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Springback Prediction Using Finite Element Simulation Incorporated With Hardening Data Acquired From Cyclic Loading Tool

Jasri Mohamad, Universiti Malaysia Pahang, Pekan, Malaysia

Mohd Zaidi Sidek, Universiti Malaysia Pahang, Pekan, Malaysia

ABSTRACT

The aims of this article are to present the accuracy of springback prediction in U-bending sheet metal forming processes using finite element (FE) simulation incorporated with kinematics or mixed hardening parameters that are derived from cyclic data provided by the developed cyclic loading tool. The FE simulation results in the form of springback angles are compared with the experimental results for validation. It was found that the mixed hardening model provides better simulation results in predicting springback. This is due to the capability of the isotropic hardening part of this model to describe cyclic transient and the kinematic hardening part to improve description of the Bauschinger effect. Kinematic hardening however, on its own is capable of providing relatively good springback simulation illustrated by errors of less than 8 percent. Overall, the data provided by cyclic loading from the newly developed bending-unbending tool is considered valuable for simulating springback prediction.

KEYWORDS

Bauschinger Effect, Bending, Constitutive Modeling, Isotropic Hardening, Kinematic Hardening, Mixed Hardening, Sheet Metal Forming, Springback

1. INTRODUCTION

Despite various efforts to improve sheet metal forming through accurate springback prediction and material modelling, there remains room for improvement of knowledge in this subject. One area of improvement is the adequacy and quality of experimental tests used to identify material parameters in constitutive equations. More accurate constitutive laws or quality data describing material behaviour are required to improve the quality of finite element simulation results so that they can better represent the real deformation process. The aims of this article are to validate the accuracy of springback prediction in U-bending sheet metal forming process using finite element simulation incorporated with kinematics and mixed hardening parameters derived from cyclic data provided by a newly developed cyclic loading tool. The U-bending simulation results in comparison with the experimental results is used to judge the reliability of the data provided by the newly developed cyclic tool and to evaluate the performance of the hardening models in predicting springback.

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2. LITERATURE REVIEW

In sheet metal forming process, cyclic loading occurs due to bending and unbending of material in the die such as when the sheet is drawn over a die corner (Sanchez, 2010; Yoshida, Uemori, & Fujiwara, 2002). This is shown in Figure 1.

Yoshida and Uemori(Yoshida & Uemori, 2003) described this cyclic process as having four distinct features: load reversal and Bauschinger point, transient behaviour, work-hardening stagnation and permanent softening. To improve sheet metal forming simulation, there is a need to incorporate an appropriate constitutive equation capable of describing the Bauschinger effect and so-called cyclic transient, which describes transition between the elastic and elastic-plastic state during repeated loading. A combination of isotropic and nonlinear kinematic hardening has been considered as one of the best material models, as the former has been associated with the capability to improve cyclic transient and the latter with the capability to take care of the Bauschinger effect (Chun, Jinn, & Lee, 2002). The Chaboche nonlinear kinematic hardening model as described by Equation 1 was chosen for kinematic hardening in this work. A combination of this hardening model and Voce isotropic hardening models in Equation 2 was selected to represent the mixed hardening model as shown by Equation 3.

$$\sigma = \sigma_0 + \frac{C}{\gamma}\left(1 - e^{-\gamma\bar{\varepsilon}}\right) \quad (1)$$

$$\sigma = \sigma_0 + Q\left(1 - e^{-b\bar{\varepsilon}}\right) \quad (2)$$

$$\sigma = \sigma_0 + Q\left(1 - e^{-b\bar{\varepsilon}}\right) + \frac{C}{\gamma}\left(1 - e^{-\gamma\bar{\varepsilon}}\right) \quad (3)$$

Figure 1. Description of Cyclic Loading (A) Draw-Bend (B) Springback (C) Stress-Strain Path (Yoshida et al., 2002)