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A Review on Springback Effect in Sheet metal Forming Process

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Abstract: *To study the significant effect of spring back on bending and other sheet metal forming process. Elastic recovery of formed part in unloading known as 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 can be obtained at the end of direct process modeling. Having the product geometry at the end of loading, geometry of die parts can be designed for production of target shape. The ultimate goal of the metal forming industry is to form components made of a specific material into a required shape without experiencing springback.The factors affecting the springback such as material properties, bend radius, sheet thickness etc.*

Keywords*:* spring back, sheet metal forming

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.

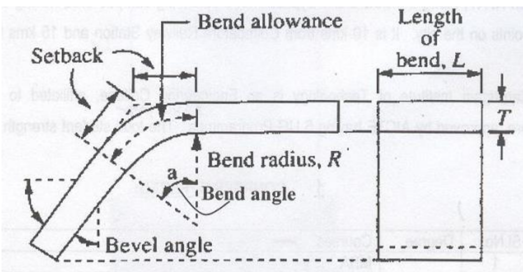

Figure 1: Bending terminology.

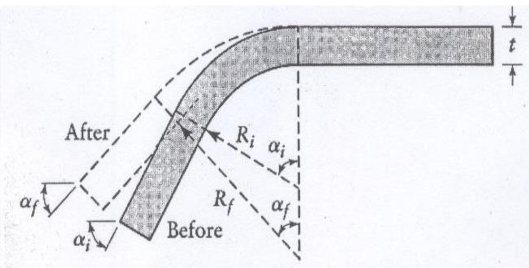

Figure 2: Terminology for spring back in Bending.

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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.

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

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, respectively. It can be noted Fromeqution 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).

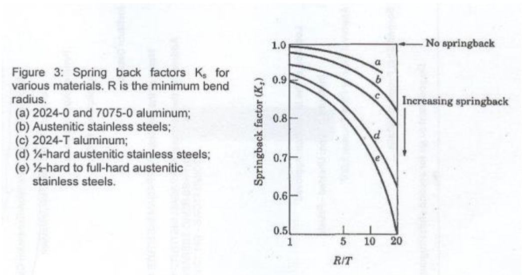

Figure.3

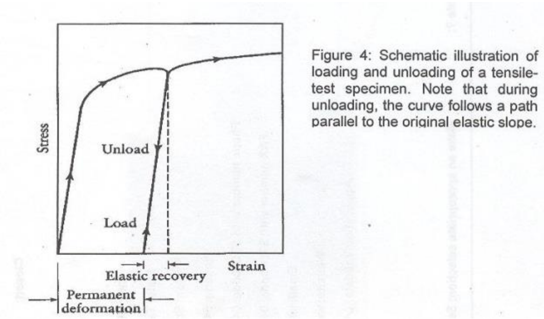

figure.4

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. Negative springback

The spring back observed in Fig. 2 can be called positive spring back. However, undercertain conditions, negative spring back are also possible In other words, the bend angle in such cases become larger after the bend has been completed and the load is removed. This phenomenon is generally associated with V-die bending (Fig. 5)

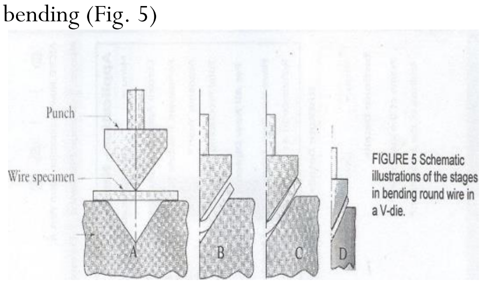

Figure.5

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The development of negative spring back can be explained by observing the sequence of deformation in Fig. 5. If we remove the bent piece at stage (b), it will undergo positive spring back. At stage (c), the ends of the piece are touching the male. Punch. Note that between stages (c) and (d), the part is actually being bent in the direction opposite to that between stages (a) and (b). Note also the lack of conformity of the punch radius and the inner radius of the part in both stage (b) and stage (c); in stage (d); however, the two radii are the same. Upon unloading, the part in stage (d) will spring back inwardly, because it is being *unbent* from stage (c), both at the tip of the punch and in the arms of the part. The amount of this inward (negative) spring back can be greater than the amount of positive spring back, because of the large strains that the material has undergone in the small bend area in stage (b), 1 net result is negative spring back.

4. Compensation for spring back

In practice, spring back is usually compensated for by using various techniques:

1. Over bending the part in the die (Figs. 6a and b) can compensate for spring back; over bending can also be achieved by the rotary bending technique_ in Fig. 6. The upper die has a cylindrical rocker (with an angle of <90^0 and is free to rotate; as it travels downward, the sheet is clamped and bent by rocker over the lowered die (die anvil). A relief angle in the lower die allows over bending of the sheet at the end of the stroke, thus compensating for spring back.

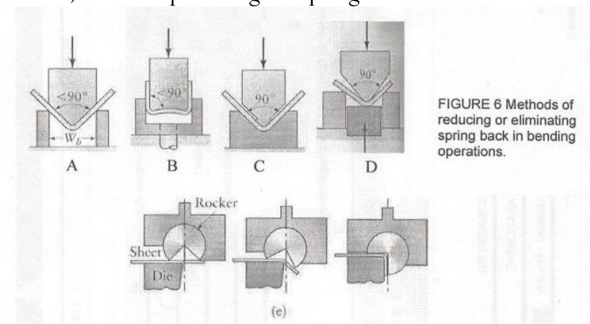


Figure.6

2. Coining the bend region by subjecting it to high-localized compressive stresses between the tip of the punch and the die surface (Figs. 6c and 6d), known as bottoming.

3. Stretch bending, in which the part is subjected to tension while being bent, may be applied. The bending moment required to make the sheet deform plastically will be reduced as the combined tension (due to bending of the outer fibers and the applied tension) in the sheet increases. Therefore, spring back, which is the result of no uniform stresses due to bending, will also decrease. This technique is used to limit spring back in stretch forming of shallow automotive bodies.

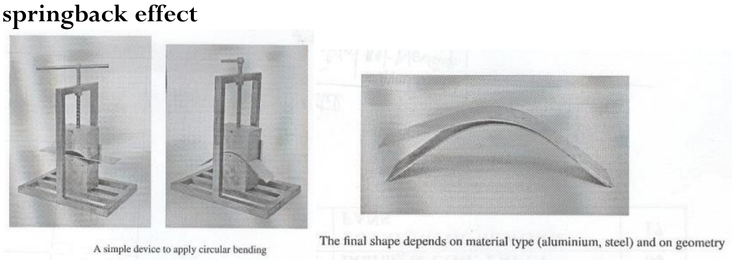
4. Because spring back decreases as yield stress decreases all other parameters being the same, bending may also be carried out at elevated temperatures to reduce springback.

Procedures:

1) Set the bending die on the pressing machine. 2) Set up the pressing machine for the test. 3) Select a sample test, and then measure its thickness (t). 4) Measure the die angle (αi) and die radius (Ri). 5) Perform the bending process by putting the flat sheet on the lower half of the bending die and then press the sheet to the required bending shape by the upper half of the bending die. 6) Measure the final sheet angle (αf) and radius (Rf). After bending. 7) Record all the measurements and observations. 8) Repeat the test for different sheet thick nesses and materials.

Example: 1

Sheet folding and elastic springback effect



This sheet folding process, with very simple modelling conditions based on pure (circular) bending solutions. One objective is to make evidence of the importance of hardening laws, by using more realistic rules that include Bauschinger effects when predicting the final shape of the product after the elastic return produced by the unloading stage. The project is organized in two steps:

– one analytical approach, as a standard exercise, considering the perfectly plastic case,– extended conditions with various isotropic and kinematic hardening rules, with simple automatic simulations. The study is based on circular bending conditions, as shown on figure , on sheets of 1 or 2 mm thickness, in aluminium or steel, with a circular preform allowing to obtain under load a curvature radius of 70 mm. Values could be changed but, under these conditions, the problem meets the small strain assumption. Elastic limit is overpassed during the loading. When unloading, a residual stress field is established and the sheet does not recover its initial plane

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shape. However, it does not maintain its 70 mm curvature radius from loading condition, the final shape having a much larger radius. Final shapes are different for steel and aluminium. Figure illustrates this fact. The objective of the project is to predict the applied bending moment and the final shape of the sheet.

Yield Criteria

The yield criteria used in the finite element anaiysis of the stretch forming process, are described in this section. The selection of these critena is govemed by the behavior of thedifferent Numinium alloys examinai in the FE analysis.

Von Mises Yield Criterion

The von Mises yield critenon is employed in characterizing the isotropic materid behavior. This model can be employed in the stretch forming of some Aluminium alloys such as isotropic Al-Zn 7075-T6 Aluminium alloy. The von Mises yield critenon is represented by the following expression:

$$Y = \sigma_y^2 = \sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2$$

where Y yield locus function,

σ_y material yield stress, and

σ_1 and σ_2 major and minor principle stresses.

In view of its high fatigue resistance, resistance to corrosion and high specific strength, Aï-Zn 7075-T6 is currentiy being used in fonning of aircraft structures. Thus, N-Zn 7075-T6 was analyzed by using an isotropic material model. The chemicai composition of Ai-Zn 7075-T6 Aluminium alloy is given in Table A. 1 of Appendix A. The measured mechanical properties of this type of Aluminium are provided in Table. If the material under consideration exhibits an anisotropic behavior, other constitutive Iaws should be used. If the material under consideration exhibits an anisotropic behavior, other constitutive Iaws should be used.

E (GPa)	σ_{eff} (MPa)	σ_u (MPa)	K_{IC} (MPa$\sqrt{m}$)
72	552	598	28

Table Mechanical properties of Al-Zn 7075-T6 Aluminium alloy (After [3.4,3.5]).

Tool material

Tooling used in the finite element analysis consists of a punch and die system. Since the conducted analysis involves stretch forming of Aluminium alloy sheets. the material used in tooling should be tool steel. For this purpose, the punch and die used are specified to be rigid throughout *the* finite element modelling and analysis.

Hardening Rule

Material strain hardening is modelled by employing a bilinear elastoplastic hardening rule. Thus, in addition to specifying the material elastic rnodulus E, a tangentid modulus Er representing the de- of work hardening must be provided to the ANSYS finite element software.

Example: 2 Determining of springback in Stretch Forming

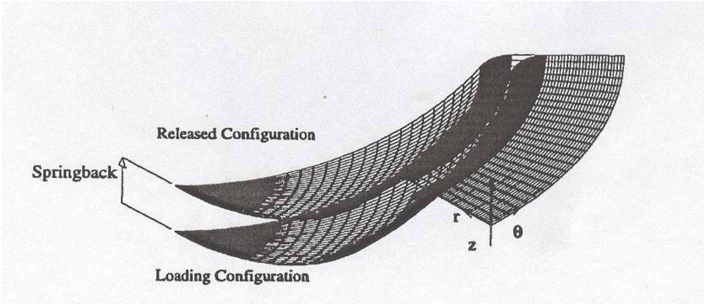

Figure Springback depicted in an Aluminium alloy blank after punch release.

Parameters Influencing Springback

The effec t of the geometric features and the tooling-blank interface fiction conditions upon the resulting blank springback are discussed in this section.

(i) Effect of blank thickness

In order to evaluate the effect of Al 3003-Hl4 Aluminium alloy blank thickness upon the resulting springback, three specimen thickness values of 1 mm, 1.5 mm, and 2 mm were chosen. The finite element solutions and experimental investigations were conducted using a punch radius r, = 17.5 mm. An unlubricated tooling-blank interface condition with a coefficient of friction p = 0.5 was assumed . The results obtained are given in Figures. From Figures, it is evident that the stretch forming force increases with the

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increased blank thickness. The punch loading force has increased by 29.7% due to an increase in the blank thickness from 1.5 to 2 mm. Springback results obtained by varying the blank thickness are given in Figure. It can be extracted from Figure that a maximum discrepancy of 10.3% exists between the springback experimental results and the FE maximum deviation prediction SPB 1. It also shows that the amount of springback, as given by the conducted experiments or numerically determined by the FE maximum deviation SPB 1, the average deviation SPB2 and the mean normal spacing SPB4,decreases by increasing the blank thickness. This finding can be attributed to the increased blank stiffness caused by increasing the blank thickness. Based on the mean normal spacing method, by increasing the blank thickness from 1.5 to 2 mm, a springback reduction of 18% is attained.

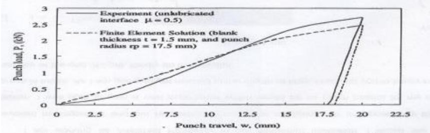

Figure Variation of the stretch forming force with punch travel for a blank thickness t = 1.5 mm.

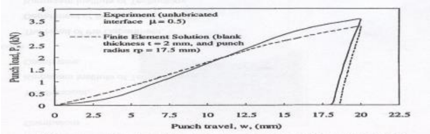

Figure Variation of the stretch forming force with punch travel for a blank thickness t = 2 mm.

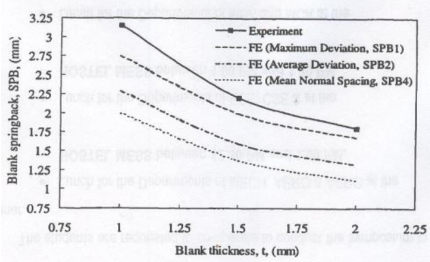

Figure Variation of springback with blank thickness (punch radius r_p = 17.5 mm, punch travel w = 20 mm, and μ = 0.5).

(ii) Effect of Punch Travel

In this subsection, we concentrate on the sensitivity of blank springback to the amount of plastic deformation caused by the prescribed punch travel. Blanlcs with 2 mm thickness were chosen for testing, since it was established in the previous subsection that they provided lower springback values than the thinner blanks. The punch travel w was varied from 10 mm to 20 mm in steps of 2.5 mm. A limiting value of w = 20 mm was used, since values of w *2* 25 mm resulted in inappropriate wrinkling and earning in the vicinity of the blank holder. Wrinkling of tested blanks at a punch travel w = 30 mm is shown in Figure .The analysis was carried out using the same punch, which under a tooling-blank unlubricated dry interface condition w = 30 mm. has a radius r, = 17.5 mm, and with a coefficient of friction p = 0.5 . The results obtained from the experiments and FE analysis for a punch travel w = 15 mm are presented in Figure . Springback findings, as defined by the maximum deviation SPB f and the average deviation SPB2, are also given in Figure . The findings extracted h m Figures illustrate that the blank springback decreases by reducing the prescribed punch travel . The springback was reduced by approximately 27.7% as a result of decreasing the punch travel w €rom 20 to 10 mm. This trend of the blank springback is due to the reduction in the elastic recovery energy at lower plastic deformations.

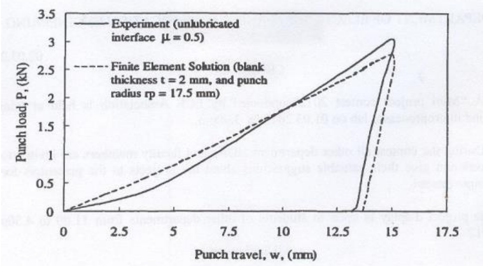

Figure Variation of the stretch forming force with punch travel for a maximum punch travel w_{max} = 15 mm.

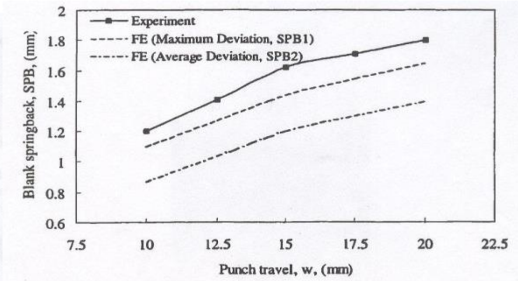

Figure Effect of varying punch travel w on blank springback (punch radius r_p = 17.5 mm, blank thickness t = 2 mm, and μ = 0.5).

(iii) Effect of Punch Radius

The analysis was further extended to examine the effect of varying the punch radius on springback. A smaller punch having a radius r, = 12.5 mm was utilized. Experiments were also carried out on blanks having a thickness of 2 mm and by assuming a coefficient of friction p = 0.5 for an unlubricated *dry* tooling-blank interface condition . The springback results obtained herein are given in Figure. Also presents the variation of the springback, as defined by the mean normal spacing SPB4, with the punch travel for two different punch radii. Figure indicates that smaller values of the punch radius r, for the same blank thickness and interface fiction condition result in smaller springback values in the deformed blanks. Springback reduction of 14.2% is evident at a punch travel w = 20 mm. as given by the mean normal spacing (SPB4) method.

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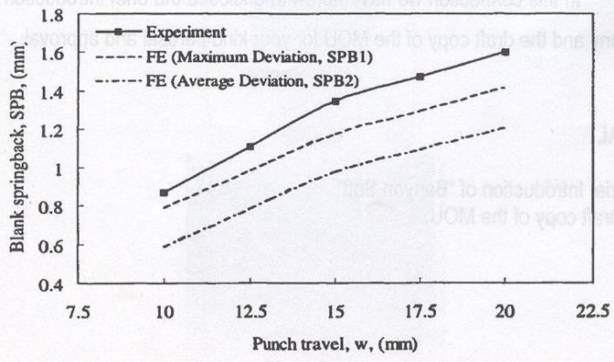

Figure Effect of varying punch travel w on blank springback (punch radius r_p = 12.5 mm, blank thickness t = 2 mm, and μ = 0.5).

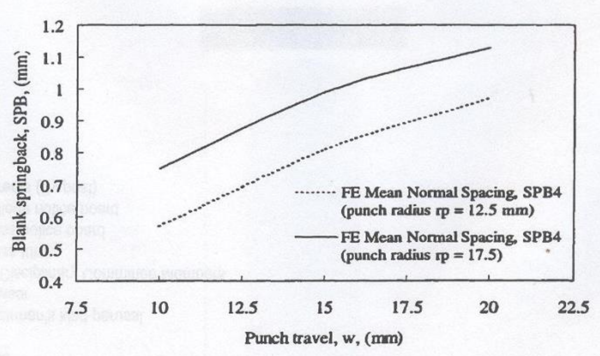

Figure Predicted dependence of springback on punch radius.

(iv) Effect of Tooling-Blank Interface Friction

The main emphasis of this subsection is to focus on the effect of friction and lubrication on the blank springback behavior. The stretch forming deformation process involves high loads and pressures at the tooling-blank contact surfaces. These forces and pressures were mitigated by using a fluid film to lubricate and cushion both the punch-blank and die blank contact interfaces. For this purpose. Grease NUiI Grade 2 was used in the conducted experiments. According to Bhushan and Szen , a coefficient of friction p = 0.05.The loading was carried out using a prescribed punch travel w = 20 mm through a punch with a radius r, = 17.5 mm. The blank thickness was 2 mm. The results obtained are depicted in Figure.

It is evident from Figure that the stretch forming force decreases with decrease interfacial friction at the tooling-blank contact surfaces. Compared to Figure , which indicated a maximum punch loading force P=3.35KN, at μ = 0.5, w = 20mm and for the same blank thickness and punch radius, results obtained from applying grease as a lubricant with p = *0.05* provided a maximum load = ,P 2.4 kN; a decrease of 32%. Grease provided a springback increase of 22.3% relative to the unlubricated dry interface condition (p = 0.5) at t = 2 mm, r, = 17.5 mm, and w = 20 mm. The above results show clearly that increasing the blank holder force as a result of friction decreases springback. This is due to the fact that in stretch forming, two deformation mechanisms operate: bending deformation and tensile deformation. Increasing the tensile deformation through friction decreases the bending component leading to an overall reduction in springback.

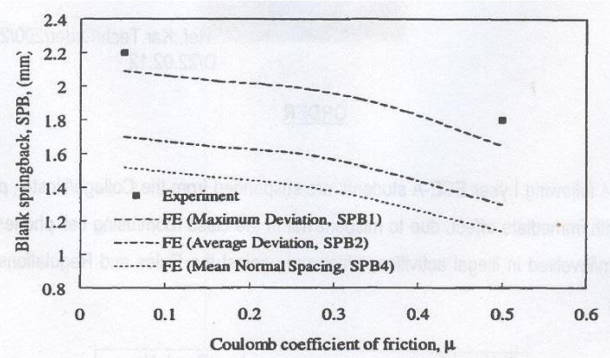

Figure Predicted dependence of springback on friction at the tooling-blank contact surfaces.

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 blank thickness, Punch Travel, Punch Radius and Tooling-Blank Interface Friction. We can reduce this type of error for increasing blank thickness, varying bend radius, reducing the prescribed punch travel, reduce the friction between blank surfaces and die surfaces by lubricant, etc.

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