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NUMERICAL ANALYSIS AND SIMULATION OF DEEP DRAWING PROCESS

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ABSTRACT
Nonlinear analysis of plastic processing was performed using DYNAFORM which represents a complete system for simulation of plastic processing with the tools.
These analyses completely enable to avoid the soft tools, reducing the total time of testing, reducing costs, increasing productivity and providing a complete verification system for designing a punch. It also makes finding alternative and unconventional forms and materials for the optimal solution.
Keywords: deep drawing, numerical analysis

1. INTRODUKCION

Finite element method is a powerful numerical technique that is used in recent years for a wide range of engineering problems. Although until recently most used FE analysis to verify structural integrity, in recent times is used to simulate the manufacturing process. In modeling and simulation of processes involving deformation, processes such as sheet metal forming, calculating the strains and stresses in the part of the process, including taking into account the contact conditions on the plate interface tool.

There are two main reasons for the application of FE analysis in industrial practice:

1. optimizing the product design by analyzing the deformability in the design phase
2. reducing time and cost, through the process predicting the deformation at the stage of design tools

To simulate the process was selected LS-Dyna explicit FE code designed for three-dimensional analysis of nonlinear dynamic problems.

Using dual-solvers called LS-Dyna is possible to obtain an efficient simulation process plastice processing as well as explicit results. LS-Dyna presents output data in the form of the distribution of equivalent stress (hypothesis Von Misses) and change the thickness of the initial pieces (samples) during the simulation. The objective of nonlinear analysis is to define the stress-strain state and strain forces in the process of lid drawing. The subject of nonlinear analysis is the processed form of cover, which is obtained by the process of plastic processing in the cold condition.

2. THE CHOICE OF MATERIAL AND YIELD CURVE

Most of the material used in sheet metal forming the elastic-plastic, anisotropic strain and strengthen with increasing degree of strain rate. For this reason, the sheet should be selected material which may be described above occur. The analysis was used to "3-Parameter Barlat" model material:

- Supports both linear and exponential flow law,
- Takes into account the anisotropy of sheet,
- Be able to describe the reinforcement strain with increasing degree of deformation.

Model Materials for executive parts of the tool is called "Material-Elastic" that requires placing an Young modulus, density and Poisson's coefficient. The material used to create the die is defined by AISI D3 represents ledeburite Cr-iron. Workpiece is shaped lid is made of quality stainless steel X5CrNi18-10 or Nirosta 4301/1.4301 according to EN 10088 / 2 thickness of 2.5 [mm], whose mechanical properties are given in Table 1.

Table 1. The mechanical properties of materials cover stainless steel

Parameter	***Value***	***Unit***
Young modulus, E	*216900*	*MPa*
Yiel stress, σ_{p02}	*332*	*MPa*
Poisson coefficient, υ	*0.3*	--
Density, ρ	*7860*	*kg/m^3*
Coefficient of deformation strengthening, C	*1380*	--
Eksponent of deformation strengthening, n	*0.44*	--

Determination of the yield curve for the degree of deformation greater than equal is derived analytic approximation. In the literature appear different analytical methods of approximation yield curve, depending on the degree of deformation:

$$K = C * \varphi^{n} \qquad (1)$$

This approximation shows good agreement with the real yield curve in the balanced strain. The coefficient of deformation strengthening, C, and exponent of deformation strengthening, n, are determined based on experimental data obtained by testing the tensile. In Figure 1a shows the results of uniaxial tensile test, and in Figure 1b, compared the results obtained experimentally and real yield curve, constructed on the basis of approximation of expression (1). The results show satisfactory agreement with experimental results approximated curve in the balanced strain.

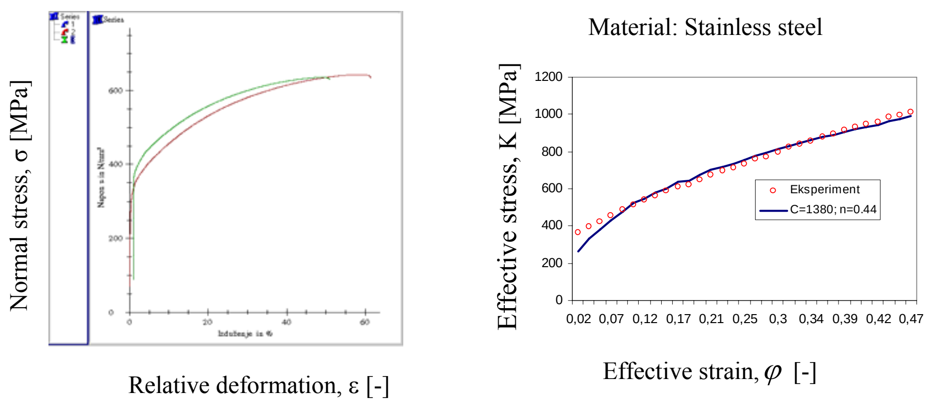


Figure 1 The results of uniaxial tensile test and yield stress for stainless steel INOX X5CrNi18-10

3. SELECTION FINITE ELEMENT BOUNDARY CONDITIONS AND LOADS

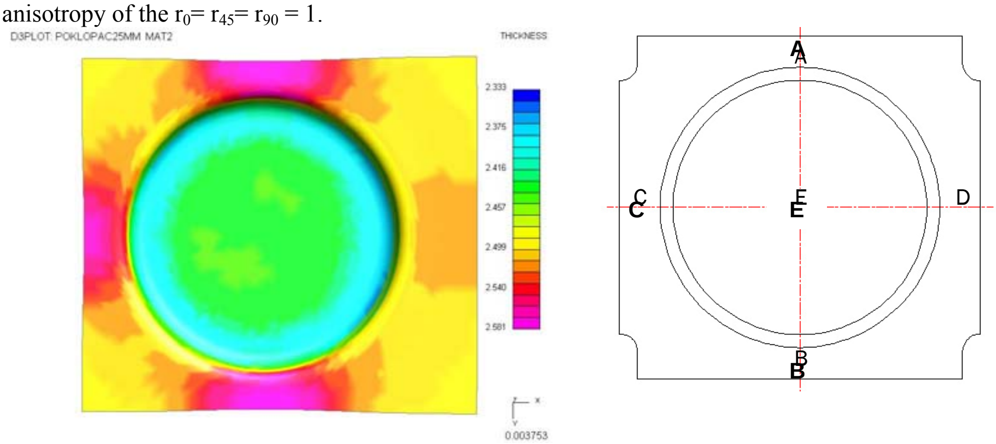
To discretize the plate were selected 3D "Shell 163" finite elements for which there are eleven different formulations. When choosing the formulation of a key criterion was that greater accuracy, and was chosen for the plate so "Fast Shell 'formulation.This formulation, compared with other formulations, requires more CPU time, but its advantage is greater accuracy and good convergence. For blank holder and immersing matrix is chosen so. "Belytschko-Tsay" formulation, with a reduced number of integration points. Punches and dies are modeled with 3D elements.

The aim of defining boundary conditions is that the real conditions during deformation to better convey the FE model, where the inevitable limitations and simplifications. Punches and die have the ability to handle sheet translation in the direction of Z axis, while their other degrees of freedom disabled. Holder for sheet and matrix is assumed to be in the process will not deform, so are modeled as solid.

Load the explicit simulation should be the default so that the calculation is as efficient as possible, on the other inertial forces must remain negligible. When defining load should take into account that during the simulation does not generate significant kinetic energy, which could lead to the solution converges to the stable. Generated kinetic energy does not exceed a few percent of the total energy that the results were acceptable. The second condition requires a small value of the acceleration in order to reduce inertial forces. The analysis was chosen velocity profile with a sinusoidal function of phase to achieve the desired virtual velocity and the phase of stopping punch. Friction in LS_DYNA based on the Colombo-s formulation, where the force is proportional to the friction coefficient of friction and normal force at a point contact. In this simulation, a dry friction is chosen with coefficient of friction μ=0,15.

4. ANALYSIS RESULTS

In the process of deep drawing up and coming changes in the thickness of metal sheet. In Figure 2 tis presented sheet thickness in [mm] there is thinning in the area of the bottom cover and the height of the lid, and an increase in the thickness of the deformation zone below the blank holder. The maximum thinning is directly below the punch radius curves. Values of stress and strain, and change in thickness of sheet metal were performed assuming isotropic material cover, coefficient of normal anisotropy of the $r_0 = r_{45} = r_{90} = 1$.



a) Changes in the thickness on the numerical model *b) Position of measuring points*

Figure 2. Change of sheet thickness as a result of strain

Control of the thickness of the cover sheet after deformation was carried out using ultrasonic thickness gauge type DMS 2 (Krautkrämer) and transducers type DA462 (Krautkrämer) measurement range from 0.6 to 50 mm. Position of measuring points is shown in Figure 4b, the results of measurements in Table 2

Table 2. The results of measurements of thickness after deformation

Model type Thickness 2,5 mm material/lubrication	Measuring point				
	A	B	C	D	E
Inox / dry	2,84	2,51	2,70	2,65	2,47
	2,68	2,68	2,79	2,76	2,45
	2,65	2,46	2,76	2,87	2,46

Measurement results show that thick in the middle of the lid there was a thinning sheet (measuring position "E") which coincides with results of numerical simulations. In other places below the blank holder there is an increase of sheet thickness. Von_Mises stresses and strains with the scale of stress values for the punches, dies, and the lid are shown in Figure 3, with maximum values at the site of the radius curves of the matrix. Stresses on the lateral edge of the matrix, the place of installation of strain gauges, were in the range 193÷239 MPa. Analysis was done under the assumption that the frame of presses, immersing matrix and blank holder are not deformed.

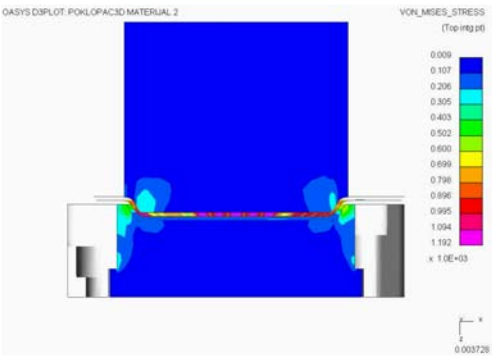


Figure 3. Von-Mises stresses and strains of punch, die and lid

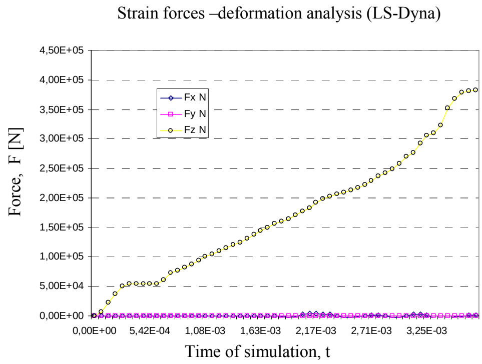


Figure 4. Relation strain force-deformation

5. CONCLUSION

In order to anticipate and avoid overloading and falling out of FE simulation tools can predict the force required for deformation. This is especially important for tools to handle rigid sheet and for cases where a small gap between the tool and holder in relation to the thickness of the sheet. The flow and the value of the reaction forces on the interface of steel - ring for friction coefficient $\mu = 0.15$, sheet thickness 2.5 mm and the selected materials are given in Figure 4. Forces in the X and Y direction (perpendicular to punch movement) are small in comparison with the force in the direction of Z axis (direction punch movement) and the maximum value is obtained by predicting the force is about 380 KN.

The accuracy of forecasting and simulation depends on:

- proper choice of initial and boundary conditions,
- fineness of the FE mesh,
- proper choice of the coefficient of friction and the parameters that define the contact between sheet and tools,
- proper choice of the sheet material (yield curve, deformation strengthening, anisotropy)
- length of time step.

6. REFERENCES

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