before their application due to the numerous parameters. Appropriate tests and robust optimal methods are needed to calibrate parameters. In this work, cyclic stress-strain curve of DP780 steel sheets are obtained by tension-compression tests, and then the parameters of modified Y-U and HAH model are identified through global optimization approach. The identified parameters are verified by the comparison between springback results of U-shape draw-bending process and simulation.

Peer-review under responsibility of the scientific committee of the International Conference on the Technology of Plasticity.

Keywords: Springback, Y-U model, HAH model, Parameter identification, Optimization

1. Introduction

Advanced high strength steels (AHSS) have been widely used in the automobile industry for weight reduction purpose. Compared with conventional steels, AHSS exhibits severe springback due to its mechanical responses. The

* Shuhui Li. Tel.: +86-021-3420-6784.
E-mail address: lishuhui@sjtu.edu.cn.

1877-7058
Peer-review under responsibility of the scientific committee of the International Conference on the Technology of Plasticity.
10.1016/j.proeng.2017.10.749

inaccurate prediction of springback leads to additional manufacturing cost which has become a big issue for autobody manufacturing industry. For this reason, many scholars have studied on the finite element simulation and materials constitutive models to predict springback accurately. The hardening behavior of AHSS is the key issue for the accurate prediction of springback. Up to now, several material constitutive models including ANK [1], Y-U [2], HAH [3] have been developed, which has capability to describe the Bauschinger effect, transient behavior, permanent softening and work hardening stagnation under load reversals. The accurate description of these complex characteristics is realized by introducing more numerical parameters in the constitutive models. Therefore, they generally include empirical parameters which often lack clear physical significance and have to be identified based on more complicated experiments and parameter calibration methods. The material parameters identification is critical to the springback prediction accuracy for an advanced constitutive model. However, with the rapid development of theoretical models, less attention has been paid on the material parameters identification method. This will restrict the wide application of advanced models in engineering reality. An inverse method was used to calibrate the material parameters of the ANK hardening model by Zang [4], Shi [5] used the LS-OPT software to identify the material parameters of Y-U model with cyclic tension-compression test. Recently, Fu et al. [6] used the virtual field method (VFM) to calibrate the material parameter of the HAH model. However, The LS-OPT software is developed for the LS-DYNA, and usually does not have the versatility for other simulation software, especially for the user defined material subroutine, such as HAH model.

Before the application of these phenomenological constitutive models which have nonlinear behavior prediction ability, the numerous material parameters should be accurately calibrated through the robust and user-friendly optimization process based on the pre-designed material testing results. Unlike the optimization process in LS-OPT, we proposed a parameter indentification method which base on the global optimization approach and can be applied to new developed model through FE software Abaqus [7]. Additionally, reliability of parameter identification has been verified by the experiment of U-draw/bending test.

2. Experiments

In present work, the uniaxial tension test and in-plane tension-compression tests were performed for the measurement of the stress-strain curves. The basic mechanical properties and isotropic hardening parameters are obtained from uniaxial tension test. However, the cyclic stress-strain curves are acquired via cyclic tension-compression or shear test.

2.1. Uniaxial tension test

A DP780 steel sheet with 1.0 mm thickness was used and the ASTM E8 standard specimen is adopted for uniaxial tension test and loading-unloading-reloading uniaxial tension test. With the data of uniaxial tension tests along 0°, 45°and 90° to the rolling direction (RD), the anisotropy factor can be calculated. Its basic mechanical properties and the degradation of Young's modulus were measured by uniaxial tension test, the results are given in Table 1. The experimental uniaxial tension flow curve was fitted by Swift and Swift-Voce law and its coefficients are given in Table 2.

Table 1. Mechanical properties of DP780 steel sheet

Material	r_0	r_{45}	r_{90}	$\sigma_{0.2}$ (MPa)	σ_b (MPa)	E_0 (GPa)	E_a (GPa)	ξ
DP780	0.888	0.881	0.794	549	920	210	258	33

Table 2. Swift and Swift-Voce hardening parameters

(1) Swift hardening parameters							
Material	K_s(MPa)	ε_0	n				
DP780	1256	0.002	0.133				
(2) Swift-Voce hardening parameters							
Material	μ	ζ	ε_0	K_{sv} (MPa)	n	σ_s (MPa)	σ_y (MPa)
DP780	0.8816	456	0.00307	1360	0.1663	881.8	76.49