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LOAD FORCE PREDICTION OF SEMI-HOT COMBINED EXTRUSION PROCESS USING FINITE ELEMENT SIMULATION

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ABSTRACT
Combined extrusion process, which simultaneousely combines the basic extrusion processes such as forward and backward extrusion, can be met in industrial praktice very often. Production of relay hausing part for automotive industry was analysed in this paper. In order to decrase load forces, work of plastic deformation, number of process steps and enhance plasticity of C15 low-carbon steel, so-called semi-hot extrusion process was used. The investigation was performed using experimental-production tool with load cell and finite element simulation. Comparison of experimental and predicted load force characteristics, where good agreement was achieved, were also presented in the paper.
Keywords: FE simulation, combined extrusion

1. INTRODUCTION
Over last years the use of finite element (FE) softwares in the metal forming radicaly changes process planning and tool design methodology. FE simulation enables detailed process analysis, based on accurate stress-strain state prediction, where different process parameters can be simultaneously obtained and analysed.
Plenty of work is reported on FE simulation of the extrusion processes in the literature and few of the more important are cited at the end (1-6). Research was mainly focused on determination of stress-strain state of the workpeace and tool elements, required deformation force and work, estimation pressures and friction on contact interfaces, etc.
Combined extrusion process, which involves two basic extrusion processes such as forward and backward extrusion, is a technology capable to produce very complex shape components. In this process billet is extruded in the forward and backward directions at the same time. Very high contact pressures during the cold forming, especially in backward extrudion, very often requires application so called semi-hot extrusion processes in order to facilitate metal flow and reduce contact pressures. The semi-hot extrusion also offers the opportunity to retaine some significant advantages of cold extrusion such as part quality, high material utilization and productivity.
In this research process of semi-hot combined extrudion of the part shown in Figure 1, has been analysed. The aim of the research was to investigate possibility of application semi-hot extrudion process through comparation of deformation forces obtained by FE prediction and experiments. The

value of maximum deformation force is very important process parameter which affects tool geometry, tool and coating materials, lubricants and metal forming machine selection.

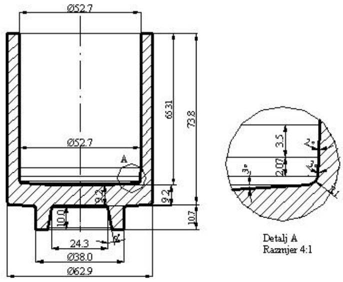

Figure 1. Geometry of workpeace after combined extrusion

2. EXPERIMENTAL WORK

The material used for the extrusion experiments is a low carbon steel C15 for cold forming, with a carbon content 0,07 to 0,15%. Flow curve of the material was determined using compression experiments (L.Šofman), at temperature T=600°C, with punch velocity u=210 (mm/s) and average strain rate 5 (1/s), Figure 2.

Figure 2. Test parts for compression test before, left) and after deformation, right)

In order to investigate the effect of lubricants on the punch force, the extrusion experiments with and without lubricant were carried out. The billet and experimental tool were preliminary heated to temperature 600-720 °C and 300 °C, respectively. The extrusion experiments were conducted on experimental tool designed for serial production. Additional part of the tool is measuring cell which uses strain gages connected in a full bridge. The characteristics of the standard strain gages are: gage factor k = 2.05, gage length L= 9 mm and the resistance R = 120 Ohm.

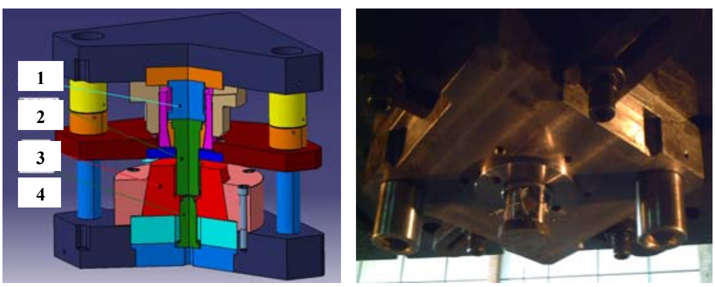

Figure 3. 3D model of the experimental tool with load cell -1, punch -2, die -3 and ejector -4, left) and experimental tool with load cell mounted in the housing, right)

The data acquisition device, specially designed and made for this study, consists of a measuring amplifier D.ER-BV-FP1130, PLC and touch panel. Device characteristics are 200 measuring signals per second and excel table recording. Calibration of the measuring chain (measuring cell and device for data acquisition) was performed on the hydraulic testing machine.

3. FE ANALYSIS

Nowadays the FE simulation is a well-tested and extremely useful tool for solving problems in metal forming, becouse it is more cost effective then trial and error approach. The use of FE analysis allows the material flow prediction, stress-strain distribution during forming, cracks appearance and parameter optimisation in process design phase etc.

Numerical simulation was performed using the Simufact Forming V10.0 software, developed for solving 2D axisymmetrical, as well as 3D non-symmetrical non-linear problems. 3D model of the tool was designed in Catia software and converted in the STL format. In order to save computation time problem was considered as 2D axisimmetrical. The material model of the workpiece was defined using experimentally obtained flow curve, while strain rate exponent was taken over from the reference [4]. Tooling was considered as deformable body. The tool elements, which are realizing contacts with workpeace during forming, and workpeace are fine meshed to avoid mesh penetration, Figure 4. In this non linear case the remeshing procedure was used in order to obtain numerical solution with a controlled accuracy.

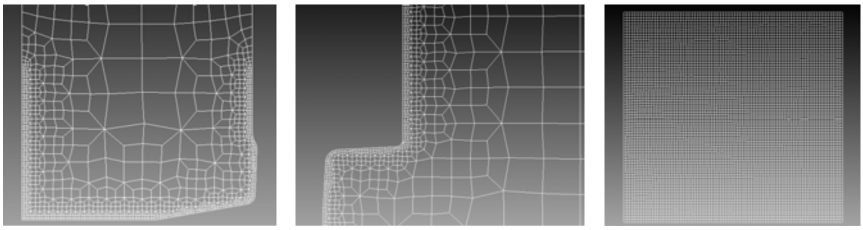

Figure 4: Punch and die meshes a) and initial mesh of the workpeace b)

4. RESULTS AND DISCUSION

In this chapter the effect of friction factor on punch force values and course was analyzed. Figure 3 a) shows comparison punch-force curves for friction factor m = 0.3 and lubricant MoS_2 used in FE simulation and experiment, respectively. Figure 3 b) shows the same comparison with only difference in friction conditions (m=0,5, experiment without lubricant). The punch force-time curves have characteristic course for both FE simulation and experiment, with increascent segment at the beginning and approximately constant values after reaching the steady-state extrusion. The results obtained with lubricant (m=0,3 in FE simulation) show that maximal measured punch force was 3873 KN, and maximal FE predicted punch force was 3778 KN. Similar results were obtained from punch forces comparison when no lubricant was used (m=0,5 for FE simulation), where experimental force was 4653 KN and predicted was 4577 KN.

A good agreement in punch forces course with only difference in the initial phase, before reaching steady-state, was observed. This difference could be explained by different amounts of the elastic deformations in real experiment and simulation. Namely, during loading in real experiment the frame and elements of the eccentric press are exposed to elastic deformation. In addition, there are the gaps between moving parts of the press affecting punch force course. Both gaps and elastic deformations were not considered in FE simulation leading to overestimation of the punch force slope in the initial phase of the extrusion process.

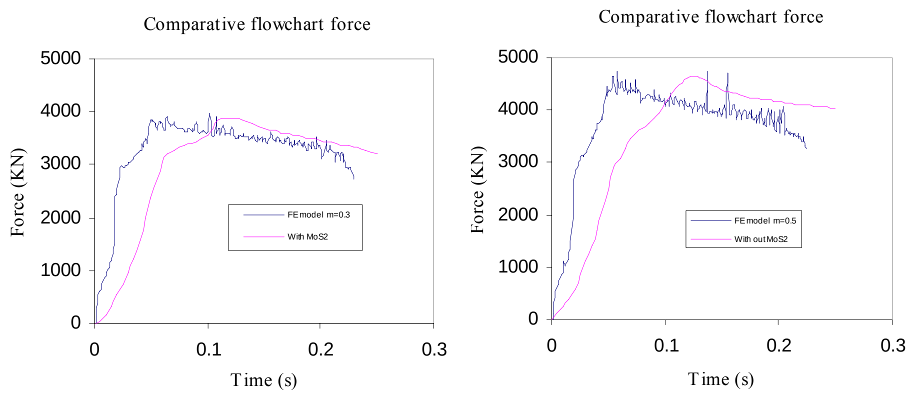

Figure 3. punch force – time curves, experiment vs. prediction with m=0,3 and MoS2 a) and with m=0,5 and without MoS2 lubricant

5. CONCLUSIONS

From the results, the following conclusions could be drown:

- The experimental and FE predicted values of the maximal punch force have good agreement, with difference in range from 1,6% to 2,5%.

- The correspondence of punch force-time diagrams obtained by FE simulation with meassured is quite well. Only significant difference in punch force-time diagrams was recorded in the first stage of the process. Difference of punch force slopes could be be explained by simplifications used in FE models.

- The satisfactory agreement of punch force maximal values and courses gives us the opportunity to evaluate the friction factor that exist in the real process from FE prediction.

6. REFERENCE

[1] Mladomir M., Đorđe Č., Dragiša V., Tomaž P., Miroslav P.: Stress-strain state of combined backward-radial extrusion process of can-flange part, Jurnal for Tehnology of Plasticity

[2] Miroslav P.: FE analysis and experimental incestigation of cold extrusion by shaped punch, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad Serbia

[3] Miroslav P., Dragisa V., Milentije S.,Dejan M., Igor K.: Orbital forging –aplausible alternative for bulk metal forming, Journal of Trends in the Development of Machinery and Associated Technology, Vol. 16, No. 1, 2012, ISSN 2303-4009

[4] S.L.Semiatin, T. Altan; Measurement and Interpretation of Flow Stress Data for the Simulation of Metal-Forming Processes, The Ohio State University, Columbus.

[5] Miroslav P., Dejan M., Dragiša V., Zlatan C., Aljoša I., Igor K.: An Analysis of non-axisymetric backward extrusion, Tehnički vjesnik 19, 4(2012), 953-957

[6] Emin S.: „Analysis of loads tools in the process of semi hot combined extrusion“, M.Sc.Thesis, University of Tuzla, Mechanical faculty, Tuzla 2012.

[7] Analysis User Manual: Simufact Forming Documentatin