NUMERICAL INVESTIGATION OF SPRINGBACK EFFECT IN DRAW-BENDING TESTS

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ABSTRACT

The deep drawn process produces high-strength, lightweight parts more cost-effectively than other methods. Among the advantages offered by deep drawing are rapid press cycle times, fewer operations required to finish a part and the ability to create complex geometries unattainable through other processes. Upon completion or during the sheet metal forming, deep-drawn and stretch-drawn parts springback and thereby affect the dimensional accuracy of a finished part. The final form of a part is changed by springback, which makes it difficult to produce the part. This study considers two draw bending tests (2D draw bending test and 2D drawbeads test) in order to evaluate the effect of springback. The springback parameters will be determined in our study in order to see and then to compare the different springbacks which will appear. The use of draw-beads has provoked a reduction of the maximal punch displacement before the fracture of the DC05 sheet.

KEYWORDS: draw bending test, drawbeads, springback

1. INTRODUCTION

Deep drawing is a metal forming process in which sheet metal is stretched into the desired part shape. As shown in figure 3 the deep drawing process requires a blank, punch, die and a blank holder with or without drawbeads around the edge of the die. The punch pushes downward on the sheet metal, forcing it into the die cavity [2].

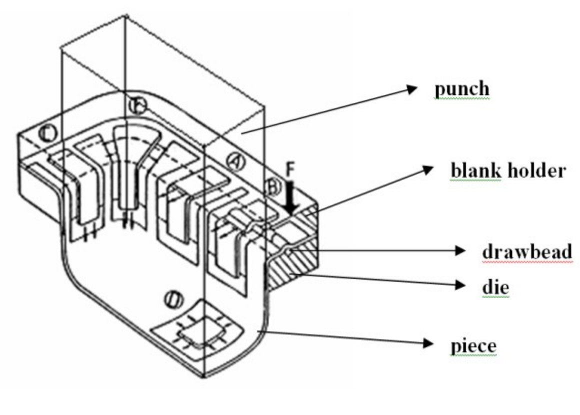


Fig.1: Complex deep drawing process [2]

When drawing complex car body parts in practice, there is usually a combination of stretch and deep drawing involved. It is necessary for the sheet metal to be stretched as well as possible without reaching the material limits (e.g. splits, wrinkles).

During and after deep drawing process, several defects can occur caused by the process or material parameters:

- anisotropy of the material;
- springback;
- blank holder force;
- restraining forces, which are not efficient enough, & all.

The springback is very important and determine the geometric change made to a part in two situations:
- at the end of the forming process when the part has been released from the forces of the forming tool;
- during the forming process due to the uncontrollable deformation of the material between two contact points sheet-tools.

As a result, the manufacturing industry is faced with some practical problems: firstly, the prediction of the final part geometry after springback and secondly, appropriate tools must be designed to compensate for these effects.

Two solutions are used in order to compensate these effects:

-increase of blank holder force, but fracture can appear if this force is too large and block the flow of the sheet in the die cavity;

-use of drawbeads in order to apply an additional local restraining force.

Different researchers initiate experimental tests in order to simulate the conditions of the sheet deformation during deep drawing process. These experimental tests are used in order to identify the influence of different parameters on the defects. The cost of these experimental tests is relatively high. For this reason numerical tests are initiated and considered a useful tool for defect prediction and control of deep drawing process.

2. METHOD PRESENTATION

2.1. Tests setup

This study considers two draw bending tests in order to evaluate the effect of springback on the dimensional accuracy of a finished part:

- test1- 2D draw bending test;
- test2 - 2D brawbead test, which is the 2D draw bending test modified by adding drawbeads.

The 2D draw bending test represents the rectangular sheet deformation in a conic deep drawing device (Fig.2). As result, it will be possible to see the springback which is due to internal stress of the sheet metal during and after deep drawing process.

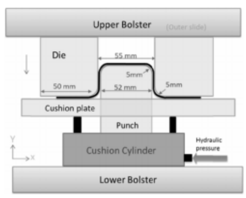


Fig. 2: Die setup of 2D draw bending test [3]

After having done a 2D draw bending test, J. R. Shah [6] & col. has found that the deformation area of sheet can be divided into five regions along the length direction as shown in Fig.3, and the stretching force and bending moment acting on each region are shown in this figure.

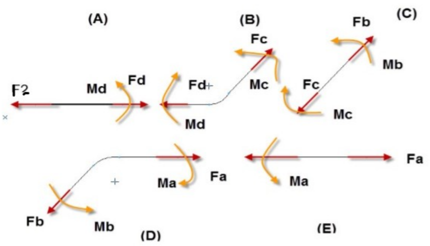


Fig.3: Deformation regions in 2D draw bending test [6]

In fact, every different zone can be seen and considered independently. The global effect is represented by the following parameters: θ_1, θ_2 and ρ θ_1, θ_2 *and* ρ (Fig. 4) [3], where θ_1 θ_1 is the angle between the 2 segments in the region (B), $\theta_2$$\theta_2$ is the angle in the region (D), and ρ ρ represents the radius of the final curve in the region (C).

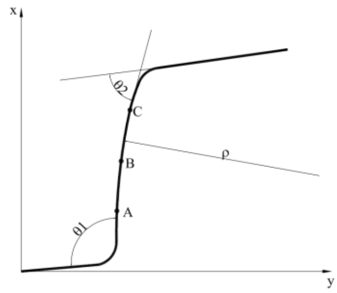


Fig. 4: View of springback parameters θ_1 θ_1, θ_2 and ρ ρ [4]

With a modified 2D draw bending test including drawbeads, the process is a little bit different.

The first step is the drawbead closure. In the second step, the punch displacement determines the sheet metal passing through the draw-bead during its deformation between the punch and die, while keeping the drawbeads closed [1]. However, the input of drawbeads has an impact on the maximal displacement the punch can have. In fact, the drawbeads displacement means a rise of the stress inside the sheet metal during the deep drawing process.

During the displacement of the punch, the part of the sheet which passes through the drawbeads will be affected. At the passing through the draw beads, the material suffers progressively cycles of deformation, type bending/unbending under tension. Consequently, the final effect of the material passing through drawbeads is a cumulated residual strength and bending moment (Fig. 5) proportionally inverse with the centerline curvature of the sheet, respectively with square [5].

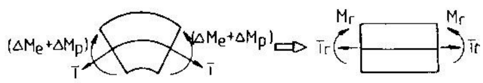


Fig. 5: Effects of a single bending/unbending under tension cycle [5]

2.2. Material properties

The material DC05 has been used for this study. A previous study about this material has been done [8], in order to find its characteristics: Young modulus, Poisson parameter, fracture limit stress, yield stress and coefficients of the hardening law. The description of the plastic zone of true strain/true stress curve is performed considering a power law:

$$\sigma = A\varepsilon^{m} \qquad (1)$$

For the considered material the identified coefficients of this law are: A = 529.5 MPa and m = 0.268.

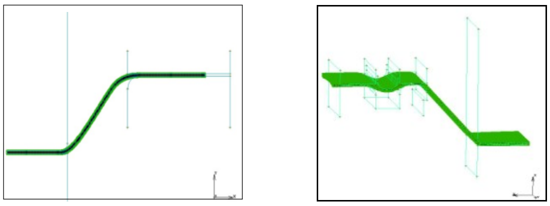
2.3. Numerical model definition

Numerical definition of the two considered tests was performed using Marc Mentat finite element code.

The tools (die, punch and blankholder) are considered rigid bodies and the material as a deformable body. In the module "Material definition" the power law is introduced using the identified coefficients. Considering the symmetry of the 2D draw bending test, only one half was modelled. It results the boundary condition represented by x and z blocked displacement. The blankholder and punch displacement are defined in order to describe the kinematic of the test.

In the case of the modified 2D draw bending test (drawbead test) the geometry of the blankholder and die was modified in order to include drawbeads.

The numerical models of the considered tests are presented in the figure 6.



a) *b)*

Fig. 6: Numerical model of tests: a) 2D draw bending test; b) 2D drawbead test

2.4. Finding of the maximum punch displacement before fracture

The first step of the numerical modelisation of draw bending tests was to define the maximal displacement the punch could have. After a test which had a maximal displacement of 50 mm, the maximal stress zones had to be found.

Thanks to the data obtained before [8], the maximal stress of the DC05 material is already known. As a result, the maximal displacement can be found on the curve Von Mises stress-punch displacement (Fig. 7) in the node of the most solicited zone. The maximal stress is reached for the first time when the displacement of the punch is at 28,8mm, in the case of 2D draw bending test.

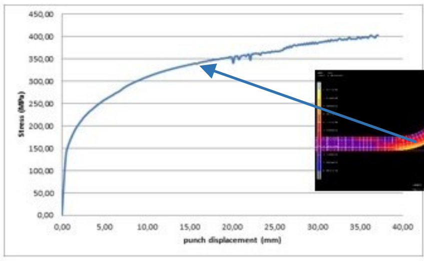


Fig. 7: Curve Von Mises stress - punch displacement

Considering the same hypothesis, the maximal stress is reached for the first time when the displacement of the punch is at 10 mm for 2 mm penetration of drawbeads, in the case of 2D drawbeads test.

3. RESULTS AND DISCUTION

The numerical and experimental studies are developed in order to:

- predict the level of the springback;
- design the appropriate tools for springback compensation.

The aim was to compare the two draw bending tests, with and without drawbeads, in order to see the impact of drawbeads on the springback.

To be able to compare the two tests, the test1 has to be modified with the same punch displacement than the test 2 during the draw-bending process.

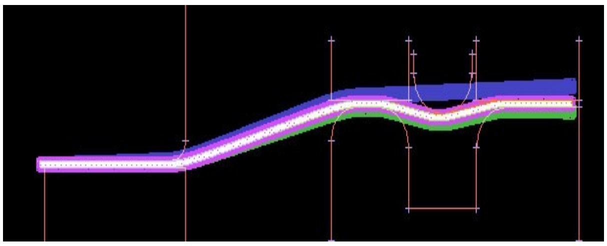


Fig. 8: Comparison between test1 and test2 pink – test2 without release; green – test2 with release; blue- test1 with release

The values of these different parameters were found:

Tab. 1: Springback parameters for test1 and test2

	θ_1 [^{0}]	θ_2 [^{0}]	ρ [mm]	$\theta_{lp/x}$
test1	165,26	14,10	5578.89	1.24
test2	166,31	13,70	10097.9	0

The θ_1 and θ_2 do not have a big difference.

However, it can be seen on Fig.8 and Tab.1 that the test1 after release also has an angle between the low-part of the sheet and the x-axis ($\theta_{lp/x}$), which is not the case for test2 after release.

Moreover, the ρ of test2 is almost the double of the test1 ρ, which means that the curvature effect with drawbeads is far less important than without drawbeads. We know that this curvature effect determine the wrinkles during the deep drawing process, one of most important defect. Using a correct penetration of drawbeads we can avoid wrinkles and fractures in the same time.

Through this numerical analysis, the metal forming process of the DC05 sheet has allowed to show the impact of the different parts on the forming process and the appearance of the springback effect.

The use of drawbeads has caused a reduction of the maximal displacement the punch can have before the fracture in the case of DC05 sheet materials. However, the drawbeads have also an impact on the springback. In fact, the comparison between the draw bending test without and with drawbeads has permitted to show the impact of drawbeads on the springback. Even if the angles are not really altered, the advantages of the drawbeads use are:

- reduction of the angle between the low-part of the sheet and x-axis;
- increase of the radius ρ.

As a result, the use of drawbeads is an asset, even if it also reduces the maximal punch displacement allowed for the metal forming process. Another test would have been done with another use of the displacement of the drawbeads in order to optimize their effect on the springback.

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