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

P125

NUMPRESS – INTEGRATED COMPUTER SYSTEM FOR ANALYSIS AND OPTIMIZATION OF INDUSTRIAL SHEET METAL FORMING PROCESSES: NUMERICAL INVESTIGATION OF SQUARE CUP DRAWING

P. Kowalczyk, J. Rojek, R. Stocki, T. Bednarek, P. Tauzowski, R. Lasota, D. Lumelskyy, K. Wawrzyk

Institute of Fundamental Technological Research, Warsaw, Poland

1. Introduction

This paper presents basic features of the NUMPRESS system and some examples of use. The system has been developed at IPPT PAN as a result of a project financially supported by European Regional Development Fund and is dedicated to small and middle enterprises (SME) dealing with sheet metal forming. The program consists of (i) an analytical finite element method module (ii) an optimization module, (iii) a reliability analysis module, and (iv) a graphical user interface enabling communication between modules. The analytical module consists of two independent programs up to the user's choice: NUMPRESS-Flow, a faster and less accurate program for implicit quasi-static analysis of rigid-viscoplastic shells (based on the flow approach) and NUMPRESS-Explicit, a program for explicit dynamical analysis of elastic-plastic shells. Both programs are interfaced to a well-known commercial graphical pre-and postprocessor GiD.

2. Program description

The NUMPRESS-Explicit is based on the explicit FE solution of the equations of motion. The theoretical formulation is based on that of Oñate *et al.* [1]. Sheet is discretized by the basic shell triangular (BST) elements [2]. The BST element features linear approximation of displacements within each triangle. Kinematics of the element is based on the Kirchhoff shell theory. The material properties are considered assuming the Hill'48 model. The implementation of the material model includes anisotropy of the sheet described by Lankford coefficients.

The program NUMPRESS-Flow is another FEA system in which a simplified rigid-viscoplastic material model is used for sheet. Elastic part of the deformation is neglected which limits its applicability. The flow approach formulation for large deformation shells [3, 4] is adopted. The constitutive model is based on the classical J_2 theory with the given nonlinear yield function $\boldsymbol{\sigma}_y(\bar{\varepsilon})$ and with the viscoplastic effects included, based on Perzyna formulation. As a result, a formulation is obtained in which a visible analogy to nonlinear elasticity equations exists (with all displacement and strain fields and arrays replaced with velocities and strain rates, respectively), which makes it easy to implement it in a FE code. This simple formulation has not yet gained wide interest by developers of academic and commercial FE codes dedicated for sheet metal forming problems.

The module NUMPRESS-Explore has been developed to facilitate the design process by providing tools to find the optimal forming parameters and to allow for a variety of probabilistic analyzes like scatter analysis or reliability analysis. NUMPRESS-Explore automates and manages the process of calling the external computational modules (Explicit and Flow), which, depending on the problem, are executed in serial or parallel mode. NUMPRESS-Explore's GUI controls problem definition, submission of computations and post-processing of the results.

3. Numerical investigation of square cup drawing

To illustrate some of the software capabilities, analysis of stamping process of an aluminum square cup is performed. Numerical results of stamping calculations is presented in Figs. 1 and 2. Comparison of the thickness strain distribution calculated by both analytical modules and experimental results is presented in Fig. 1. Results received by the module NUMPRESS-Explicit using planar and transversal anisotropy formulations are close to each other. Good agreement is seen between numerical and experimental results. For the square cup model on stamping depth 20 mm, we expect that we obtain failure because during experiments failure in specimen occur for the same depth. It is seen on the forming limit diagram presented in Fig. 2a. Strains marked by red color are close to forming limit curve, so we can take that such strains are in almost in failure zone. Such strains occurs in corners of the square cup (Fig. 2b).

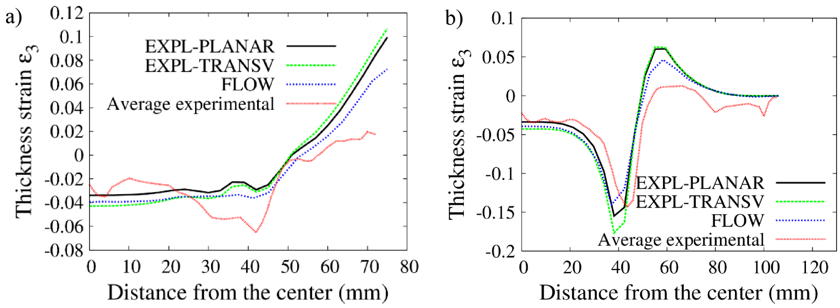

Fig. 1. Numerical results of thickness strain distribution in square cup specimen, stamping depth 15 mm, along the cross section: a) centerline, b) centerline rotated 45°.

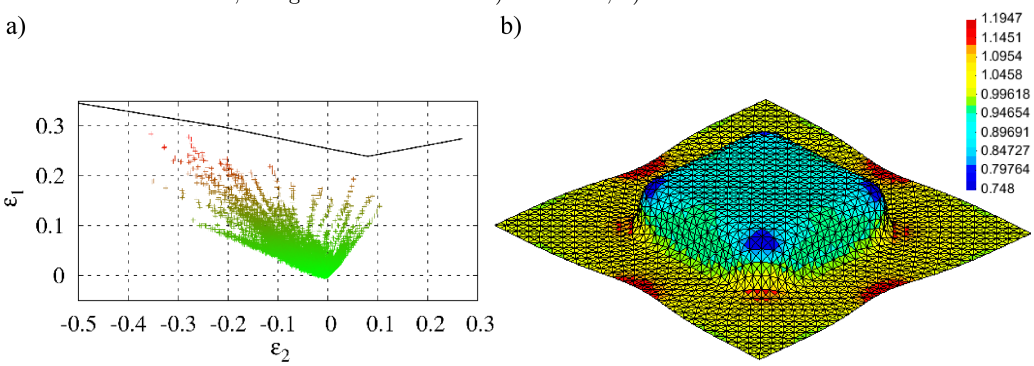

Fig. 2. Numerical results of strain distribution (a) in square cup specimen compared with experimental forming limit curve and thickness ratio (b), stamping depth 20 mm.

Acknowledgments

Financial support from European Regional Development Fund within the framework of the Innovative Economy Programme (project no. POIG.01.03.01-14209/09, acronym NUMPRESS) is gratefully acknowledged.

References

1. Oñate E., Rojek J., Garcia Garino C. (1995). NUMISTAMP: a research project for assesment of finite element models for stamping processes, *Journal of Material Processing Technology*, 50, 17–38.
2. Oñate E., Cervera M. (1993). Derivation of thin plate bending elements with one degree of freedom per node: a simple three node triangle, *Engineering Computations*, **10**, 6, 543–561.
3. Oñate E., Zienkiewicz O.C. (1983). A viscous shell formulation for the analysis of thin sheet metal forming, *International Journal of Mechanical Sciences*, **25**, 305–335.
4. Agelet de Saracibar C. (1990). *Finite Element Analysis of Sheet Metal Forming Processes*, PhD thesis (in Spanish), Universitat Politecnica de Catalunya, Barcelona.