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MODELING AND SIMULATION OF TINPLATE CONTAINER LIDS STAMPING PROCESS

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ABSTRACT
This paper presents the use of numerical modeling, simulation and analysis in order to establish most appropriate tinplate container lids stamping process regarding strain energy. The numerical modeling, simulation and analysis were performed using Abaqus 6.4-1.software It is useful to perform the numerical simulation of the strain energy of production process on computer before expensive real manufacturing process. In this way, energy consumption in production can be made at the start stage of design, before tools and process parameters are set. In the paper for the numerical modeling, analysis, simulation and experimental investigations the material TS 275 (according to the European Standard EN 10202) [1] were used.
Keywords: numerical modeling, numerical simulation, stamping process

1. INTRODUCTION
Modern tinplate possesses several important advantages: excellent drawability combined with good strength, good solderability and corrosion resistance and an attractive appearance, due to the unique properties of tin. It is an eco-friendly packaging material offering 100 percent recyclability – any number of times, and without quality loss. Stamping process, although deceptively simple, involves a complex interplay between material properties, tools geometry, process variables and lubrication conditions but due to its material savings, very high productivity, and increasingly reduced processing time has become one of the most promising production technologies. Continuous demands for reduced consumed energy and more economic parts production have led to the strain energy approach which uses numerical modeling and simulation of production process. This process analysis means defining the correlation among the influent variables of the process in order to improve it. Continuous demands for improved quality and more economic production have led to the development of highly sophisticated computer techniques. The essential aim of this paper is to present an outline of numerical approach used and their effects on production, in the belief that it will be of help in the development of improved and new better container lids stamping process. It is clear that numerical simulations allow to model any modification before the expansive stamping process and also to model the possible behavior for a new grade of friction, wall thickness and yield strength affecting the grade of strain energy. Then, a set up models can be used to answer the question of how much the process strain energy changes, if input data change within values under the experimental design. As it is about production of different shapes of lids numerical simulation can be used to assess the dependency of strain energy on the variation in input parameters. Possible behavior for a new grade of material, wall thickness and lubrication affecting the strain energy process which leads to savings in consumption of energy. When the technology and its parameters became better understood, the tools, material, friction and machinery became more reliable and processes stabilized [2].

2. NUMERICAL MODELING

The experimental determining of the flow curve has been performed by means of tensile testing machine Amsler equipped with: optical measuring system (3 CCD cameras) measuring converter, PCI (data processing system supported with Lab View software for Windows). The tensile testing machine uses three cameras, which allows the system to monitor both the operating conditions and the measuring conditions simultaneously during each measurement. This ensures that thousands of measured points are always exact and reliable. The flow curve investigated material can be represented by a power relationship of the Ludwik′s law [3, 4]:

$$\sigma_f = 581.55 \cdot \varphi^{0.157}, \tag{1}$$

where: σ_f - true stress, 581.55- strength coefficient,

0,157 - strain hardening exponent, φ - true strain

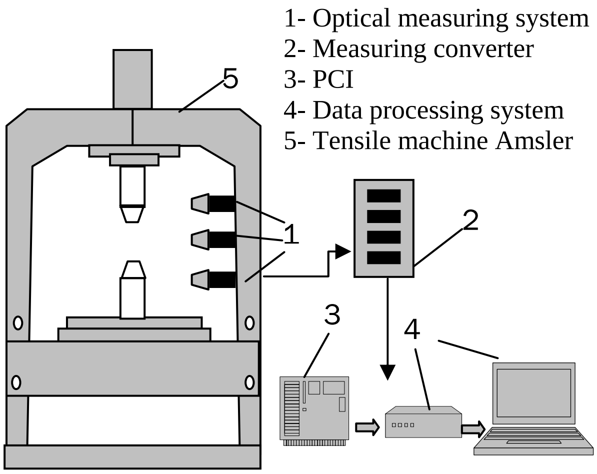

Figure 1. System for determining of flow curve

A tinplate lid model creation, in this analysis, was made by means of ABAQUS/CAE. This part of ABAQUS plays a role of pre and post-processor. ABAQUS/CAE is divided into modules, where each module defines an aspect of the modeling process as: defining the geometry, defining material properties, assembling the parts generating a mesh, etc. Steel sheet model is formed by use of CAX4R elements as an axisymetric body. In Abaqus library that means continuum axisymetrical element with 4 points reduced integration. Tinplate material is modeled as an elastic part and anisotropic plastic part by the use of Hollomon-Ludwik′s power law input as described previous chapter. The tools (punch, die and blank holder) are described as rigid axysimetric body i.e. lines and curves that define the die and punch were interpreted as rigid unmovable body fixed with a determined point on them [5]. Further, the material is assumed to obey the von Misses yield criterion. The elastic characteristics of material are governed by Poisson′s ratio and modulus of elasticity. In the case of this stamping it is very important to define an appropriate model between the material and the tooling. The interaction modeling consists of the contact behavior in the tangential direction in the sheet surface and contact behavior in the normal direction against the sheet metal surface. For the material stamping simulation friction coefficient normally changes during the forming step and it also depends on the contact pressure. In the case of the lids stamping simulation it was not taken into account. The friction was varied: $\mu = 0.03$; $\mu = 0.05$; $\mu = 0.1$; $\mu = 0.15$; $\mu = 0.17$. The different shape simulation models of the lids and tools according to experimental design are shown in figure 2a and 2b. Varying in shape tool geometry most directly affects the strain energy savings in the production of lids and because of that numerous modeling and simulations of stamping process have been done.

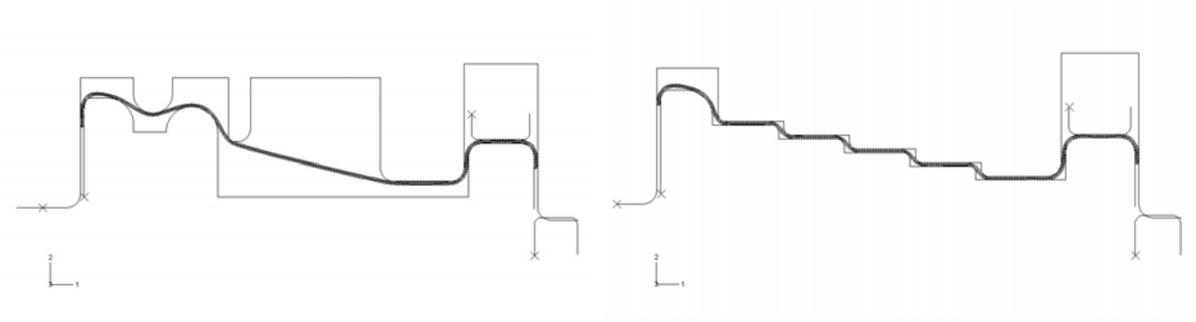

Figure 2.a. First tool and sheet model variation, 2. b. Second tool and sheet model variation

3. NUMERICAL SIMULATION AND ANALYSIS

Model from which ABAQUS/CAE generates an input file is submitted to ABAQUS/Explicit for analysis, part of ABAQUS which plays role of solver [6]. Performed numerical simulation of the lid stamping process serves for the simulation of other varying lid shapes to optimization processes. Finally, to predict the consumed energy in stamping process (on TS 275 specimens), numerical modeling of strain on the basis of active experimental designs was done. On the basis of subroutine that determines the total load placed on the lid, the strain energy curve has been constructed. By means of numerical integration at this curve, the strain energy (W) is calculated. Thus, results of strain energy stamping with five different coefficients of friction and five different wall thicknesses were obtained. In Figure 3. a. and b, two different shapes (presented with tangential strain as PE33 in Abaqus library) of lid obtained through numerical simulation of stamping process are shown.

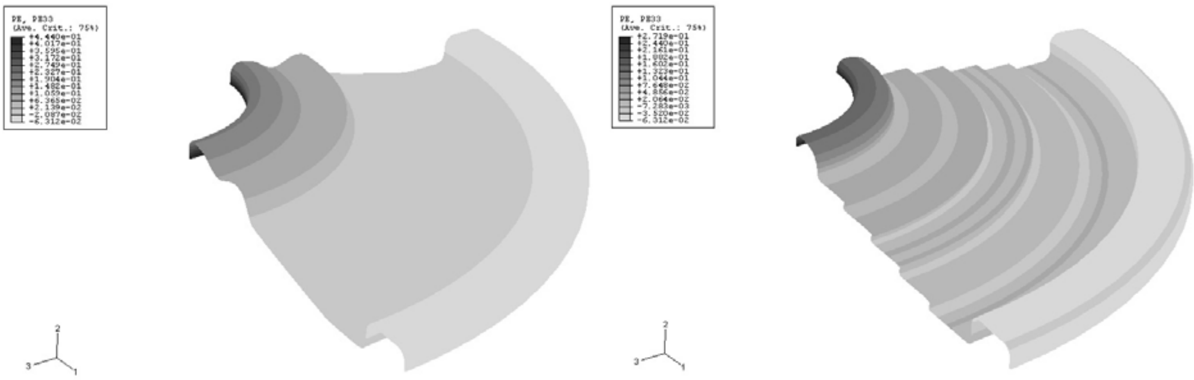

Figure 3.a. First model variation, 3. b. Second model variation

Abaqus relationship for determining of strain energy (W) is:

$$W = \frac{1+\nu}{3 \cdot E} \cdot q^2 + \frac{3}{2} \cdot \frac{1-2\cdot\nu}{E} p^2 + \frac{n}{n+1} \frac{\alpha}{E \cdot k_{f0}^{n-1}} q^{n+1} \quad (2)$$

where: q- the Mises equivalent stress,
p - the equivalent hydrostatic stress,
ν- Poisson's ratio,
φ - true strain,
α - yield offset in the sense when $\sigma = k_{f0}$.

In the figure 4 the best results from the numerical simulation of strain energy among different parts (lids) is presented. It could be displayed a plot of model showing the strain energy at the end of the analysis. By means of presented method is possible to find out the optimal force and strain energy as measure of consumed energy for described stamping process in order to raise it to a higher techno economic level regarding energy consumption. These simulations allow to model any modification before the stamping process was set up. Numerical simulations allow to model the predicted behavior for a new grade of lubrication and wall thickness affecting the grade of consumed energy. Experimental researches are also conducted and they confirmed results of numerical simulations [7].

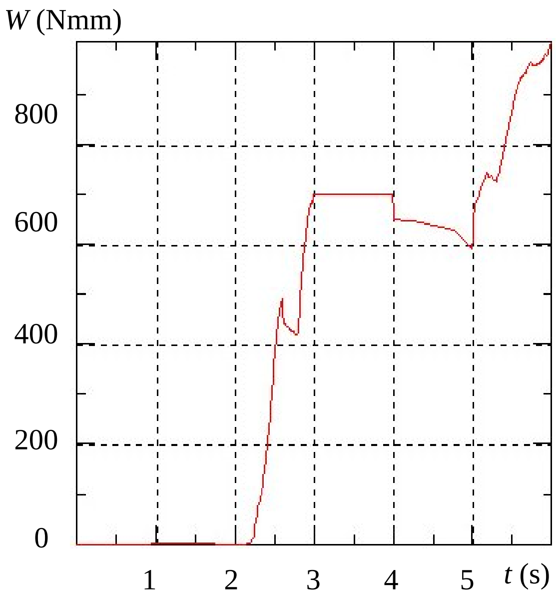

Figure 4. Distribution of strain energy

4. CONCLUSION

It is useful to perform the numerical analysis of processes before expensive manufacturing process because the savings in process and tool improvements can be made at the start stage of process, before its establishing. Thus, the parameters of process became better-understood and it is possible to find out the optimal force and strain energy as a measure of consumed energy for this process. Experimental research conducted in these investigations serves for the checking and the verification of numerical results was done. According to the experiments numerical modeling and simulation are very satisfactory. Generally boundary conditions (not boundary condition in simulation) are determined by the limits of cans which lids cover. In this way by means of numerical simulation with determined boundary condition and goal function the best results are obtained. In, average obtained results are better about 10%, i.e. reduced values of strain energy obtained by means of numerical simulation leads to reduction of consumed energy.

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