Investigating Bauschinger Effect and Plastic Hardening Characteristics of Sheet Metal under Cyclic Loading

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ABSTRACT

To improve sheet metal forming process simulation using finite element method, there is a need to incorporate an appropriate constitutive equation capable of describing the Bauschinger effect and the so-called cyclic transient, derived from a near to actual sheet metal forming process testing tool. A cyclic loading tool has been developed to test and record the characteristics of sheet metal deformation by investigating the Bauschinger effect factors (BEF) and cyclic hardening behaviour. Experimental investigation conducted on low carbon steel and stainless steel demonstrates that the tool is able to record sheet metal behaviour under cyclic loading. The results are analysed for signs of the Bauschinger effect and cyclic hardening effect. It was found that the Bauschinger effect does occur during bending and unbending loadings in sheet metal forming process.

KEYWORDS

Bauschinger Effect, Cyclic Hardening, Kinematic Hardening, Mixed Hardening, Sheet Metal Forming

INTRODUCTION

In sheet metal forming process, cyclic loading occurs due to bending and unbending of material as in the die draw bead and when the sheet is drawn over a die shoulder corner as shown in Figure 1 (Hosford and Caddell 1993; Sanchez 2010; Yoshida et al. 2002). The bending-unbending deformation causes an effect where the yield stress during reversal loading is lower than the yield stress during forward loading. This effect is known as the Bauschinger effect.

The Bauschinger effect, by definition, is the reduction of yield stress on the reversal of loading when compared to the forward loading. The Bauschinger effect factor (BEF) has been used to quantify the Bauschinger effect according to the following formula:

\[
BEF = \frac{Y_1 - |Y_2|}{Y_1}
\]  

(1)

where \(Y_1\) and \(Y_2\) are shown in Figure 2. A zero BEF value indicates that no Bauschinger effect is present in the loading and unloading deformation (Weinmann et al., 1988).

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Figure 1. Description of cyclic loading: (a) Draw-bend, (b) Springback, (c) Stress-strain path (Yoshida et al. 2002)

(a) Draw-bend

(b) Springback

(c) stress-strain path

Figure 2. Weinmann's cyclic loading effect (Weinmann et al., 1988)
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