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NUMPRESS – integrated computer system for analysis and optimization of industrial sheet metal forming processes: examples of use

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Abstract

This paper presents NUMPRESS System that has been developed in IPPT PAN as a result of a project financially supported by European Regional Development Fund (within the Innovative Economy Programme) and is dedicated to small and middle enterprises dealing with sheet metal forming.
It seems undoubted that efficient design of an industrial sheet forming process requires reliable computer simulations and a tool for numerical optimization of the process parameters. It has to be also admitted that, among small and medium enterprises (SME) in this industrial branch, there are many who do not use any such numerical tools in their practice.
Computer simulation of sheet metal forming processes is a very specific branch of computational mechanics. Finite element systems dedicated strictly to this kind of processes are needed and actually present on the market. Commercial systems (like Autoform, PAM-Stamp, Stampack, etc.) are, due to their prices, usually beyond financial ability of SME.
Design of the drawing process and tools, i.e. choice of proper values of several design parameters, require efficient optimization strategy. In this process, random character of at least some of the parameters has to be taken into account. In view of this fact, the traditional, deterministic approach to optimization is insufficient and elements of robust design optimization techniques and reliability analysis have to be included in the formulation of the optimization problem. It has to be admitted that, even if some of the mentioned commercial simulation systems offer numerical optimization modules, not all of them reach beyond the deterministic concept of the optimization process.
For the above reasons, we have come up with an idea of development of a widely available system of computer simulation and optimization dedicated for this specific area of applications. The system is named NUMPRESS and consists of the following modules:

i. an analytical module for analysis of forming processes with the finite element method,

ii. a design exploration (NUMPRESS-Explore) module controlling execution of the analytical module and performing such tasks as:
   - design optimization, using standard deterministic as well as robust formulation,
   - reliability analysis and scatter analysis, to assess how random distribution of design parameters affects forming results,
   - design of experiments (DOE) and response surface creation, to build computationally efficient meta-models for expensive FE models,

iii. a graphical user interface enabling communication between modules and easy definition of design parameters and optimization criteria.

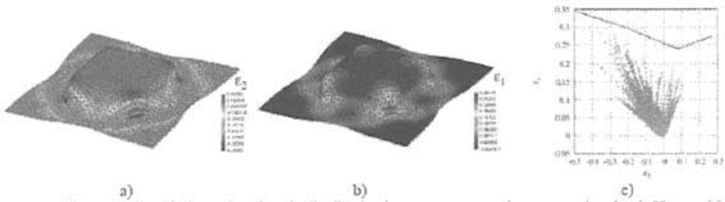
In the analytical module, the user may choose between two programs:

a) NUMPRESS-Flow – a faster and less accurate program for implicit quasi-static analysis of rigid-viscoplastic shells (based on the flow approach) – dedicated for rough optimization processes (where multiple analysis runs are necessary),

b) NUMPRESS-Explicit – a program for explicit dynamical analysis of elastic-plastic shells, featuring much more precise formulation and a wider library of constitutive models.

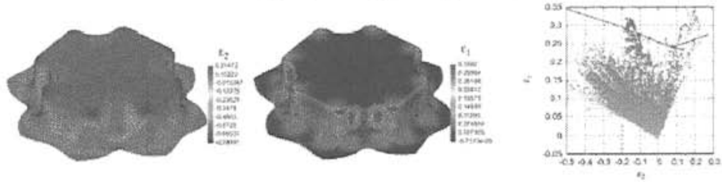
Both programs are interfaced to a well-known commercial graphical pre- and postprocessor GiD.

The system NUMPRESS is dedicated to work on a standard PC. However, it naturally employs multi-thread algorithms and formulations and thus it is especially recommended for multi-core computer systems. To illustrate at least some of the software capabilities, the reliability analysis of stamping process of an Aluminum square and cross shaped cup is performed. Numerical results of stamping calculations are presented on *figures 1* and *2*. Strain distributions is shown on surfaces and compared with the experimental forming limit curves on forming limit diagrams. For the square cup model on stamping depth 20 mm we expect that we obtain failure because during experiments failure in specimen occurs for the same depth. In cross shaped model we specially set up such conditions that on stamping depth 20mm specimen will definitely cracked.



a) b) c)

Figure 1. Numerical results of strain distribution in square cup specimen, stamping depth 20 mm: (a) minor strain, (b) major strain, (c) forming limit diagram



a) b) c)

Figure 1: Numerical results of strain distribution in cross shaped specimen, stamping depth 20 mm: (a) minor strain, (b) major strain, (c) forming limit diagram.

The system NUMPRESS described in this paper is still under development. The numerical examples presented above shows only some of its present or planned capabilities. More advanced constitutive material models with variety of yield criteria are being developed for the NUMPRESS-Explicit code, such as modified Burzynski model [1], taking into account anisotropy and strength differential (SD) effect, or Barlat–Lian model [2]. Parameter sensitivity analysis is also under development for the NUMPRESS-Flow code [3]. Features of the system are inevitably narrower than those proposed by known commercial systems, but its most important advantage is its accessibility, planned to be free of charge during the first years after the project's closure.

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