39th Solid Mechanics Conference
Zakopane, Poland, September 1–5, 2014

P132

METAL CUP DEEP DRAWING PROCESSES – NUMERICAL SIMULATION AND EXPERIMENTAL VERIFICATION

Z. Nowak[1], F. Grosman[2], D. Lumelskyy[1], M. Nowak[1], R.B. Pęcherski[1], J. Rojek[1], M. Tkocz[2]

[1]Institute of Fundamental Technological Research, Polish Academy of Sciences, Warsaw, Poland

[2]Silesian University of Technology, Katowice, Poland

1. Introduction

Finite element method is an efficient numerical tool to analyse problems of the sheet metal forming processes in particular cup drawing and stamping. Proper description of material properties is crucial for accurate analysis. In particular, the anisotropy and asymmetry of elastic range, which is related with strength differential effect (SDE), of considered materials play an important role in finite element simulation. For metal forming analysis with use of traditional models many experimental tests are usually needed to obtain the adequate description of anisotropic behaviour of metal sheets. Therefore, the search for new models, which are based on simplified description of the effects of anisotropy and SDE requiring less experimental tests seems to be justified.

The paper presents the application of a new yield criterion for the transversal isotropy of metal sheets under plane stress conditions. The proposed criterion is based on the study of yield criteria accounting for the SDE and anisotropy made by W. Burzyński [1]. The system of equations describing the sheet metal forming process is solved by the algorithm using the return mapping procedure. Plane stress constraint is incorporated into the Newton-Raphson iteration loop. The proposed algorithm is verified by performing the numerical calculations using shell elements of the commercial FEM software ABAQUS/EXPLICIT with own VUMAT subroutine. The Fig. 1 shows deformation of the square DP600 steel blank at the punch stroke 40 mm for the cup deep drawing with application of the proposed yield condition Eq. (1) with the isotropic power hardening law.

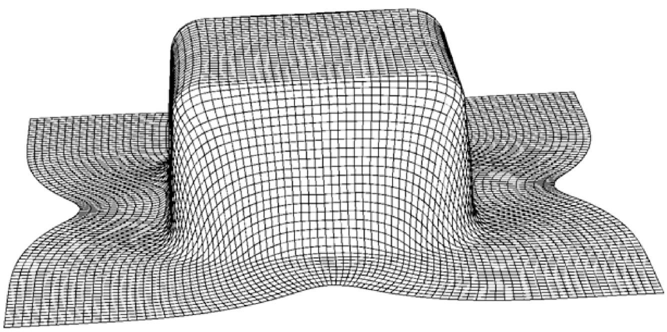

Fig. 1. Deformation of the square blank at the punch stroke 40 mm for the cup deep drawing.

2. Yield condition

To perform finite element simulations of cup deep drawing processes, three independent values of yield strength $(\sigma_Y^T, \sigma_Y^C, \tau_Y)$ are required, which can be obtained from: the uniaxial tensile test, uniaxial compression test and shear test. The proposed yield condition is based on the analysis of limit condition for transversally isotropic solids. In the case of plane stress state the yield condition takes the following form:

$$f = \frac{1}{2k_1}\left\{3(k_1-1)p + \sqrt{9(k_1-1)^2p^2 + 4k_1q^2}\right\} - \sigma_Y^T(\bar{\varepsilon}_p) = 0 \tag{1}$$

where

$$p = \frac{\sigma_x + \sigma_y}{3}, \quad q = \sqrt{\sigma_x^2 + \sigma_y^2 + R_B\sigma_x\sigma_y + (2-R_B)\sigma_{xy}^2}, \quad R_B = 2 - \frac{1}{k_1k_2^2} - \frac{2}{k_2} + \frac{2}{k_1k_2},$$

and $k_1 = \sigma_Y^C/\sigma_Y^T$, $k_2 = f(\sigma_Y^T, \sigma_Y^C, \tau_Y)$.

3. Cup deep drawing process

The aim of the paper is to simulate the metal cup deep drawing process and verify the computational results with own experimental data obtained in the laboratory of the co-authors from the Silesian University. Additionally, the independent calculations were performed with use of the known plasticity model, which is based on the anisotropy yield condition proposed by Hill in 1948. The model was implemented in finite element program NUMPRESS – EXPLICIT to perform the simulation of the discussed cup deep drawing process. The comparison and detail discussion of two sets of data obtained in both numerical simulations with the results of experimental observations of the same process and the results of measurement of the change of thickness of drawn cup along chosen paths leads to interesting conclusions regarding the possible applications of the proposed simplified model.

Acknowledgments

The research reported in the paper was partly obtained in the framework of the research project NUMPRESS carried out in IPPT PAN (Poland), co-funded by European Regional Development Fund grant nr: POIG.01.03.01-14-209/09.

References

1. W. Burzyński (2009). Selected passages from Włodzimierz Burzyński doctoral dissertation "Study on material effort hypotheses", *Engng. Trans.*, **57**, 3–4, 185–215, published originally in Polish: W. Burzyński (1928). Studium nad hipotezami wytężenia, *Nakładem Akademii Nauk Technicznych*, 1–192, Lwów.