Designing of a Reconfigurable Set of inverse Re-Drawing Dies Aided by FEM Simulation

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Abstract

This paper deals with the methodology for developing a laboratory inverse re-drawing device. The drawing process is performed in two phases: a direct drawing of a circular blank followed by a second reverse re-drawing phase on the same device. Finite element simulations are carried out in order to i).define geometrical characteristics of the modular re-drawing device and to ii). estimate the punch force evolution for different dimensions of punch, die and blankholder and for a large class of materials. Based on such FEM simulations, springs for the developed reverse deep drawing device are dimensioned. The use of springs gives the possibility to deform the material with an imposed blank-holder force. Finally, a draw of the designed modular device is presented considering all the results of the finite element simulation..
Keywords: *finite element simulations, inverse re-drawing, strain path, modular device.*

1. Introduction

The analysis of the inverse re-drawing process provides several advantages as (i) the imposed strain path changes are severe and complex leading to a better analysis of the accuracy of the finite element analysis, (ii) large amount of deformation can be imposed where limitations due to the localization problems are reduced, (iii) the imposed strain path changes can determine the compensation of the bending-unbending effects (tensile stress and bending moment) due to the material flow over the tools radius during the first stage of the deep-drawing process.

In this study we propose to proceed with a direct drawing of a circular blank followed by a second inverse re-drawing stage using a laboratory device. These two stages must to be progressive in order to avoid the errors due to the positioning of the piece obtained in the first stage.

2. Design of the inverse re-drawing dies

The laboratory device is designed considering these cases:

- material – AL5182, DP600, HSLA (table 1);
- pieces type 1 and 2 (fig.1, table 2).

Table 1

Material	Y_0 [Mpa]	R_m [Mpa]	E [Mpa]	ν
AL5182	130	340	72000	0.32
DP600	260	840	210000	0.33
HSLA	370	530	210000	0.33

Table 2

Type of the piece	D [mm]	T [mm]	H [mm]	R [mm]
1	78	1	70	8,5
	74	1,2	70	10
	70	1,5	70	11
2	60	1	70	8,5
	52	1,2	77	10

This device has changeable tools (punch, die, blankholder) in order to assure the conditions to obtain all pieces, using all materials considered.

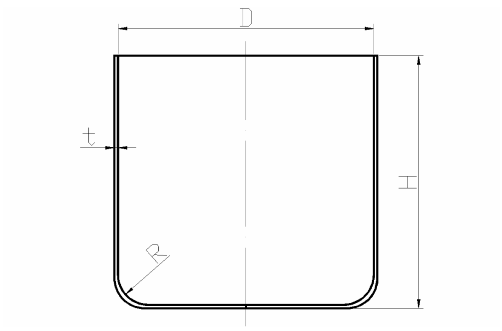

Figure 1.

The definition of the tool-sets (punch, die, blankholder, clearence) and choice of process parameters (number of forming stages, forces to apply) must be performed for every type of the piece and material considered.

Improvement of design and tryout procedures using numerical simulation may have a significant impact on the cost of the tools and on the reduction of the total time from design to manufacture, also with the possibility to provide better solution than those determined from purely experimental tryout procedures.

Following the preliminary design, the tools must have the geometry presented in figure 2 in order to perform the deep-drawing in two stages on the same device.

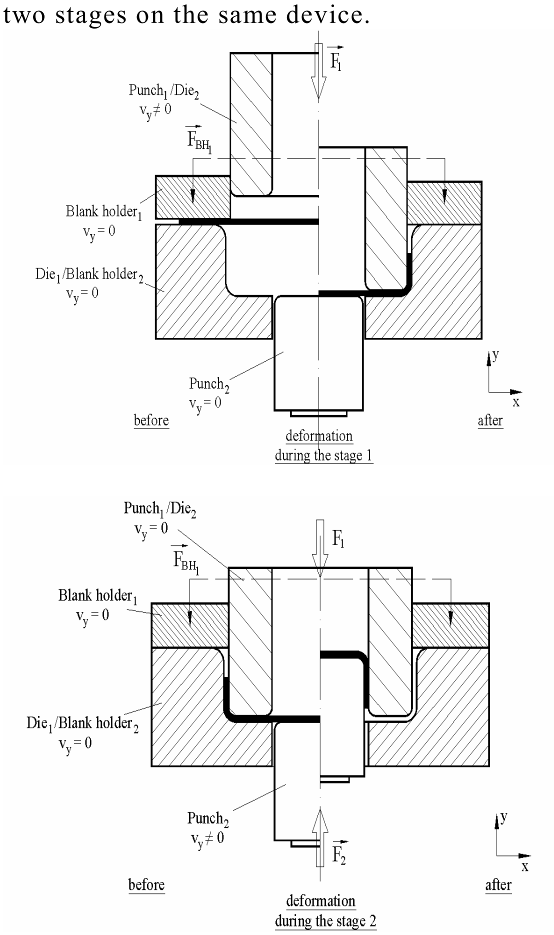

Figure 2

3. Finite element simulation

Finite element simulations using a static-explicit finite element code STAMP3D, released within Integrated V-CAD Research System Program in RIKEN Institute, Japan, and an implicit code MARC Mentat 3.2 are carried out in order to estimate the punch force evolution for different dimensions of punch, die and blankholder, and for a large class of materials.

We considered the symmetry of the system and its result, in order to model only half of it (figure 3).

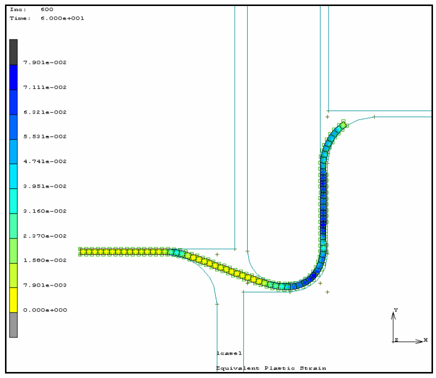

Figure 3. *Equivalent plastic strain distribution during the second stage.*

The type of the finite element used is plane stress quadratic (4 nodes) element in MARC Mentat 3.2 Hardening law considered is Swift (isotropic hardenind) for steels (DP600 and HSLA) and Voce (isotropic hardening) for aluminium alloy.

Table 3. *Swift law (isotropic hardening) parameters [1].*

Parameter	DP600	HSLA
Y_0	308.3	367.7
ε_0	0.00082	0.07157
n	0.132	0.139
C	720.2	530.9

Table 4. *Voce law with kinematic hardening parameters [1]*

Parameter	Value
Y_0	148.5
C_R	9.7
R_{sat}	192.4

The simulation with the initial parameters has two problems: firstly the simulation doesn't reach the end and undulations appear.

Generally when the simulation doesn't reach the end it's due to the nodes positions when they enter in contact, or fast stress increases at an increment of the simulation.

These problems could be solved by some geometrical modifications, or punch speed modification.

The parameters are modified one by one in order to keep reversibility if the simulation doesn't well run.

The first modifications were made to make the simulation reach end. The first idea is to decrease stress due to the first pass by modifying the first pass geometry. But the solution was to change the second step clearance.

Once the simulation reach the end, we try to reduce undulation by reduce the second step clearance. The optimized value of the second step clearance is 1,22 mm (calculate by the Kaszmarek relationship but we arrived to obtain results for clearance a few bit inferior to that (1,2 mm). The First step clearance was also enlarge to decrease stress.

Chronology of geometrical adjustment is presented in the table 5.

Table 5

Simulation #	Inc stop (last inc=1014)	Drawing depth	Clearance 1	Clearance 2	Punch Round Radius 1	Die Round Radius 1	Punch Round Radius 2	Die Round Radius 2	Relative sliding velocity
0	593	30	1,3	5,2	5,5	8	8,5	5,5	1
10	809	**58,5**	1,3	5,2	5,5	8	8,5	5,5	1
20	924	54,5	1,3	5,2	5,5	8	8,5	5,5	1
Seek optimized first pass parameters									
21	802	58,5	1,3	5,2	**5,5**	**8**	8,5	5,5	1
22	809	58,5	1,3	5,2	**6**	**8**	8,5	5,5	1
23	419	58,5	1,3	5,2	**6,5**	**8**	8,5	5,5	1
24	413	58,5	1,3	5,2	**5,5**	**8,5**	8,5	5,5	1
25	417	58,5	1,3	5,2	**5,5**	**9**	8,5	5,5	1
26	840	58,5	1,3	5,2	**6**	**8,5**	8,5	5,5	1
31	407	**58,5**	**2,1**	5,2	6	8,5	8,5	5,5	1
32	289	58,5	**3,7**	5,2	6	8,5	8,5	5,5	1
Seek optimized second pass parameters									
40	1000	58,5	1,3	**2,2**	6	8,5	8,5	5,5	1
41	1014	58,5	1,3	2,2	**5,5**	**8**	8,5	5,5	1
Reduction of the undulation									
50	787	58,5	1,3	**1,5**	5,5	8	8,5	5,5	1
60	1005	**57,5**	**1,5**	1,5	5,5	8	8,5	5,5	1
70	1014	57,5	1,5	1,5	5,5	8	8,5	5,5	**0,075**
80	910	58,5	1,5	**1,3**	5,5	8	8,5	5,5	0,075
81	1014	58,5	1,5	1,3	**6**	8	8,5	5,5	0,075
90	783	58,5	1,5	**1,2**	6	8	8,5	5,5	0,075
91	1014	58,5	1,5	**1,22**	6	8	8,5	5,5	0,075
100	1014	58,5	1,5	**1,2**	**5,5**	8	8,5	5,5	0,075

Following the finite element analysis we obtain the punches force evolution (fig. 4) necessary to define the final dimensions of the tools and to select the optimum necessary press-machine. We represented in figure 4 the evolution of the punchs force in the intermediary state during the second stage, the same state like in figure 3. Maximum forces to apply are obtained for first stage (on the punch 1) of the process. This values is used to define the final dimensions of the tools.

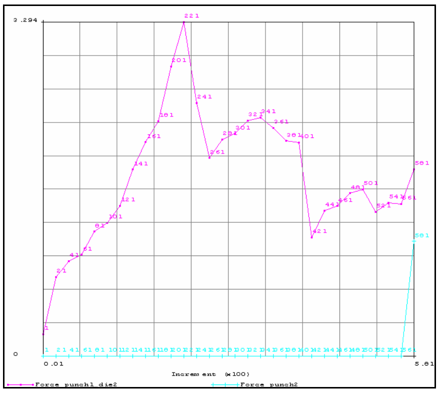

Figure 3. *Punch 1 and punch 3 force evolution*

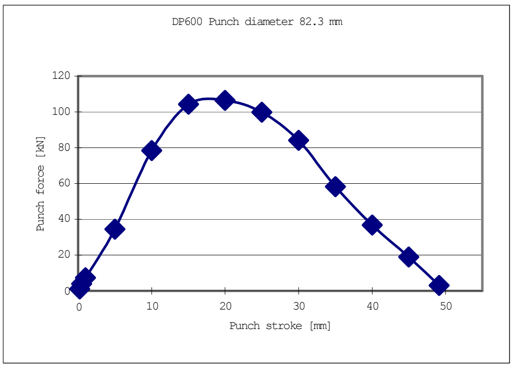

Figure 4. *Punch 1 force evolution for DP600.*

On the figure 5 we can notice the earing effect due to the anisotropy (fig. 6) of the material and we use this one in order to check the height of the piece obtained in the first stage of the process.

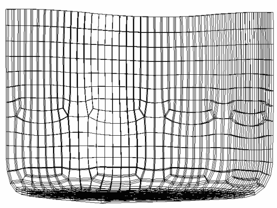

Figure 5. *Earing effect for DP600 at 50 mm height obtained after the first stage*

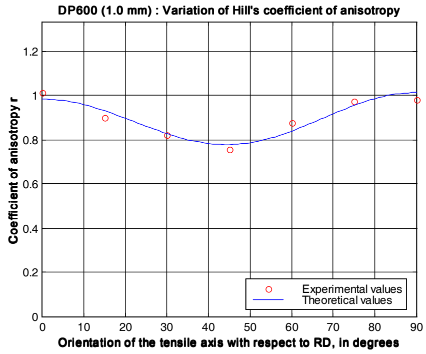

Figure 6. *Anisotropy of DP600*

4. Conclusions

For the reverse re-drawing simulation the geometry of the dies is defined. The DP600 and HSLA steel have the abilities to support the severity of reverse re-drawing process. In the same time theses steels are designed for this kind of operation. The evaluate draw ratio (β_{21im} =1,75) on the second pass is very good (superior to the draw ratio on the first pass).

5. Acknowledgements

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Proiectarea unui echipament tehnologic reconfigurabil pentru ambutisarea inversa, utilizand simularea cu EF

Rezumat:

Aceasta lucrare are ca obiectiv dezvoltarea metodologiei de proiectare a unui echipament tehnologic de laborator pentru ambutisare inversa, avand elemente active schimbabile. Procesul de deformare se realizeaza in 2 etape: ambutisarea directa a unui semifabricat plan de forma circulara, urmata de a doua ambutisare pe acelasi echipament, in sens invers sensului de deplasare a materialului de la prima ambutisare. Simularea cu elemente finite s-a realizat cu scopul: i). definirii caracteristicilor dimensionale ale echipamentului modular si ii). estimarii evolutiei fortei de deformare pentru diferite dimensiuni ale poansonului, placii active si placii de retinere, pentru o gama larga de materiale. In final, echipamentul tehnologic de laborator este dimensionat pe baza rezultatelor simularilor numerice.

Conception d'un équipement de laboratoire pour l'emboutissage inverse, en utilisant la simulation EF

Résume:

Ce papier a comme objectif le développement de la méthode de conception d'un équipement de laboratoire pour l'emboutissage inverse, ayant le couple poinçon - matrice changeable. Le processus de mise en forme se déroule pendant deux étapes : l'emboutissage directe d'un ébauche plan de forme circulaire, suite par le deuxième emboutissage réalisé sur le même équipement, dans le sens inverse de déplacement du matériau que le premier emboutissage. La simulation EF a été réalisée au but de : i). définir les characteristiques dimensionales des différents modules de l'équipement ; ii). évaluation de l'évolution de la force du poinçon pour différents dimensions des modules de l'équipement et différents matériaux de l'ébauche. A la fin, la conception de l'équipement de laboratoire est faite à base des résultats de la simulation numérique