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A Review on Springback in Sheet Metal U Bending

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Abstract: *Elastic recovery of formed part in unloading known as springback causes shape error in final product of sheet metal forming processes. All the forming processes are more or less prone to the springback depending upon different material properties and process parameters. Bending processes are very widely used in the manufacturing of sheet metal products, particularly in automobile industry. This paper deals with a review on Springback in Sheet Metal U Bending such as eliminate springback of HSS sheets, experimental and numerical investigation of the effect of the punch speed, investigate cyclic plasticity and unloading behavior, conventional mode and a non-conventional mode consisting of successive tool holdings during forming.*

Keywords: *spring back, sheet metal forming, U-Bending*

1. INTRODUCTION

The sheet metal forming process involves a combination of elastic–plastic bending and stretch deformation of the workpiece. These deformations may lead to a large amount of springback of the formed part. It is desired to predict and reduce springback so that the final part dimensions can be controlled as much as possible.

One of the most common metal working operations is bending. This process is used not only to form parts such as flanges, seams etc. but also to impart stiffness to the part by increasing its moment of inertia. The terminology used in bending is shown in figure 1.

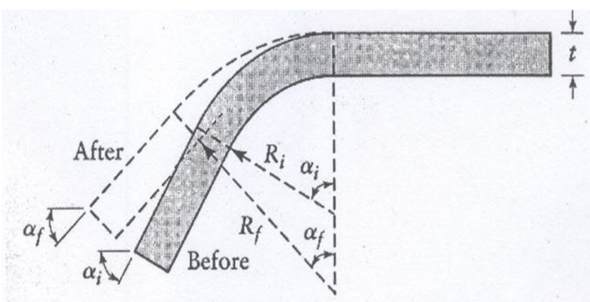

Figure 2: Terminology for spring back in Bending.

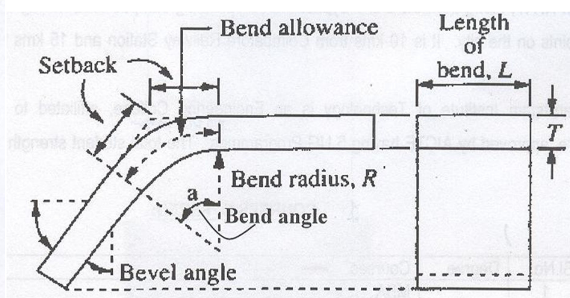

Figure 1: Bending terminology.

The outer fibers of the material are in tension and the inner fibers are in compression. Theoretically, the strains at the outer and inner fibers are equal in magnitude and are given by the equation.

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$$e_0 = e_i = \frac{1}{(2R/T)+1} \quad (1)$$

2. SpringBack

Because all materials have a finite modulus of elasticity, plastic deformation is follow' by elastic recovery upon removal of the load; in bending, this recovery is known as *springback.* As shown in Fig. 1, the final bend angle after spring back is smaller and the final bend radius is larger than before. This phenomenon can easily be observed by bending a piece of wire or a short strip metal. Spring back occurs not sheets or plate, but also in bending bars, rod, and wire of any cross-section. A quantity characterizing springback is the springback factor Ks, which is defined as follows. Because the bend allowance is the same before and after bending (see figure 1), the relationship obtained for pure bending is

$$\text{Bend allowances} = \left(R_i + \frac{t}{2}\right)\alpha_i = \left(R_f + \frac{t}{2}\right)\alpha_f \quad (2)$$

from this relationship, Spring factor, Ks is defined as:

$$K_s = \frac{\alpha_f}{\alpha_i} = \frac{(2R_i/t)+1}{(2R_f/t)+1} \quad (3)$$

where Ri and Rf are the initial and final bend radii, respictively. It can be noted Fromequtîon 2 that Ks depends only on the R/t ratio. Where R is the minimum bend radius. A springback factor of Ks =1 indicates no springback, and Ks=0 indicates complete elastic recovery (see figure 3).

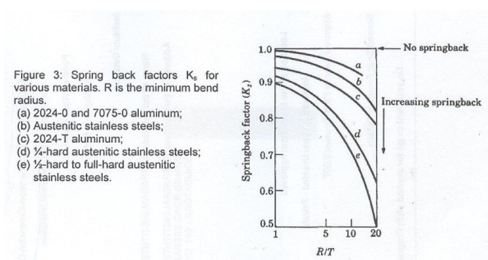

Figure.3

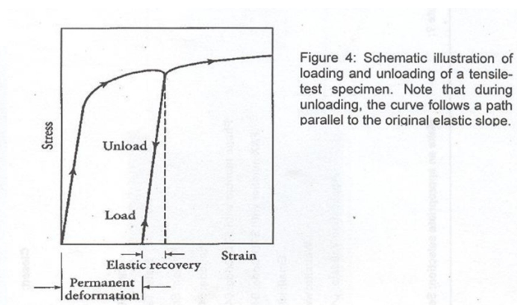

figure.4

The amount of elastic recovery - as shown in figure 4 - depends on the stress level and the modulus of elasticity, *E,* of the material; hence, elastic recovery increases with the stress level and with decreasing elastic modulus. Based on this observation, an approximate formula has been developed to estimate spring back:

$$\frac{R_i}{R_f} = 4\left(\frac{R_i Y}{Et}\right) - 3\left(\frac{R_i Y}{Et}\right) + 1 \quad (4)$$

In this equation, *Y* is the uniaxial yield stress of the material.

3. Eliminate Springback of HSS Sheets

3.1. Comparison between Experimental and Analytical Results of Springback

Figure 5 shows the comparison of the calculated results of springback angles of 980Y sheet with the corresponding experimental data for various bottom pushing-up forces F2 under a constant clamping force F1 = 2 kN, when using the punch with hollow depth Dh = 1.5 mm. In the calculation, two types of material models were employed, i.e., a classical model of isotropic hardening that neglects the description of the Bauschinger effect, and the Y-U model that describes it accurately. From this figure, it is found that the Y–U model predicts the springback angles fairly well, whereas the IH model apparently underestimates it. This is because the Y-U model describes the plastic strain dependent Young's modulus and the Bauschinger effect which affects springback of HSS sheets. In the following discussions, therefore, only the analytical results with the Y–U model are used.

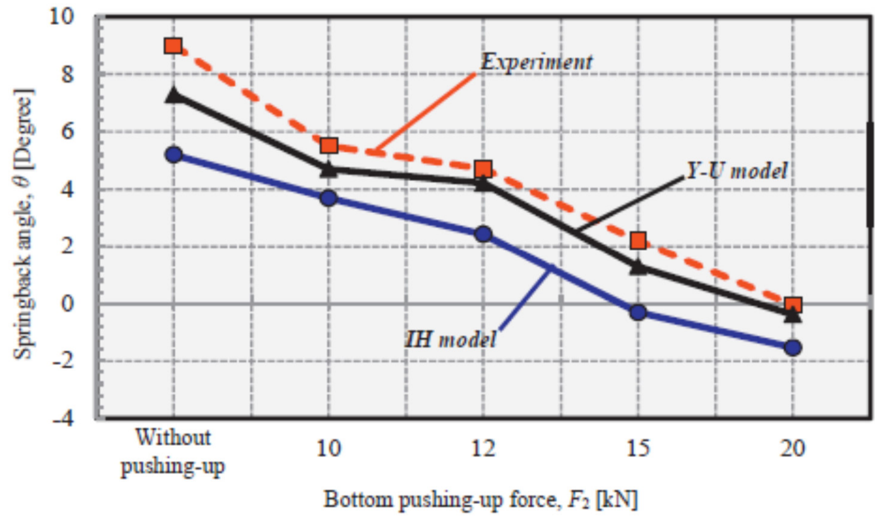

Fig.5. Comparison of springback angles calculated by Y–U model and the IH model for 980Y sheet with corresponding experimental data forvarious bottom pushing-up forces F2 under constant clamping force F1 = 2 kN.[1]

3.2. Effects of Clamping Force and Bottom Pushing-Up on Springback

The experimental data of springback angle of 980Y sheet for various clamping forces and bottom pushing-up forces, when using the punch of Dh = 1.5 mm, are shown in Fig. 6. From these results, it is found that the springback angle decreases with increasing bottom pushing-up force F2 under any clamping force F1. Springback also decreases with increasing clamping force F1 when the final bottom pushig-up was not applied (F2 = 0). On the other hand, springback get larger with increasing clamping force when large bottom pushing-up force was applied.

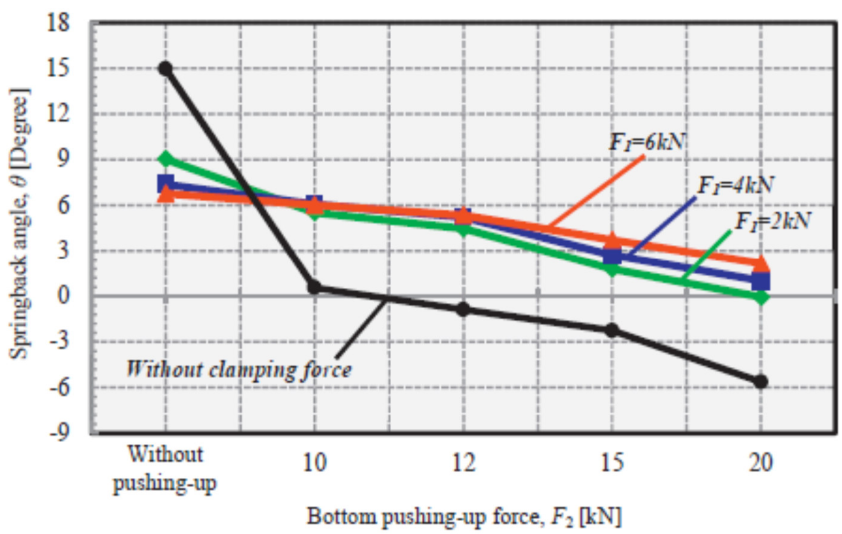

Fig. 6. Comparison of springback angles of 980Y sheet for various clamping forces F1 and bottom pushing-up forces F2 when using the punch of Dh = 1.5 mm.

Fig. 7 summarizes the experimentally obtained geometries of 980Y sheet after U-bending for various combinations of clamping forces F1 and bottom pushing-up forces F2. From these results, it is found that: - the application of clamping force F1 is essential to have a flat bottom, and - springback decreases with increasing bottom pushing-up force F2.

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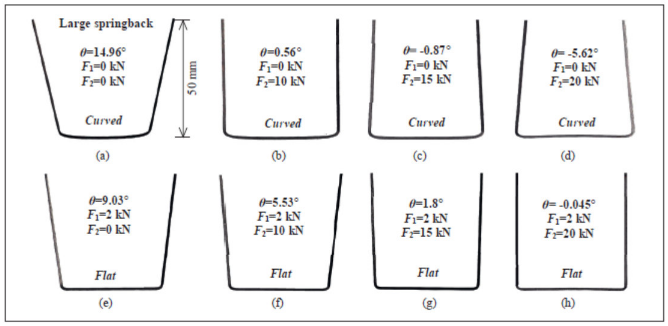

Fig. 7. Experimentally obtained geometries of 980Y sheets after U-bending for various clamping forces F1 and various bottom pushing-upforces F2 when using the punch of Dh = 1.5 mm and the counter punch of Wcp = 39.4 mm.

For U-shaped channel, a precise bent angle (no springback) is essential, and furthermore, most of the cases flatness of the bottom plate and sharp bent corner are required. To satisfy these requirements, an optimum combination of clamping force F1 and pushing-up forces F2 should be determined. In the case of bending without clamping force (F1= 0 kN) combined with bottom pushing-up force F2=10 kN, it was found that, springback angle is almost zero. However, the bottom part of the U-bent sheet is slightly curved and the bent corner radius is much larger than the punch corner radius because of springback (see Fig. 7(b)). In the case of larger F2 (up to 15 and 20 kN), the bottom sheet is still curved, and the negative springback (so-called 'spring-go') of the sidewall appears (see Fig. 7(c) and (d)). The very best result of the springback angle (almost 0 degree), together with the flat bottom and sharp bent corner, was obtained at the clamping force of 2 kN and the bottom pushing-up force of 20 kN(see Fig. 7. (h)). Furthermore, Fig. 8. illustrates the major stress (membrane stress) distributions when applying the bottom pushing-up force (before springback, F1 and F2 conditions of Fig. 8. (a)-(c) correspond to those of the experimental results shown in Fig. 7(d), (f) and (h), respectively. When applying a large bottom pushing-up force (F2 = 20 kN) with an appropriate clamping force (F1 = 2 kN), the large compressive stress appears at the end of rounded corner (see Fig. 8(c)). It also reduces springback (see Fig. 7(h)).

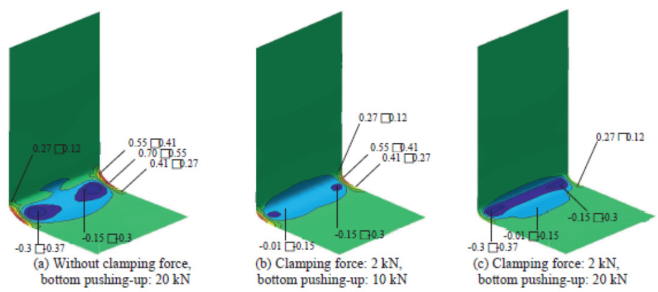

Fig. 8. Major stress (membrane stress; GPa) distributions of 980Y workpieces formed by the U-bending for the bottom pushing-up force at the bottom part.

To verify the above explanation, FE simulation of bending followed by the bottom pushing-up was conducted. Fig.9 shows the calculated bending moment acting on a cross-section near the curved corner of the bent sheet, when applying various amount of bottom pushing-up load F2. The bending moment decreases markedly with increasing bottom pushing-up load F2, and it turns to have a negative value at F2 = 20 kN.[1]

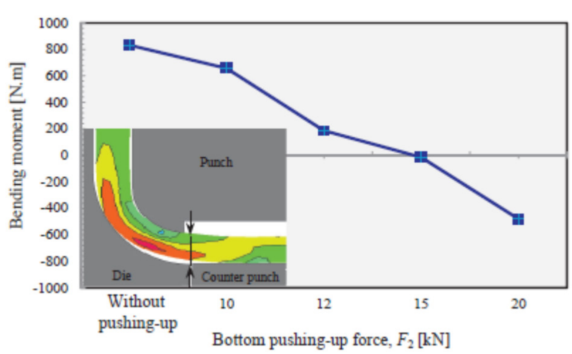

Fig. 9. Calculated bending moment at bottom pushing-up stage for various bottom pushing-up forces when clamping force F1 = 2 kN when using the punch of Dh = 1.5 mm.

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4. Experimental and Numerical Investigation of the Effect of the Punch Speed

Numerical simulations of U-bending tests at the case of punch speed of 0.07 and 70 mm/s for both steel sheets were conducted and springback parameters were analyzed. Blank profiles after the numerical simulations with test results are displayed in Fig. 10. The simulation results well predicted the test results as well as springback behavior with various punch speeds although small discrepancy appears in the flange region. Discrepancy between the test results and the numerical results can be reduced by using more accurate hardening model considering variation of unloading modulus as well as the strain rate.

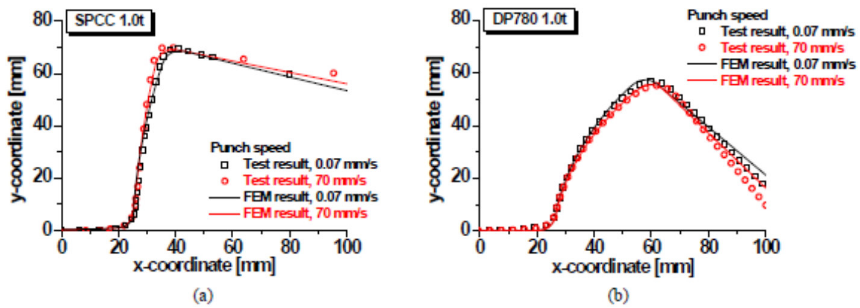

Fig. 10. Blank profiles after numerical simulations with test results for (a) SPCC (b) DP780.

To investigate different springback behavior of SPCC and DP780 with various punch speeds, tangential stress distribution in the blank was investigated by defining local coordinate system in the FEA model since the amount of springback is determined by tangential stress difference through thickness direction of blank. From this investigation, it seems to be due to the inertia effect of SPCC at the punch speed of 70 mm/s. When the punch moved fast, the deformation of SPCC blank at the sidewall region through the tangential direction was not uniform by the inertia effect thus the amount of reverse bending was different along the sidewall. This led to small difference of tangential stress between top and bottom layer at the sidewall region so that the amount of springback decreased with increase of punch speed. On the other hand, the amount of springback increased with increase of punch speed in the case of DP780 due to strain rate sensitivity of hardening behavior.[2]

5. Conventional Mode and A Non-Conventional Mode Consisting of Successive Tool Holdings during Forming

The springback profiles after U-draw bending tests for the two modes, V-mode and stepwise, are presented in Fig. 11. According to the experimental results (Fig.11(a)), the forming mode does not affect the springback profile of DP780 significantly. The results of the FE simulations are summarized in Fig. 11(b). This figure confirms the finding of the experiments. For further analysis, the through-thickness stress distribution at the end of forming and before final springback for an element located in the sidewall area was considered. As Fig. 12 indicates, the stress distributions are almost identical for two different forming modes, which lead to identical final springback profiles. In addition, the stress drop during holding at three strokes, namely, 30, 50 and 70 mm, for an element located in the sidewall were investigated as presented in Fig.13. This figure demonstrates that the stress relaxation took place during each holding step, with most of the stress drop occurring in the first few seconds. However, the amount of stress drop was in the range of 50 MPa, which appears to be insufficient to change the final springback significantly. The amount for stress reduction in uniaxial tension (Fig. 11) can be compared to the stress drop during the U-draw bending test in the stepwise mode (Fig. 13). It can be speculated that if the amount of stress drop in uniaxial tension test is not significant, the stepwise motion is not expected to modify the springback drastically. To justify this conclusion, additional investigations should be conducted on other materials.[3]

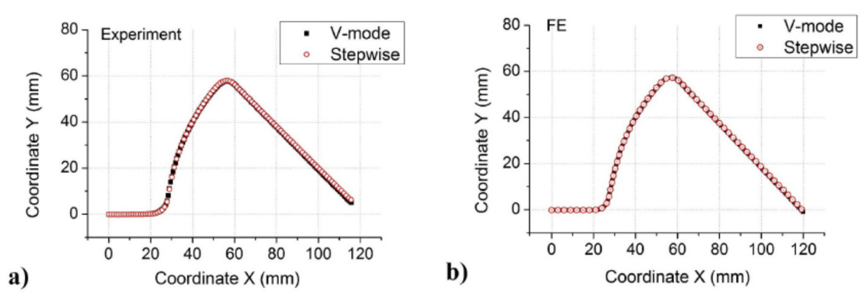

Fig. 11. Springback profiles of V-mode and stepwise mode: a) experiments, b) FE simulations.

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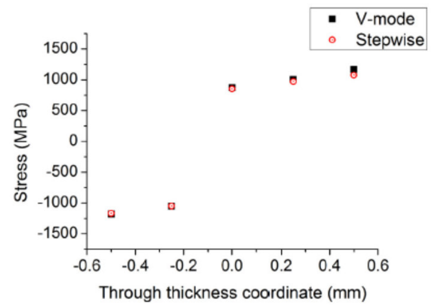

Fig. 12. Predicted through-thickness stress before final springback for an element located in the sidewall.

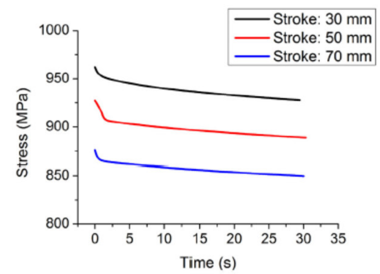

Fig. 13. Stress relaxation of an element located in the sidewall.

Conclusion

Springback causes shape error in final product of sheet metal forming processes. The springback occurs at the last step of process and the final geometry of work piece .Parameters Influencing Springback such as;

1. An appropriate combination of the sheet clamping and the bottom pushing-up force is able to eliminate springback entirely and remove the geometrical imperfections.
2. The amount of springback varying according to punch speed. To improve the dimensional accuracy of a formed part, it is necessary to investigate effect of punch speed on the springback behaviour of the material.
3. The stepwise motion was shown to be ineffective for the reduction of springback because the amount of stress drop during relaxation was not adequate to change the through-thickness stress distribution.

Other Parameters Influencing Springback such as blank thickness, Punch Travel, Punch Radius and Tooling-Blank Interface Friction, etc.

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