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THEORETICAL AND EXPERIMENTAL STUDIES REGARDING THE SEMI SPHERICAL PUNCH PROCESS OF STEEL SHEETS A5 STAS 10318-80

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Abstract. In order to establish sheet deformation for deep drawing several parameters should be considered, such as: maximum stress and limite dome height (LDH). Within a part there are various kinds of deformations. The present paper deals with cupping behaviour of sheet steel A5 STAS 10318-80, material which largely utilized in the car industry. To this purpose, the authors evaluated the evolution of punch force and the limite dome height obtained experimentally and by simulation in the process of semispherical punch (Nakazima test) for different stresses of the material, and also the influence of material stress on the distribution of strains. The simulation was done by means of ABAQUS v 6.5. code.

1. INTRODUCTION

Simulation made considerable progress in the past twenty years due to the development of the capacity of accounting and stockage of the computer associated with graphic interfaces which are in hand to the CAO users. As a simulation method one uses the method of the finite element which due to the solid algorithms can treat the non-linear problems introduced by the material's behaviour, the piece's geometry and friction. The simulation programmes dispose of graphic interfaces which allow the analysis and visualisation of the results.

In order to reduce the experimentation periods which can be long and expensive many researches have been made concerning the simulation of the deep drawing process through the method of the finite element. The simulation of the deep drawing process allows one to know even from the designing stage whether a piece with a certain configuration can be obtained through the deep drawing process or not, taking into account all the factors that influence this process: the features of the steel sheet, the shape of the tools, the deep drawing conditions.

In this work we studied the behaviour of steel A5 STAS 10318-80 during the deep drawing process, a material largely used in the automotive industry. In order to do so we analysed the evolution of the punch force, the limit dome height obtained experimentally and through simulation in the semi spherical punch process (the Nakazima test) for various applications of the material and the influence of the material's applications on the strains distribution. The simulation took place with the help of the program ABAQUS/Explicitly v6.5.

2. EXPERIMENTAL PROCEDURE

For the semispherical deep drawing process we used square (200x200mm) and rectangular (200x80mm) specimens made of steel sheet A5 STAS 10318-80 being 1mm thick. The equipment used in this case is presented in the work [4]. We used the traction machine, the deep drawing process and semispherical punch with a 70mm diameter. In order to decrease the punch-specimen friction at some tests we used Teflon.

3. NUMERICAL PROCEDURE

The geometry used for the simulation of the deep drawing process corresponds to the experimental stand and is presented in figure 1.

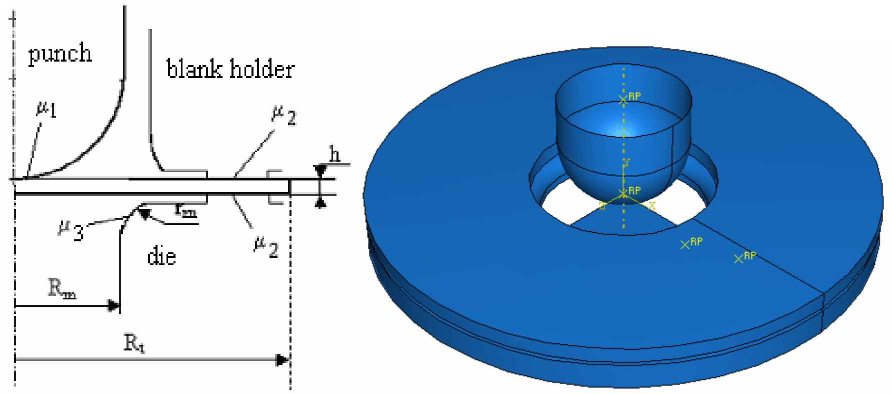


Fig.1 Geometry used for the simulation

The geometry used for the simulation is defined by the following parameters: the punch's radius R_p=37.5mm, the interior radius of the die R_m=50 mm, the joining radius of the die r_m=10 mm, the joining radius of the blank holder r_s= 10 mm, the initial radius of the steel sheet Rt = 100 mm, the initial thickness of the steel sheet h = 1 mm.
The specimen is a deformable element and is defined as the "shell" element in order to decrease the period of time needed to calculate the stress and strains. The tools are rigid elements defined as "analytical rigid". In the first stage of the simulation we have defined the sheet's material, the tools and the type of contact between the surfaces.
We define the plastic and elastic behavior of the material and its density. The material's density is 7.8•10-6 kg/mm3. The plastic behavior is defined from the results obtained at the traction test with the help of the Hill plastic criterion. In this respect we used the VUMAT subroutine, realised in Fortran.
We establish between the surfaces a Coulomb type of friction contact and the value of the friction coefficient.

Three types of friction coefficients are defined, according to the friction existing between the real surfaces, figure 1:
- specimen-punch friction coefficient, μ_1= 0,05 (with Teflon) and μ_1=0,2 (without Teflon);
- specimen-blank holder friction coefficient and respectively specimen-blank holder friction coefficient, μ_2= 1;
- the friction coefficient between the specimen and the joining radius of the die μ_3= 0,15.

The deep drawing simulation takes place in two stages. In the first stage a 200 KN force is applied to the blank holder and in the second stage the punch moves with a speed of 10mm/min. The period of time imposed depends on each trial and corresponds to the experimental deep drawing period of time.

4. OBTAINED RESULTS

The results obtained experimentally and through simulation are presented in table 1.

Table 1

No	Application methods	Friction coefficient	Imposed time [min]	Maximum punch force, KN			Limit dome height of the deep drawing, mm		
				abq	exp,	E,%	abq	exp,	E,%
1	Biaxial traction	0,05	4,5	55,08	55,4	0,58	40,5	36,41	11,23
2	Biaxial traction	0,2	4,0	49,80	49,4	0,81	33,0	34	2,94
3	Axial traction	0,05	5,5	40,33	43,3	6,86	55	52,5	4,76
4	Axial traction	0,2	5,5	39,71	37,13	6,95	55	46	19,57

The difference between the values obtained through simulation and through experiment can be accentuated by calculating the error with the help of the formula:

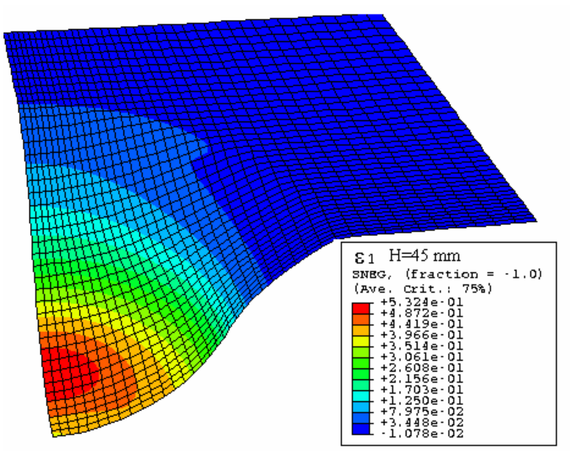
$$E = \frac{\left| V_{\exp} - V_{sim} \right|}{V_{\exp}} \cdot 100 \ [\%] \quad (1)$$

where: Vexp is the value obtained experimentally
Vsim is the value obtained through simulation.

After the simulation stress and strains are obtained in every knot of the structure as well as the variation of the punch force and limit dome height according to time.

Different methods of application were obtained by using various widths of the specimen. So the application in the case of the specimens with a 200 mm width is biaxial traction and in the case of the specimens with an 80 mm width is single axial traction.

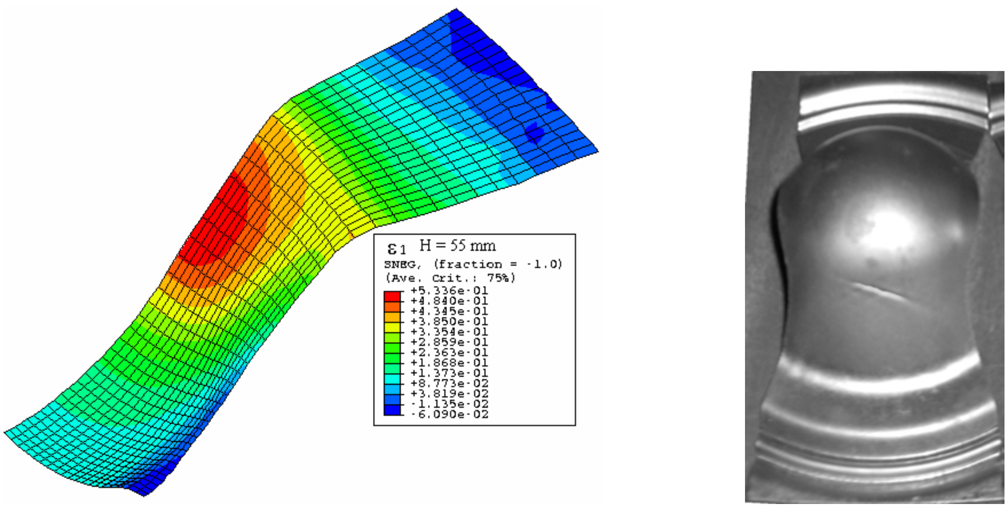
In figure 2 are presented the cupped specimens, model 1 from the table and in figure 3 the 3rd model.



a

b

Fig. 2 Cupped blanks biaxial traction



a **b**

Fig.3 Cupped blanks axial traction

The punch force obtained through simulation with Abaqus according to the dome height is represented in graph from fig. 4 for the specimens having a 200 mm width and respectively an 80 mm width.

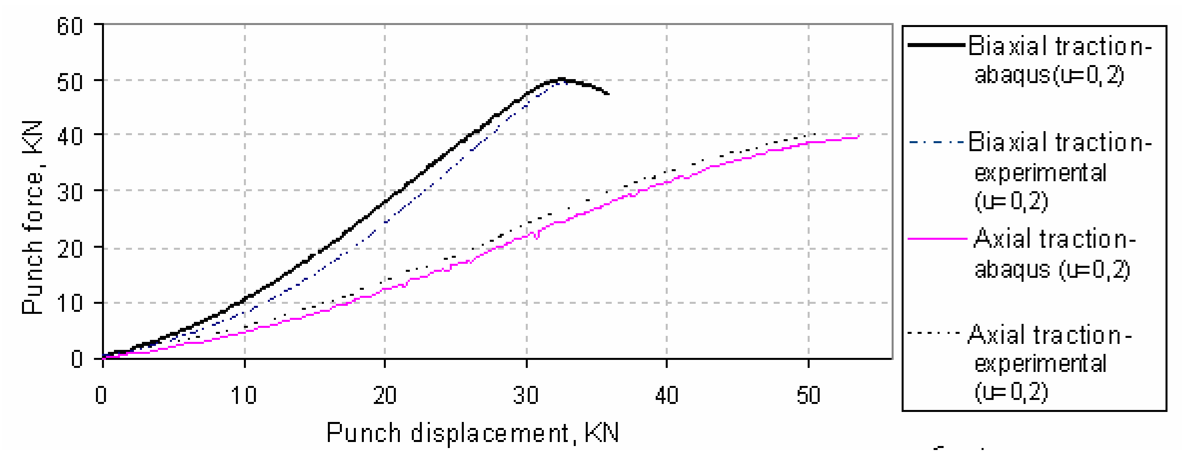


Fig.4 Punch force for axial traction

The results obtained with the Hill criterion are good. The necessary punch force is bigger in the case of the biaxial traction application than the one in the case of the single axial traction application.

In order to establish the limit dome height of the deep drawing in the case of the semi spherical drawing process the straining trajectory was represented for each model. Thus, the main strains were determined for various dome heights of the deep drawing, tables 2 and represented in the system of axis ε_1-ε_2, fig. 5

Table 2

No.	Model	Limit dome height of the deep drawing, mm	ε_1	ε_2
1	Biaxial traction, u=0,05	31,5	0,2196	0,177
		36	0,2975	0,2525
		38,25	0,3438	0,2929
		40,5	**0,397**	**0,3413**
		42,75	0,458	0,388
		45	0,5296	0,438
2	Biaxial traction, u=0,2	22	0,0412645	0,1219
		30	0,23876	0,0863713
		32	**0,287531**	**0,09947**
		34	0,411301	0,105242
		38	0,718921	0,105517
3	Axial traction, u = 0,05	44	0,3165	-0,2094
		49,5	0,4024	-0,2651
		55	**0,5321**	**-0,335**
4	Axial traction, u = 0,2	44	0,3459	-0,232
		49,5	0,4477	-0,2892
		55	**0,568**	**-0,359**

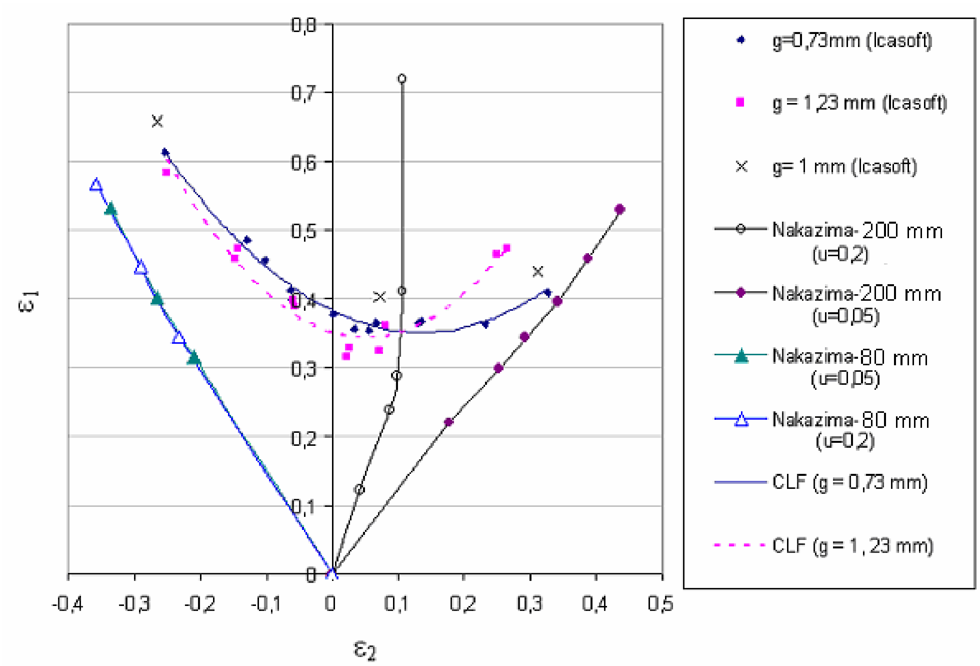


Fig. 5 Strain-paths, and limit strains at necking obtained in the Nakazima punch tests

The dome height for the deep drawing is represented in bold in table 2 and corresponds to the strains obtained before reaching the limit curve of straining, fig 5. The values obtained for the limit dome height of deep drawing are closer to the experimental ones; they are bigger in the case of single axial traction than in the case of the biaxial stretch and they are also bigger in the case when we used Teflon than in the case when we didn't.

The distribution of strains can be followed in fig. 6 for single axial traction and in fig. 7 for biaxial traction.

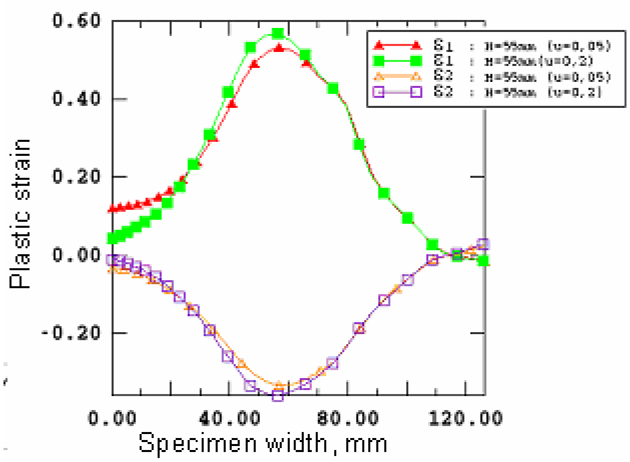


Fig. 6 Distribution of strains for axial traction

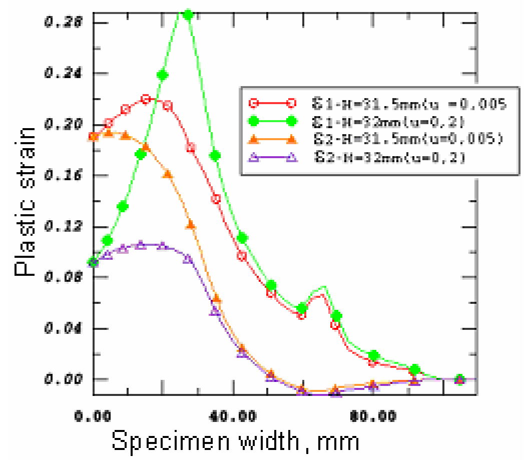


Fig. 7 Distribution of strains for biaxial traction

4. CONCLUSIONS

The results obtained with the Hill criterion are good. The necessary punch force is bigger in the case of the biaxial stretch application than the one in the case of the single axial traction application.
The values obtained for the dome height of deep drawing are closer to the experimental ones; they are bigger in the case of single axial traction than in the case of the biaxial stretch and they are also bigger in the case when we used Teflon than in the case when we didn't.
The distribution of strains shows that the material cracks near the punch's radius in the case of single axial traction and close to the middle in the case of biaxial stretch.

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