11th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2007, Hammamet, Tunisia, 05-09 September, 2007.

DEFORMATION MODELING AT BULK PROCESS FORMING

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ABSTRACT
To determinate deformation parameters, a numerical simulation of bulk deformation in open dies of an axi-symetrical working piece was carried out in numerical FEM systems. DEFORM-2D software package meant for analyzing plane and axi-symmetrical deformation is used in numerical simulation. A graded convex shape of die working piece dimensions and distribution of node points whose dislocations are followed in deformation process have been adopted. Numerical simulation consist of three phases.
A numerical experiment is carried out in the first phase, and point movement at the end of deformation process for the accepted coordinate points in a non-deformed state are obtained. Based on these data on point dislocation, deformation state parameters are determined. This numerical experiment relates to the process continuity.
The second phase relates to the numerical experiment realized for the same initial conditions, but bulk deformation process is observed in deformation phases, and deformation parameter are determined in each of them, based on which the parameters at the end of deformation process are obtained.
The third phase relates to the deformation state parameters determined by DEFORM-2D itself, and they refer to the same initial conditions.
Keywords: Numerical Simulation, FEM, Discretization, Bulk Deformation Process, DEFORM-2D

1. INTRODUCTION
Within deformation process, bulk metal forming is specially characterized for its complexity. To be successful at projecting any technological procedure by deformation process, it is of great and importance to know the parameters of strain state. The best way is testing on real object, being quite expensive one and demanding a lot of time for investigation, so numerical experiments that are cheaper and quickly realized have been more applied lately.
Recently, thanks to a rapid development of computer engineering, a numerical approach of solving problems has become of great importance. Finite Element Method (FEM) has been used as the most powerful one. Based on this model several commercial software packages for numerical simulation of bulk deformation process have been made. One of the most known software packages for numerical simulation of bulk deformation process have been made. One of the most known software packages is DEFORM, whose producer is Scientific Forming Technologies Corporation (SFTC), where simulation and the abtained results presented in this paper have been carried out.

2. BASIC PARAMETERS OF NUMERICAL EXPERIMENTAL INVESTIGATIONS
DEFORM-2D software package (V7.2) will be used for numerical simulation. Bulk metal forming in open die process implies a lot of problems both from the point of view of geomtry and technological condition. An element shown in Fig. 1. is observed in the paper with next conditions:
- Meterial is an aluminium alloy AlMgSi0,5.

- Investigation is carried out at hot forming temperature of T=440 [^{o}C].
- Deformation is obtained by a small constant deformation velocity of v=2 [mm/s].
- Strain hardening curve parametres are c=30.34434 an n=0.097808 for AlMgSi0.5 aluminium alloy and temperature T=440 [^{o}C].
- Friction factor is m=0.114.
- Tool shape is gradually convex (Fig. 1.). It consists of two dies, upper and lower ones. The upper part of die consists of two degree heights whereas lower one has one height degree (level).

Working-pieces are cyllindrical, of diameter d_0=33.56 [mm]. Height h_0 is determined by the conditions of constant working-piecs volume before and after pressing process for adopted die dimensions given in Fig. 2. and it amounts to h_0=33.94 [mm].

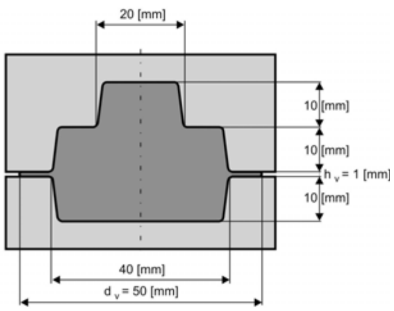


Fig. 1. Working-piece within die

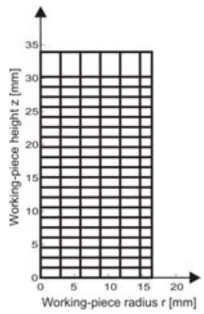


Fig. 2. Adopted net of a working-piece

3. NUMERICAL SIMULATIONS

3.1. Numerical eksperiment for process continuity

To carry out a numerical simulation, it is necessary to put gradually some known data into DEFORM module Pre Processor.

The simulation done, the results obtained may be interpreted in Post Processor module in both graphical and data forms. A final look of the working piece with the network of finite elements in mesh with dies is given in Fig. 3.

To compare data, it is necessary to input info sub-module Point Tracking, the adapted node points r_{p0} and z_{p0}, and their arrangement is given in Fig. 4. By Data Extract order, coordinates of node points at the end of deformation phase are obtained.

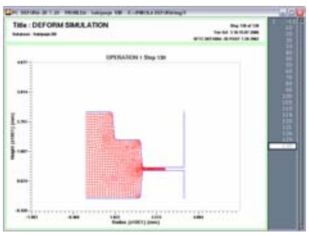


Fig. 3. Working-piece in mesh with dies at the end of deform process

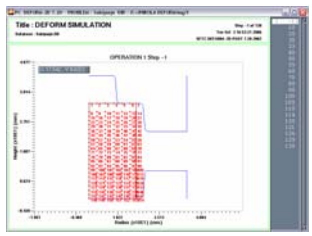


Fig. 4. Adopted arrangement of node points in non-deformed state

Based on the obtained node point coordinates at the end of deform process, data processing is done by means of a programme made in MATLAB programme language (v. 7.0). Input data are: node point coordinates at the beginning r_{p0} and z_{p0} and at the end of deform process r_{p13} and z_{p13}.

Based on movements of points u_{r13} and u_{z13} partial movement derivation per radius and height are calculated: $\partial u_r/\partial r$, $\partial u_r/\partial z$, $\partial u_z/\partial z$ and $\partial u_z/\partial r$. Using such obtained partial derivations it is possible to determine components of small deformations [6]. By applying a relation of relative and logarithm deformations (3.2), values of logarithm deformations are obtained to comparisons with numerical values of FEM simulation.

The values of effective logarithm deformation are given in the form of a three-dimension diagram in Fig. 3a.

3.2. Phases of Numerical Experiment

The data obtained by numerical simulation, due to a great number of possibilities DEFORM-2D programme package possesses, relate to a complete bulk deformation phase may be reached by means of the generated data base.

When numerical experiment in phases is concerned, the idea was to determine deformation in each phase of numerical experiment. To determine the values wanted, we get the needed data on radial and axial coordinates, adopted node points in each step out of DEFORM Tracking-Point- module.

Based on the obtained node point coordinates per steps, data processing is made by means of a programme made in MATLAB programme language. Input data are: node point coordinates at the beginning r_{p0} and z_{p0} and at the end of steps: r_{pi} and z_{pi}, $i = 1,2,...,13$.

Based on dislocation of points u_{ri} and u_{zi}, $i = 1,2,...,13$ partial displacement derivations for radius and height: $\partial u_r/\partial r$, $\partial u_r/\partial z$, $\partial u_z/\partial z$ and $\partial u_z/\partial r$ in each step are calculated. Out of these partial derivations, relative deformations are obtained per phases. Logarithm strain values in the 13th step (at the end of bulk deformation) are calculated as sum of strains calculated per phases. Effective logarithm deformation values obtained per steps are given in the form of a three dimensional diagram in Fig. 3b.

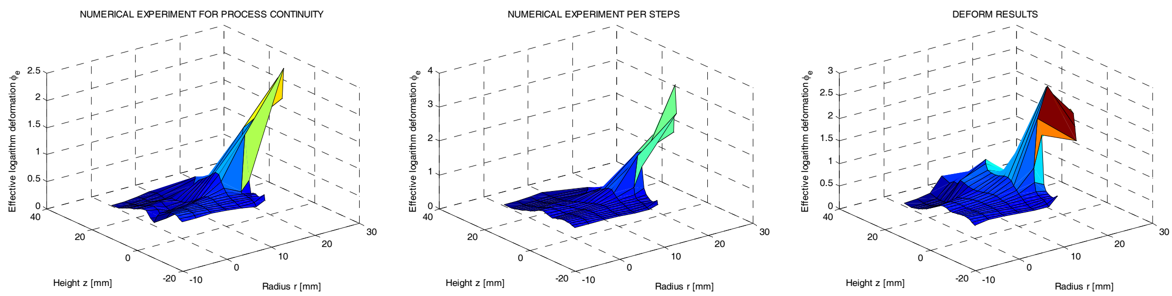
3.3. DEFORM Results

An important results that can be achieved by numerical simulation, apart from geometry change and dislocation of the points observed, is also deformation distribution in each point of plane and axi-symmetrical deformations.

DEFORM-2D software package has an advantage if compared to other software packages in the field of bulk deformation, so it gives deformation values in each step for the observed node points for the adopted node points r_{p0} and z_{p0} at the beginning of the process in non-deformed state.

Point Tracking sub-module enables generation of Point tracking Graphs, as well as showing of the obtained results in both graph and data forms.

Effective logarthm strain obtained by DEFORM simulation is given in Fig. 3c.



a) b) c)

Fig. 4. Effective logarithm deformation φ_e obtained by: a) numerical experiment for process continuity, b) numerical experiment per steps, d) DEFORM

4. ANALYSIS AND COMPARISON OF OBTAINED RESULTS

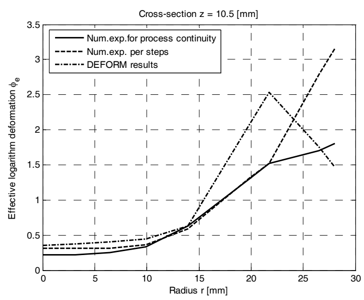


Fig. 5. Effective logarithm strain φ_e for spliting plane cross-section

On the base of previously given space diagram and deformation state parameter values derived from numerical experiment, an analysis and comparison of the obtained data have been made. For complete analysis and comparison, a programme was made in MATLAB given average diagrams in a meridial plane of a working-piece for any cross-section. The splitting plane cross-section corrisponds to a grade plane of a working-piece and of height value z = 10.5 [mm].

Two-dimension logarithm deformation diagrams for all three cases investigation approaches are given in meridial plane of working-piece for a characteristic spliting plane cross-section are given in Fig. 5.

At all the three investigation approacher, for all deformation parameters, two value zones are evident: wreath zone and zone corresponding to interior part of die (die zone).
Comparing logarithm deformation component shear deformation and effective logarithm deformation, at all the three investigation approaches of stepped convex die shape, it is evident that components are of similar change character and the values obtained are of the same value order. Maximum values are obtained in the wreath zone with all the three investigation approaches, i.e. when high deformation values are in question, it is evident the logarithm deformation values calculated per steps in the wreath zone are higher than the ones calculated for process continuity. Deviations are evident with DEFORM results where extreme values at one fourth of the wreath zone appear at wreath.

5. CONCLUDING CONSIDERATION

Deformation state of stepped convex working-pieces at bulk deformation in open dies has been determined in the paper. Deformation state has been analyzed and compared. Investigation process consist of three steps: numerical experiment for process continuity, numerical experiment per steps and DEFORM results.
To carry out numerical experiment, DEFORM-2D software package is used, this being made on the base of elasto-plastic formulation of the finite element method and may be used in bulk deformation in open die simulation process, followed by a great number of deformation. The application of the programme for carrying out the process needs defining a set of input parameters connecting, above all, with: geometry, material, bonndary conditions and working regimes. After the numerical experiment is carried out, the obtained results are stored on PC computer hard disk, this enabling their futher computer processing. To use the obtained results successfully, programmes were made within MATLAB programme language. Based on the obtained coordinates of node point dislocations, by using MATLAB programmes, deformation state parameters given in three-dimensional diagram shape are determined.
Comparison and analysis of the obtained results are mode, and conclusions are the following:

- Differences obtained by using an investigation approach relate mostly to the way of determining parameters. At numerical experiment for process continuity, deformations were determined by model of small deformations for the whole deformation process. At numerical experiment per steps, deformations are determined by dislocation per steps, where total deformation is obtained as a sum of deformation obtained for some steps. At DEFORM results, deformations are determined by mathematical apparatus using DEFORM-2D.
- At discretization process per steps of bulk deformation in open dies and determination of deformation parameters in all phases, a more successful modelling of real process is achieved.
- A strong expansion of computer engineering and software nowadays make it possible for body discretization and process discretization to be a way to greater accuracy in engineering investigations.

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