



Elimination of springback of high-strength steel sheet by using additional bending with counter punch



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ARTICLE INFO

Article history:

Received 3 July 2014

Received in revised form 25 August 2015

Accepted 29 August 2015

Available online 1 September 2015

Keyword:

Counter punch

Bending

Springback

High-strength steel sheet

ABSTRACT

This study proposes a new technique to eliminate the springback of high-strength steel (HSS) sheets in the U-bending process. In this technique, the bottom plate is additionally bent with a counter punch at the final stage of the U-bending process. In an experiment, a flat-headed punch with a shallow hollow on the punch head was employed in combination with a counter punch. The U-bending process consists of four sequential steps: (1) clamping of a sheet between a punch and a counter punch, (2) U-bending under a constant clamping force, (3) bottom pushing-up by the counter punch, and (4) final unloading process. From the experiment on a 980Y HSS sheet, an appropriate combination of the clamping force and the final bottom pushing-up force that eliminates springback entirely was found. To investigate the mechanism of the reduction in springback in this process, an FE simulation of this process was conducted using the Yoshida–Uemori model, an advanced kinematic hardening model. The simulation result showed that the major mechanism of springback elimination is the “spring-go” induced by the release of the negative bending moment generated by bottom pushing-up.

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1. Introduction

High-strength steel (HSS) sheets are widely used nowadays in automotive structural components to improve crashworthiness without increasing the body weight. The most serious problem in the press-forming of HSS sheets is their extremely large springback. Therefore, a new technique to eliminate springback is urgently needed in the stamping industry.

The most effective method to suppress springback is to reduce the bending moment that is its driving force. Several techniques have already been proposed for this purpose. Nevertheless, such techniques have limitations in eliminating springback, especially that in ultrahigh-strength steel sheets. Yamano and Iwaya (2005) proposed a sequential bending-unbending technology by using a specially designed punch called an over-run inducing punch. However, the springback reduction achieved by their method is strongly influenced by the tool shape, and once it is fixed, the

level of springback for a given sheet cannot be controlled. Ogawa and Yoshida (2011) investigated the effect of die-corner bottoming on U-bending springback and found that this process effectively reduces springback to some extent; however, a certain amount of springback always remained even under a large bottoming force. An alternative approach is springback compensation through appropriate die design. For example, Sachs (1956) employed a rounded-head punch and counter punch (which they called “arc bottoming”) for counteracting the effect of springback. Liu (1984) proposed a new forming technology characterized by two-stage restrikes that induce bending and unbending (which they called the “double-bend technique”) for U-channel forming. One of the problems in these approaches is that the level of springback compensation is directly related to the tool shape (e.g., arc radius of punch head in arc bottoming) and it does not include a controllable process parameter; therefore, different tool shapes have to be prepared for each type of sheet.

In this study, to eliminate the U-bending springback of HSSs, a new forming technique that includes additional bending with a counter punch is proposed. As shown in Fig. 1(a), for a U-shaped channel, the following three geometrical qualities are important:

- precise bending angle (no springback),

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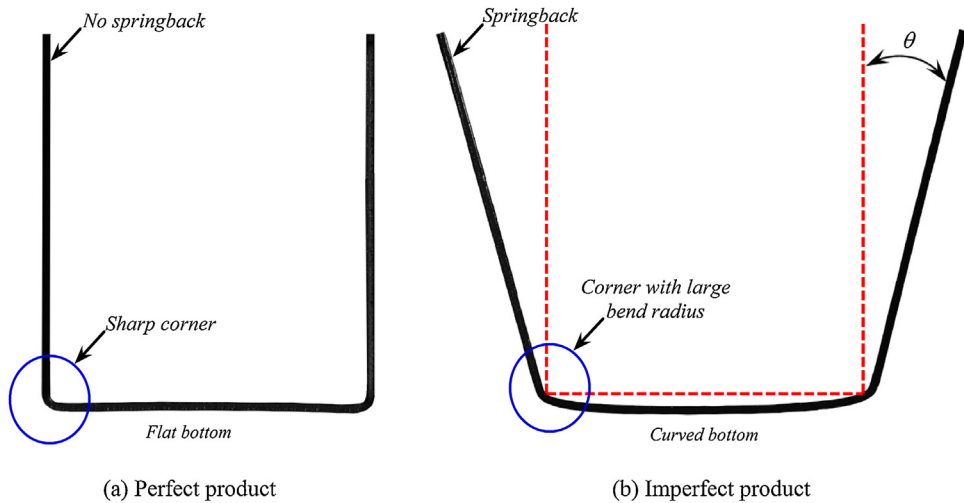


Fig. 1. Examples of U-bent products.

- sharp bending corner,
- flatness of bottom part.

Fig. 1(b) shows an imperfect product that has geometrical imperfections for all of the above qualities. To obtain an ideally shaped product, in the present work, the optimum process parameters, i.e., clamping force, bottom pushing-up force, and punch shape, in the new technique are examined. The mechanism of springback elimination in this process is discussed through both a U-bending experiment on a 980-MPa-level HSS sheet and the corresponding FE simulation.

2. Procedure and experimental setup

2.1. U-bend experiment

The U-bending apparatus consists of a die, a punch, and a movable counter punch, as schematically illustrated in Fig. 2. The newly proposed U-bending process has four sequential steps, as also shown in Fig. 2: (a) clamping of a sheet between a punch and a counter punch (clamping force: F_1), (b) U-bending keeping the clamping force constant, (c) bottom pushing-up with the counter punch (pushing-up force: F_2), and (d) removing the sheet from the die. Fig. 3 shows the tool dimensions. The flat-headed punch

(width: 47.4 mm) has a shallow hollow on the punch head (three different hollow depths, $D_h = 0.5, 1.0,$ and 1.5 mm). The punch-corner radius was 1.2 mm and the die-corner radius, 2.96 mm. The width of the counter punch was 39.4 mm. The level of bottom pushing-up force F_2 to eliminate the springback would be also influenced by radii of the punch-hollow and the counter-punch corners. In this experiment, they had zero corner radius (sharp edges).

To examine the shape of the final product, the springback angle θ defined in Fig. 2(d) was measured. A 1.22-mm-thick dual-phase 980-MPa-level HSS sheet (hereafter denoted by “980Y”) was used in this study. The workpiece was rectangular with dimensions of 45 mm $\times$ 160 mm.

The effects of the following process parameters on the elimination of springback as well as other geometrical imperfections were investigated:

- clamping force, F_1 , and bottom pushing-up force, F_2 ,
- depth of hollow on punch head, D_h .

Every experiment was repeated five times for each experimental condition of F_1 and F_2 for a given D_h punch.

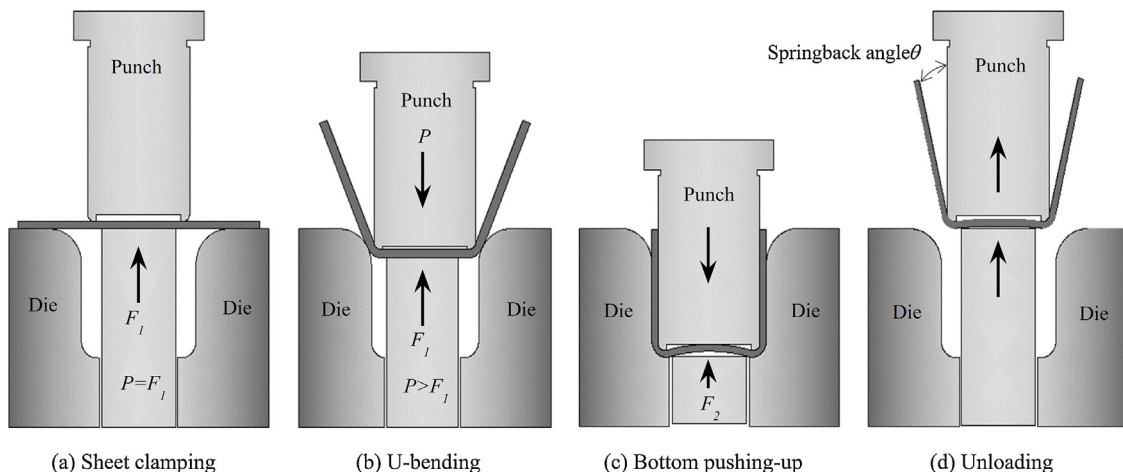


Fig. 2. Schematic illustration of U-bending with bottom pushing-up.

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