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STRESS-STRAIN STATE OF COMBINED BACKWARD-RADIAL EXTRUSION PROCESS OF CAN-FLANGED PART

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ABSTRACT

Application of computer based techniques has led to significant changes in the metal forming industry, which we are witnessing every day. Process simulation enables not only simplification and acceleration of the process and tool design, but also provides process improvement and development of new procedures, better material utilization, increase in quality of final part together with reduction of total manufacturing costs, etc. FEM software ABAQUS is a powerful engineering tool which is widely used for solving different types of problems - both linear and non-linear. In this paper, the process of combined extrusion of a part for car industry was analyzed using ABAQUS. The analyzed process consists of two stages: backward extrusion and radial extrusion.
***Key words**: Process simulation, FEM analysis, backward-radial extrusion*

1. INTRODUCTION

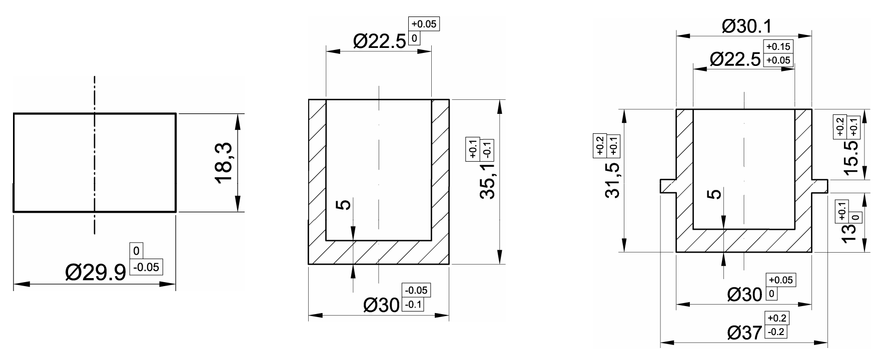
Over the last years the field of metal forming is characterized by dynamic development. There are several reasons for this, but one of the most significant undoubtedly is the use of computers and powerful software, which radically changed the approach and the way of process design and planning. Previously, process and die design were based mostly on empirical experience and trial-and-error steps, which not only caused high production costs but was also time consuming. However, recent developments of computer system and numerical analysis techniques have made it possible to utilize computerized forming process design. It enables detailed process planning and design where many options can be simultaneously considered and different parameters analyzed. Owing to this, optimal solution is reached very easily, quickly and without many charges.

Development of computers and software enabled not only the optimization of the design of forming process, but also the improvement of the existing, and development of new production methods by which it is possible to produce parts which are ready for grinding or directly assembled (NSF-Net Shape Forming) or parts which require finishing machining only on some surfaces, most of which are non-active (NNSF-Near Net Shape Forming) [4]. Reaching the goal of NNSF and NSF - parts with very narrow shape and geometrical tolerances, many activities have to be performed. Usually it implies a long way of continuous process improvement considering entire manufacturing process including machine and tool system, die life, part design etc. The application of NNSF and especially NSF technologies means higher initial time and money investments for manufacturers, but very soon its considerable techno-economical advantages can be noticed, especially in the case of mass production of complex parts.

Cold extrusion is a modern manufacturing technology which makes possible to produce different small and medium size parts with enhanced mechanical and geometrical properties. Most of such way obtained part can bi classified as NNSF or NSF parts. Along the basic or primary cold extrusion processes such as forward extrusion, backward extrusion, radial extrusion, very often in industrial practice can be met so cold combined processes of extrusion. In this processes billet is extruded simultaneously in the forward, backward or radial directions through multiple necks in the tool set. Owing to material flow in different way the combined processes offer the possibility of producing a variety of very complex shape components but precise at the same time. Also the combination of basic operations make possible to be reduced the number of stations required for forming relatively complex parts.

Backward-radial extrusion is a process in which one or two punches press the billet material which is then forced to flow backward between punch and die and radial into a gap between top and bottom die by means a flange and can are formed. It is possible to restrict metal flow into the flange or can by die and punch geometry, gap size, tribological condition etc. Being that backward can extrusion of steel is one of the most critical forging operations due to the very high normal pressure on the punch, the procedure of process and tool design in case of combined backward-radial extrusion is more complex and demands many analyses to be done.

In this paper process of backward-radial extrusion of the part shown in Fig.1.a, has been analyzed The investigation was performed using FEM simulation and ABAUQUS explicit code with the aim of finding stress-strain distribution over the workpiece volume and improving tool design.



a) Billet *b) Geometry of workpiece after backward extrusion* *c) Geometry of workpiece after radial extrusion-final shape*

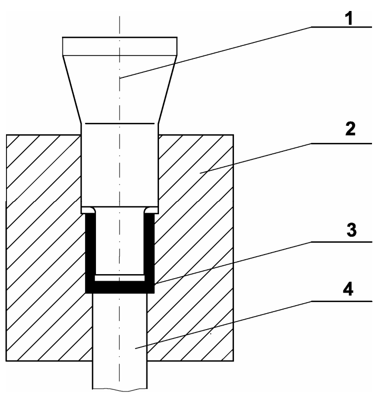
Figure 1 - Geometry of workpiece by phases

2. FEM ANALYSIS

Finite element method is one the most utilized and effective techniques for investigating and optimizing a process. Application of FEM in the field of metal forming, allows many problems to be analyzed and successfully solved, such as forecast of material flow with the forming process, distribution of stress and strain over the part, crack prediction, optimization of the process parameters, die design etc.

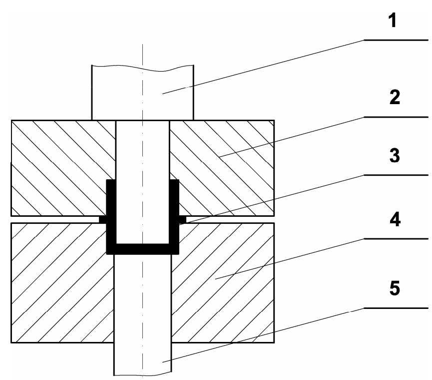
Numerical FEM analysis of investigated model was conducted using ABAQUS software package. ABAQUS is a highly sophisticated, general purpose finite element program, designed primarily to model the behavior of solids and structures under externally applied loading [7]. By using ABAQUS it is possible to solve both linear and non-linear problems.

Virtual model for simulation of analyzed combined extrusion process was conducted on the base of the workpiece geometry given in Fig.1 and procedure shown in Fig.2. Tool and billet geometry including starting FE net, were set in the ABAQUS/CAE module. Tooling was considered as rigid body and workpiece material as elasto-plastic body. The model of workpiece was initially meshed with 1650 quadrilateral elements. In order to get more accurate results and to minimize the effect of tool penetration through elements due to large workpiece deformation, the billet was divided into five zones according to expected strain level and remeshing procedure was performed on every 100 increments. The zones were distinguished by the size and by the number of elements. Material of the workpiece was Yugoslav steel C1221 (corresponding UK steel is En2E) whose analytical form of the stress-strain curve is $\sigma = 660\,\varphi^{0.23}$ [MPa]. Friction conditions were given by factor of friction m=0.173 (μ=0.1).



1- puch, 2- die, 3- workpiece, 4- ejector

a) Sheme of backward extrusion



1- punch, 2- upper die, 3- workpiece, 4- botton die, 5- ejector

b) Scheme of radial extrusion

Figure 2 – Phases of combined extrusion proces

3. ANALYSIS OF RESULTS

The workpiece obtained by FEM simulation is depicted in Fig.3. The FEM simulation has been carried out in two continuous steps. In the first step, the process of backward extrusion was simulated and can-like part obtained (Fig 4.a), while in extension of the simulation (radial extrusion) the final shape of part (Fig 4.b) is reached. Simulation shown that it is possible performs both operations with only one tool.

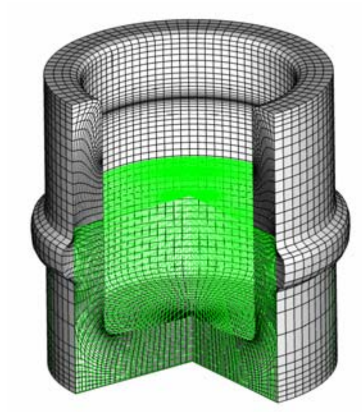
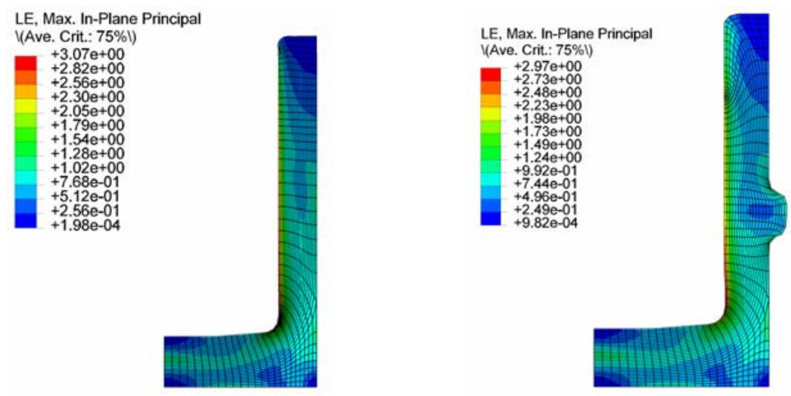


Figure 3 - Final part (ABAQUS/Viewer)

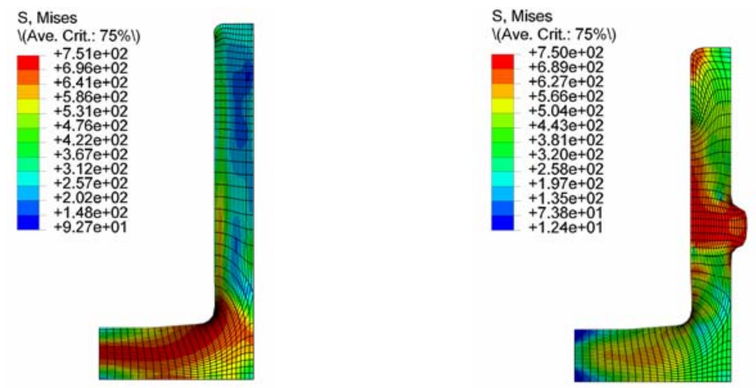
Fig 4 shows effective strain state and effective strain distribution during combined backward-radial extrusion. As it can be seen from Fig.4, strain distribution over the workpiece is very heterogeneous. In the process of backward extrusion maximum values of effective strain appears on the internal surface with the pick at the corner zone (zone between bottom and wall of workpiece). On the top of the workpiece there is zone which is not almost included in deformation process-dead zone. Such zone also exists below the punch. In the beginning of backward extrusion “dead zone” under the forehead of the punch is quite large, but with the punch moving down, it becomes smaller. The strain values displayed Fig 4.b, indicate that the top of workpiece stayed very low deformed and after radial extrusion process. It means that this part of workpiece behaves like a rigid body that transfer load only. In the flange zone realized strain level is low too, so there is no real danger regarding to crack appearance.

The effective stress state given in Fig.5 is also not uniformly distributed along the cross section of the workpiece. FEM simulation has shown that normal pressure depends on the punch stroke. Highest value of 2750 MPa appeared at the end of the process of backward extrusion. Such high value is effected by a very small thickness of the bottom of the workpiece, which results in high loaded punch in phase 1. In the phase 2 (radial extrusion) normal pressures are lower than in previous one with maximum values of about 2000 MPa. This value is obtained in the case where there was a contact between the central punch and workpiece bottom (bottom calibration), while in the case without calibration, the maximum reached value was 1640 MPa.



a) backward extrusion *b) radial extrusion*

Figure 4 - Distribution of effective strain



a) backward extrusion *b) radial extrusion*

Figure 5 - Distribution of effective stress

FEM simulation has also shown that the investigated radial extrusion process is very sensitive to the buckling of the workpiece. It could lead to material absorption phenomena which occurs in the flange level of the inner side of part wall (Fig. 6). To avoid this, it is necessary, among others things, to design the punch and die radii properly.

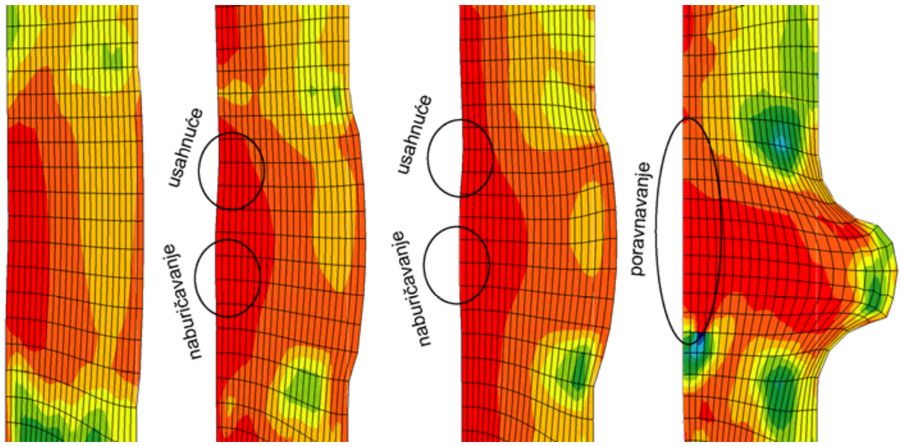


Figure 6 – Defect in the process of radial extrusion

4. CONCLUSION

In this paper the process of combined backward-radial extrusion was analyzed by FEM simulation and ABAQUS/Explicit. Can-like part with a central flange was obtained in two subsequential phases. The aim of this investigation was to determine stress-strain state along the workpiece volume, to analyze material flow and check-out of critical points in the procedure. Based on the simulation results, the following can be concluded:

- The stress-strain state is very heterogeneous along the workpiece
- Maximum values of stress and strain appears at the corner zone of the bottom of workpiece
- In the flange zone of workpiece there is not real danger regarding to crack appearance
- For the chosen workpiece geometry punch for backward extrusion was highly loaded.
- Normal pressure is not critical for radial extrusion, but there is a potential problem with material absorption in the flange level of the inner side of part wall due to buckling of workpiece wall.
- The geometry of upper and bottom die influences very much the size of material absorption and this problem can be avoided by choosing proper geometry.

For the verification of the obtained results experimental investigation of the process will be carried out in the laboratory for technology of plasticity at the University of Novi Sad.

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NAPONSKO DEFORMACIONO STANJE U PROCESU KOMBINOVANOG SUPROTNO-SMERNOG I RADIJALNOG ISTISKIVANJA DELA OBLIKA ČAŠE SA VENCEM

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REZIME

Savremeni način projektovanja procesa obrade metala deformisanjem nezamisliv je bez primene računara i odgovarajućih software-skih paketa namenjenih za simulaciju i proračun parametara procesa. Većina ovih simulacija bazira na primeni MKE, a njihov značaj ne ogleda se samo u činjenici da olakšavaju i ubrzavaju postupke projektovanja procesa i konstrukcije alata, već istovremeno obezbeđuju njihovu optimizaciju, doprinose poboljšanju kvaliteta i tačnosti gotovog proizvoda uz istovremeno smanjivanje troškova proizvodnje, pomažu razvoj novih postupaka itd. Jedan od takvih softwer-a jeste i programski paket ABAQUS. Baziran na primeni MKE, ovaj software predstavlja moćan inženjerski alat pomoću koga se može rešavati čitav niz problema počev od jednostavnijih linearnih pa sve do veoma kompleksnih nelinearnih problema. U ovom radu programski paket ABAQUS primenjem je za analizu procesa izrade dela oblika čaše sa spoljašnjim vencem kombinovanim postupkom suprotnosmernog i radijalnog istiskivanja.
***Ključne reči**: simulacija procesa, MKE, kombinovano istiskivanje*