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Sheet Metal simulation

Dr. Ragba Mohamed Abdusslam

Abstract: *Finite element method is an important modeling tool in sheet metal forming industry. The knowledge of the sheet springback after forming is necessary to control the manufacturing process. Nowadays, the significance of this issue increase because of the use of steel sheeting with high stress yield. In this paper the numerical simulation of springback and side wall curl in 2-D draw bending has been achieved done using ELEFEN software. An anisotropy property for material was considered. The modeling of the problem has been performed by the by the explicit method for the loading stage and the combination of the implicit and explicit method for the unloading.*

Keywords: *sprinback, U-bending, ansiotropy, simulation and finite element method.*

I. Introduction

In sheet metal forming operation, the blank being formed conforms closely to the shape when it is in press. When the load is released and the part taken out of the press, however, there is change in the shape. This change is referred to as springback. In today's engineering practice, the tools are modified in order to compensate for expected sprinback. These modifications are based on experience and empirical formulas regarding magnitude and appearance of the shape deviations. Since it is very difficult to make accurate judgments concerning the magnitude of the sprinback, even for highly experienced engineers, the design and tryout of the pressing tools often have to be done in several loops. Three kinds of approaches for calculation of the springback have usually been used; analytical method, experimental, and numerical method. Gardiner established an analytical solution for sprinback of plane stress, pure bending for plastic-perfectly plastic materials [1]. Queener and De Angetis extended it to plane strain [2]. Yu, T.X. and Gohnson developed formula of springback for non-linear materials [3]. With the rapid increase in computation power, finite element method (FEM) was widely used in the field of sheet metal forming. Results on sprinback simulation by the FEM vary according to the manner in which the given problem is modeled. Actual forming operation such as 2-D draw bending is used to assess practical sprinback. This geometry is the most studied of sprinback cases because of its practical importance. This phenomenon is a result of residual stress through the sidewall thickness. Pourboghrat used a semi-analytical approach to predict sprinback in sheet metal forming process [4]. Li presented a model for evaluating sprinback in sheet metal forming based on the explicit finite element method [5]. The use of high-strength steel has increased the need for springback control because of its higher yield strength to elastic modulus. In this study the aim is simulating sprinback and side wall curl in 2-D draw bending by ELEFEN software. The high steel material with anisotropy is assumed

II. D draw bending problem

Fig 1 describes the geometry of the problem. In Fig 2 the parameters used for characterising the sprinback and sidewall curl are shown. These are the angles

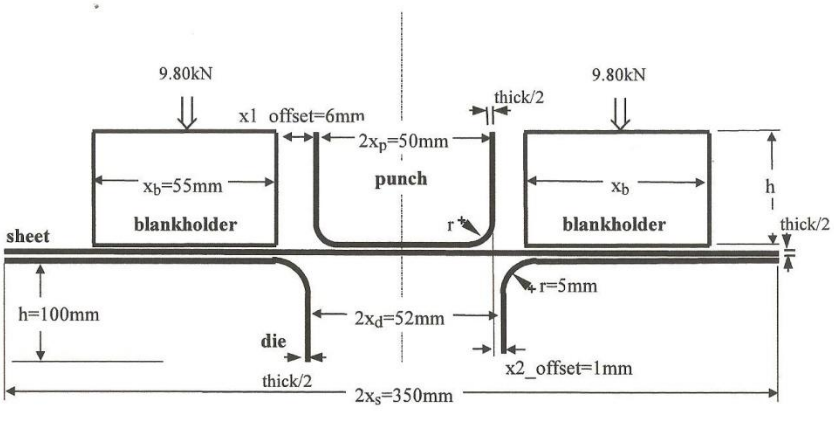


Fig.1. Schematic Of The Problem

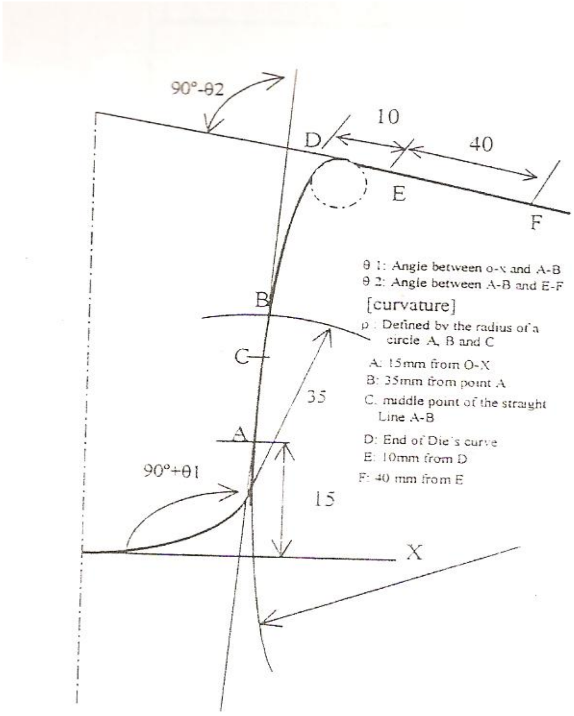


Fig.2. Description of the three quantities θ1,θ2 and P to quantify springback and sidewall curl.

$\theta_1 and \theta_2$ and radius of curvature, ρ. The effective stress-strain relation is given in the form:

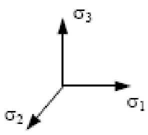
$$\sigma = K(\varepsilon_0 - \varepsilon_p)^n \qquad (1)$$

Where σ is the effective stress, K is the strength coefficient, is the constant value, ε_p is the plastic strain and n is the strain hardening exponent. The sheet material is assumed to have planar isotropic characteristic. The normal anisotropy of the sheet can be represented by a single parameter r which is defined as:

$$r = \frac{\varepsilon_w}{\varepsilon_t} \qquad (2)$$

where w and t refer to the width and thickness of strip respectively. Also

$$\sigma_{11} = \sigma_{22} = \sigma_y \qquad (3)$$



$$\sigma_{33} = \sigma_Y \sqrt{\frac{1+R}{2}} \qquad (4)$$

$$\sigma_{12} = \sigma_{13} = \sigma_{23} = \frac{\sigma_Y}{\sqrt{3}} \qquad (5)$$

Where is the reference or uniaxial yield stress, directions 1, 2, and 3 are related to length width and thickness of blank respectively. The densities of the blank and the blank holder (deformable bodied) have been artificially increased by a factor of ten to increase the critical time step for the problem. As the problem is quasi-static, the change in density does not affect the solution. The critical time step is given by:

$$\Delta t_{cr} = \frac{l}{c} \quad \text{where } c = \sqrt{\frac{E}{\rho}} \qquad (6)$$

Where l is the length of smallest blank element, c is the wave speed, E is the young's modulus, and ρ is the density. The problem was intended to be analysed for high strength steel. The material parameters are given in Table 1.

Table1. High steel parameter used in simulation

Parameter	Value
E (N/mm²)	206000
K(N/mm²)	681
Blank size(mm)	350 35 0.74
R	1.66
υ	0.3
ε_0	0.0125
N	0.218
μ	0.129

III. Numerical modelling

Loading

For the 2-D bending problem, a sheet metal is clamped by a constant blankholding force and then subjected the bending. The punch and die were modeled as rigid surface. In this study a structural mesh of linear 4-noded elements was used and the simulation carried by ELFEN software. Since the width of the blank was much greater than its thickness, the problem was considered to be plane strain. Due to symmetry a half of the geometry was modeled for simulation. 5 stages were considered; 2 stages for loading and 3 for unloading. The loads, constraints and contact sets required in each stage are summarized in Table 2. The blankholding force is equal to 2.45 KN this load is applied to the upper surface of blankholder see Fig 1. The other load is punch movement is applied in stage 2 to achieve a total displacement of 70 mm.

Table 2 Process data required for simulation

Stage No	Load	constraint	Contact
1	BHF	Blank Blank holder Die	Blank-die Blank-blank Holder
2	BHF Punch movement	Blank Blank holder Punch Die	Blank-die Blank-blank Holder Blank-punch
3	BHF Punch removing	Die Blank Blank holder punch	Blank-die Blank-blank Holder Blank-punch
4	Holder removing	Die Blank Blank holder	Blank-die Blank-blank Holder
5	ejection	Blank Die	Blank-die

Contacts

Three contact sets created for this simulation see Table 3. The punch and die surface are treated as rigid, while the blank and the blank holder are deformable. In this paper contact with friction are used.

Table 3 contact data required for simulation

Contact set	Contact surface	Contact mode
Blank-punch	Blank-top and punch	Deform/rigid
Blank-blank holder	Blank-top and plank holder	Deform/deform
Blank-die	Blank-top and die	Deform/rigid

Constraints

The symmetric face of blank (at the centre line) is constrained in X direction, while the punch is constrained in X direction and Z rotation, Die is fully constrained in X and Y direction and Z rotation.

Unloading (Springback simulation)

The amount of springback is the difference between the final shape and the shape after punch travel, Indeed after the removal of the tools, the deformed part shape undergoes another significant geometric changes. This such as blankholder forcc and friction between the blank and tools.

There are two method for springback modeling . In the first method , tools are removed and all contact nodal forces are recovered. Then all these contact nodal forces are decreased to zero value , so the sheet is set free from contact nodes.

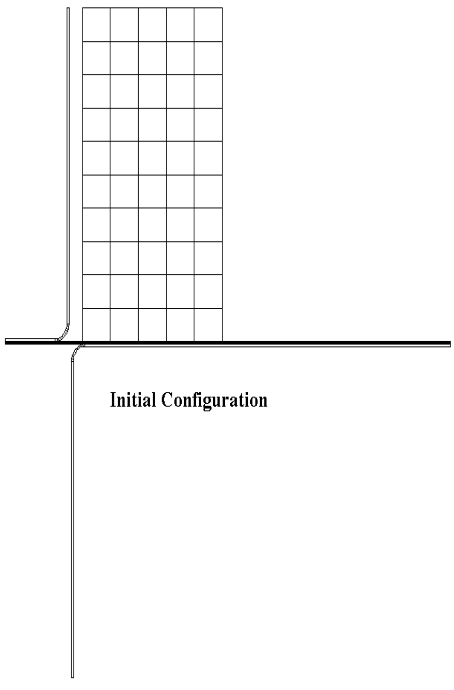
In this method, it is also necessary to add new conditions to avoid rigid body motion. In the second method ,an opposite motion is given to the tools at the end of the loading stage and the computation continues until no contact with the sheet metal. In this paper, the second approach for springback modeling is used.

The explicit scheme cannot be used for springback simulation because this would give undamped vibrations of the upper part of the blank after ejection. These vibrations would never be damped out, which is physically incorrect and would unable the measurement of springback because the blank would have no static final shape. Therefore the implicit solver is used for stages 3 and 5.

In stage 4, the implicit scheme for blank holder removal phase was not used because this would necessitate a vertical degree of freedom constraint in order to prevent a rigid body movement from making the iterative process diverge, also this would have prevented modelling all the springback effects correctly.

Thus for stage 3, punch-remove load is applied for punch-remove a reference displacement is taken as +1 mm in the Y direction with the total displacement of 140mm (see fige. 4 and 5).

In stage 4, blank holder-removing load is applied. The total time of 0.01 ms is considered for this stage. The change in the blank are shown in fige. 6 and 7. In the last stage , the blank is allowed to move and be free. The final shape of blank is shown in fig.8.



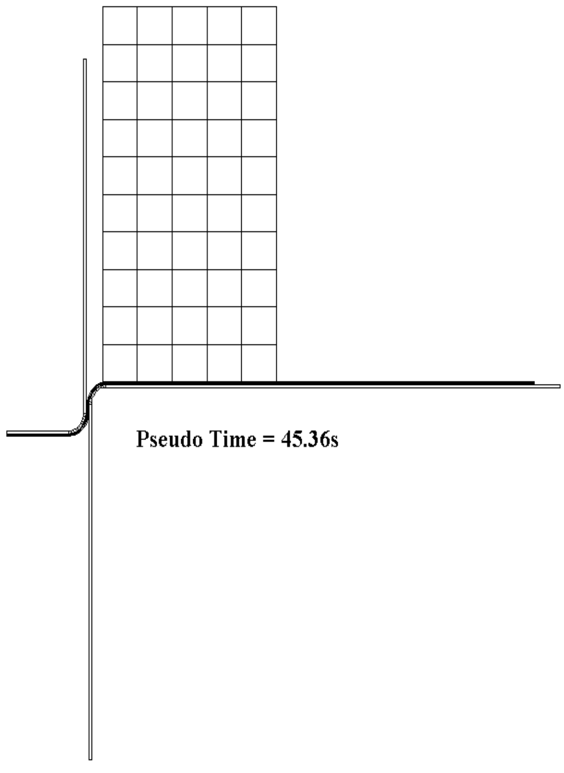
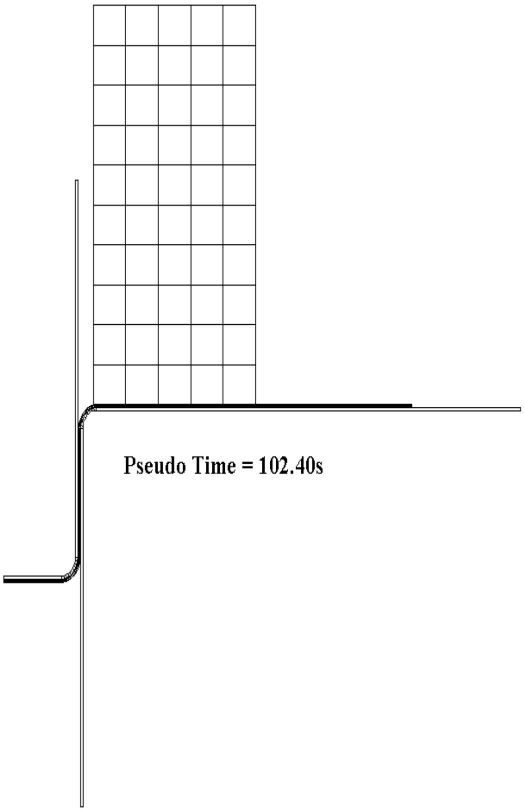


Fig.3. Applating blank holder force (stag 1). **Fig.4.** Punching phase (stage 2).



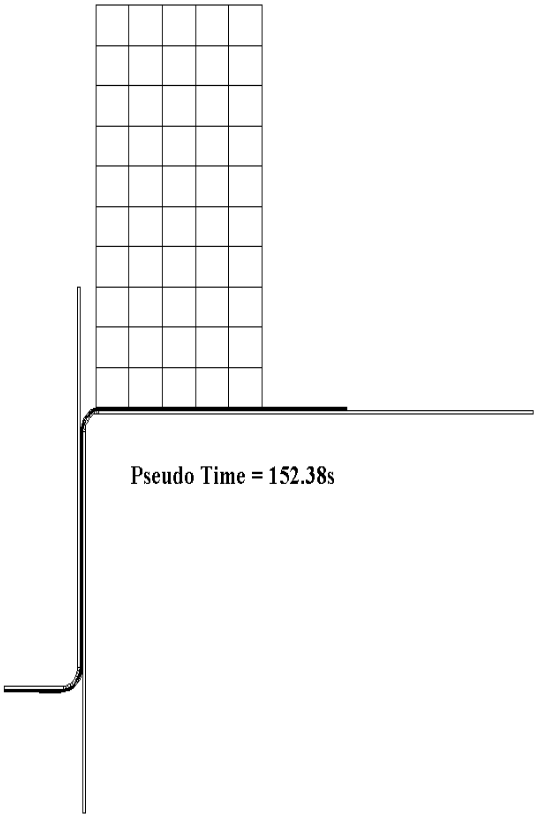
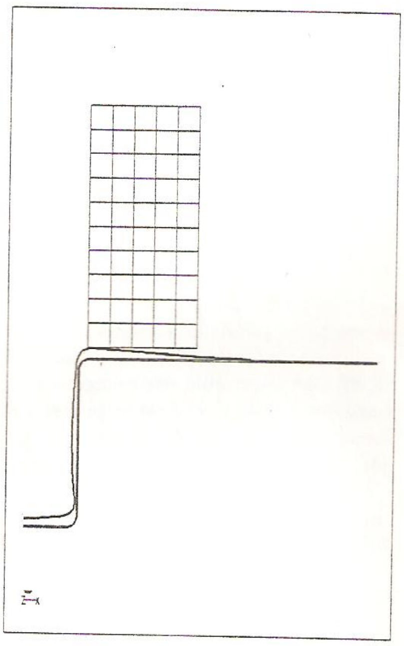


Fig.5. End of punching phase (stage 2**).** **Fig.4.** Punch removing phase (stage 3).



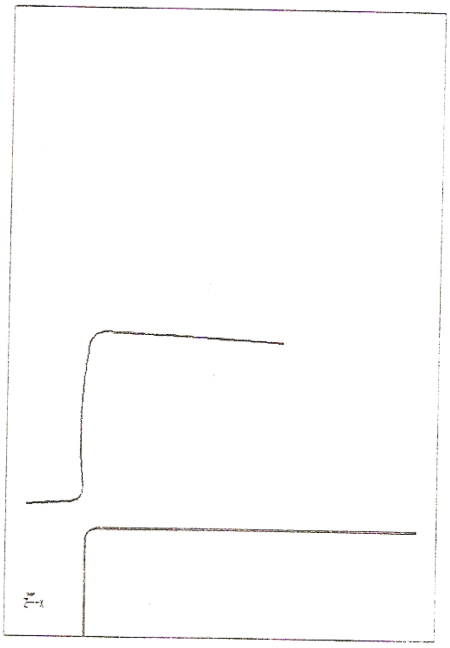


Fig.7. End of blank holder removing (stage 4**).** **Fig.8.**Ejection phase (stage 5).

IV. Conclusion

A finite element code was described to simulate the springback and aidewall curl in 2-D draw bending. Five stage have been applied for simulation of whole process, two stages for loading and three stages for unloading. In loading process explicit solver has been used, whereas both implicit and explicit solver have been used for unloading process. The results showed that the springback and sidewall curl phenomena could be completely simulated by ELFEN software for sheet metal forming of high strength steel.

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