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THE EFFECT OF PLASTICITY CRITERIA ON PART ACCURACY IN SHEET METAL FORMING SIMULATION

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ABSTRACT
The sheet metal forming processes are applied with the intention of manufacturing products with a high shape and dimensional accuracy. An incorrect design of tools and blank shape or an incorrect choice of material and process parameters can yield a product with a deviating shape or even with failures. In simulation, a great accent is put on the material behaviour description. The aim of this work is to analyze the influence of material behaviour on the final part accuracy, by using different criteria of plasticity. The analysis is made by using the ABAQUS software.
Keywords: criteria of plasticity, shape and dimensional part accuracy, simulation

1. INTRODUCTION
Many metal products such as car bodies, furniture, elements of domestic appliance and other metal fancy goods are obtained by sheet-metal forming processes. In the last few years forming processes of sheet metals have undergone important developments. However, sheet metal forming is an industrial process strongly dependent on numerous interactive variables: material behaviour, forming equipment, process parameters, etc. The correct choice of these parameters is one of the main aims in modern industry. In order to achieve this task, the understanding of the fundamentals of deformation mechanics involved in the process is required. Without proper understanding of the effect of different variables, the design process would be difficult, time consuming and expensive. Also it would not be possible to predict and prevent defects occurrence until it is too late.
The finite element method seems to be the most popular and dominant method of the forming process analysis that allow to determine the geometric, cinematic and dynamic factors during forming. Finite element analysis models could be used to achieve a better understanding of the deformation of sheet metal during the forming process and as a predictive tool for several failure modes, such as necking, wrinkling, springback etc., to reduce the number of costly experimental verification tests. Commercial FEA codes are robust enough that they can be used with confidence as a predictive tool if the correct description of complex geometrical contacts, forces and displacement conditions, material behaviour, etc. is incorporated. The importance of the correct parameters description increases even more when material anisotropy is considered.
The aim of this paper was to investigate the shape deviations of the virtual parts due to springback, taking into account the material anisotropy that was described by using two criteria of plasticity: Ferron and Hill 90, respectively.

2. SIMULATION OF DEEP-DRAWING PROCESS

2.1 Conditions and methodology of simulation

A 3D numerical analysis of the deep-drawing process was conducted by using the 3D model presented in figure 1. Analytical rigid surfaces were used to model the punch, die and holder, whose motion was governed by the motion of a single node, known as the rigid body reference node. Therefore, only the sample (200 mm diameter x 0.8 mm thickness) was considered deformable with a planar shell base. The elements used to mesh the sample were of S4R type, with 5 integration points through the sheet thickness.
Transversal anisotropy of Hill and Ferron's theory of plastic anisotropy was adopted to describe into ABAQUS/Explicit the anisotropic characteristics of the sheet metal. For this purpose, the VUMAT subroutine was used. The coefficients which intervene into the equations of the used criteria are given in table 2 and were calculated with the help of the Fortran programme, on the base of the anisotropy coefficients experimentally determined.
The material used in simulation was FEPO 5MBH steel, whose mechanical characteristics are presented in table 1. These characteristics were determined by uniaxial tensile tests on a universal testing machine equipped with Hottinger cell force of 25tf and an electronic data acquisition system, of Spider 8 type. The measurement of specific strains for determination of the stress-strain curves was performed using a uniaxial extensometer and Hottinger electric resistive wire strain gauges. Data acquisition, processing and visualisation were performed by using the Catman - Professional software. The used rate of data acquisition was of 5 points/sec for a crosshead-rate of 10 mm/min. The specimens were cut as a function of the rolling direction being achieved sets of specimens corresponding to the directions of 0º, 45° and 90° and were worked by milling and grinding in order to obtain the prescribed dimensions. The reference length of the specimen was equal to 50 mm (fig. 2). To obtain a good accuracy of the results, 3 specimens were tested for each determination.

Table 1 Mechanical characteristics of the FEPO 5MBH steel

Orientation against rolling direction	**Young's modulus**	**Yield strength [MPa]**	**Total Elongation [%]**	**Anisotropy coefficient r**	**Hardening coefficient n**
0	198000	306	34.7	0.82	0.234
45	200000	360	44.1	0.77	0.232
90	200000	375	26.1	0.81	0.233

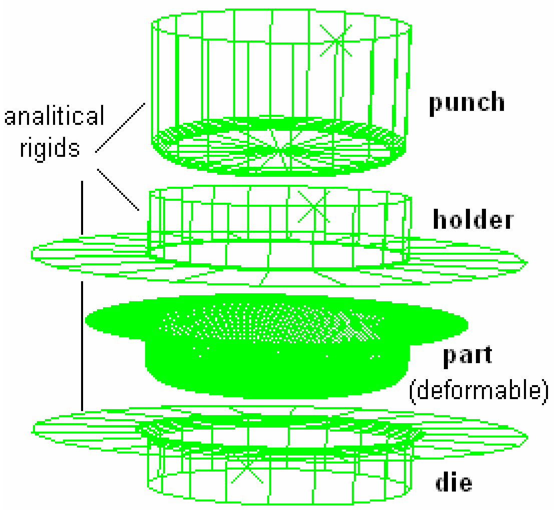


Figure 1. Model used in simulation

Table 2 Coefficients corresponding to the used plasticity criteria

Criterion	A	B	k	m	n	p	q	a	B
Hill	4.128	9	0	2	1	1	1	-0.12848	0.60729
Ferron	2.953	8.859	0.2	2	2	2	1	-0.07264	0.87256

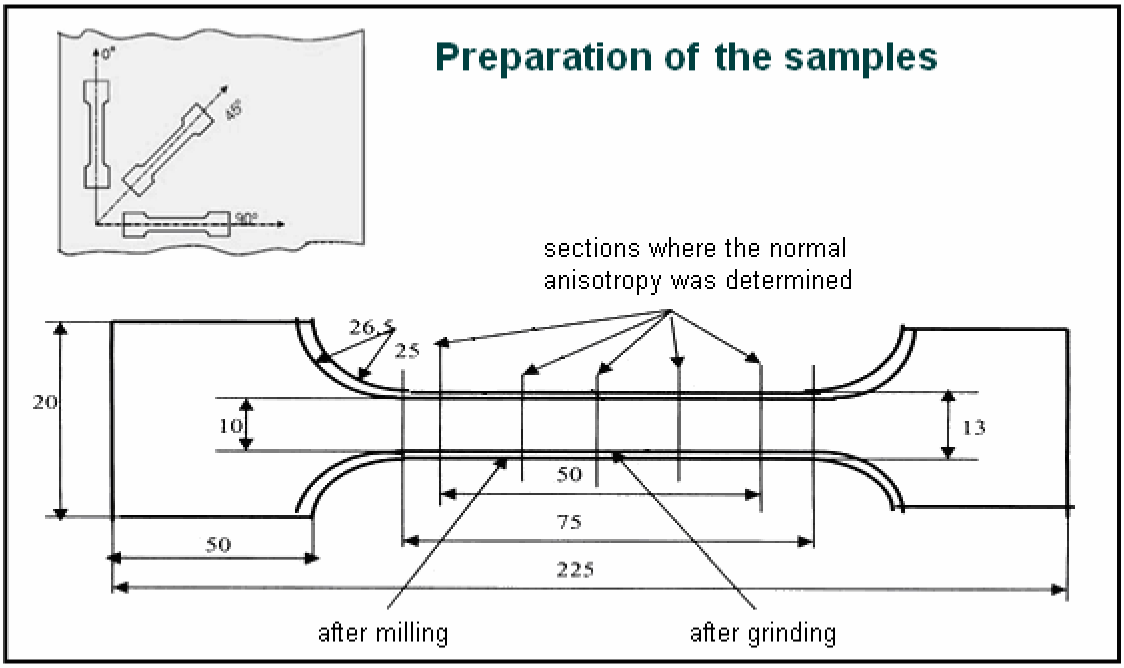


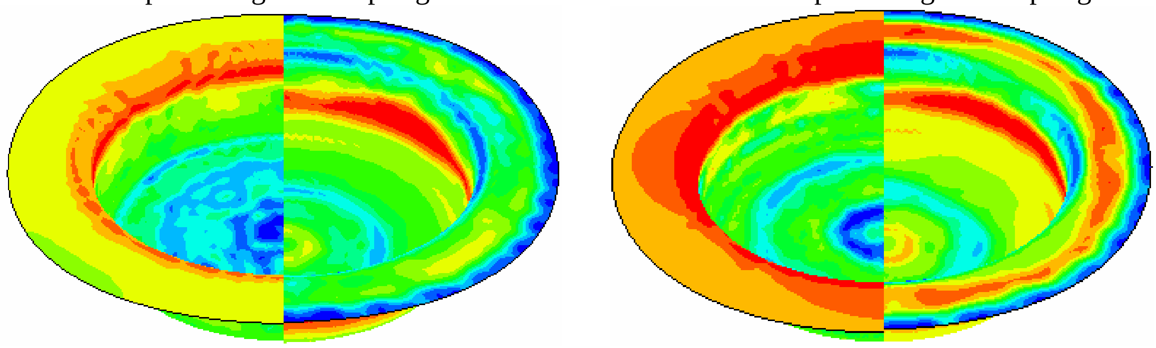
Figure 2. Samples geometry

The process parameters used in simulation were as follows: punch velocity = 18 mm/min, unique value for the coefficient of friction = 0.1, blankholder force = 25, 50, 75, 100, 125 kN.

2.2. Results of simulation

Two of the virtual parts obtained as result of simulations by using the two criteria of plasticity and the above mentioned process parameters are present in figure 3. In order to get data concerning the parts accuracy (table 3), their profile was determined by using some macros and sheets of calculus and then post-processing the resulted clouds of nodes into a CAD software (fig.4).

after deep-drawing after springback after deep-drawing after springback



in the case of Hill criterion *in the case of Ferron criterion*

Figure 3. Virtual parts resulted from simulation, F = 25kN

Table 3 Geometry of part

Hill criterion	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
F = 25 kN	5.23	5.23	8.67	8.76	94.92	93.40
F = 50 kN	5.16	5.16	7.07	7.07	94.92	94.92
F = 75 kN	5.50	5.50	9.62	9.17	94.92	91.21
F = 100 kN	5.49	5.36	8.25	7.68	94.92	92.42
F = 125 kN	5.36	5.27	9.12	7.87	94.92	91.75
Ferron criterion	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
F = 25 kN	5.27	5.23	9.40	9.22	94.92	91.01
F = 50 kN	5.27	5.23	9.40	9.22	94.92	91.65
F = 75 kN	5.70	5.70	7.87	7.87	94.92	95.43
F = 100 kN	5.50	5. 66	7.17	7.17	94.92	94.92
F = 125 kN	5.87	5.87	7.07	7.07	94.92	94.92

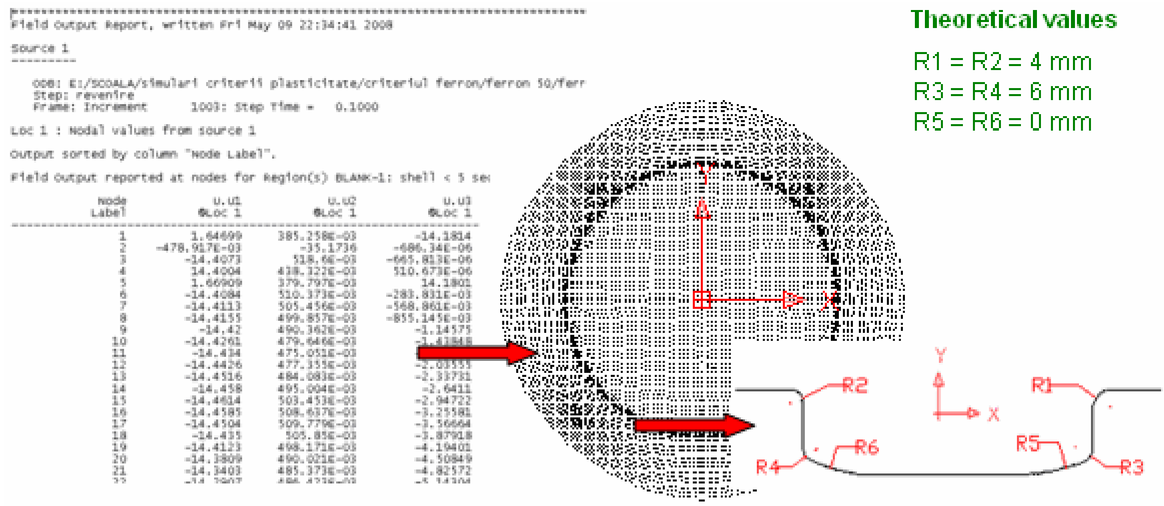


Figure 4. Determination of the virtual parts profile

3. CONCLUSIONS:

By analyzing the obtained results, the following remarks can be stated:

- when tools are released, the shape of part distorts due to the stresses redistribution within the part; this deviation could be seen especially at the part bottom which are no more flat at the edge but curved. Therefore, the radius of part corresponding to the punch radius is very large compare to its nominal value (around 9 mm against 6 mm).
- the deviations resulted when the Hill criterion was used are easy smaller than the deviations obtained in the case of Ferron criterion.
- in order to obtain convincing results as concern the relation between description of the material behaviour and virtual part accuracy, many process variables should be taken into account, like different coefficients of friction between the contact surfaces, different punch velocities, bigger values of the blankholder force.

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