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# THE APPLICATION OF THREE-DIMENSIONAL COMPUTER SIMULATION WHEN DEVELOPING DIES FOR EXTRUSION OF ALUMINIUM SHAPES

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*Preliminary Note - Prethodno priopćenje*

The automated system of three-dimensional computer simulation with use of FEM is developed. The model is based on the Euler approach. The function of Markov variation principle is used for derivating. The connected task of thermo-viscous-plasticity is solved. The flat die is designed for extrusion of the thin-walled shape from a soft aluminium alloy 6060.

***Key words:*** *three-dimensional simulation, finite element method (FEM), aluminium, extrusion, shape, die*

**Uporaba trodimenzionalne simulacije za razvoj matrica za ekstruziju aluminijskih profila.** Razvijena je automatska trodimenzionalna kompjutorska simulacija uporabom FEM-a. Model se temelji na Eulerovom pristupu. Za deriviranje se koristi funkcija Markovog načela varijacije. Riješen je zadatak termo-viskozne plastičnosti koji je s time povezan. Projektirana je ravna matrica za ekstruziju profila s tankim stjenkama iz mekane aluminijske legure 6060.

***Ključne riječi:*** *trodimenzionalna simulacija, metoda konačnog elementa (FEM), aluminij, ekstruzija, profil, matrica*

## INTRODUCTION

The existing practice of aluminium shapes production for construction consists in extrusion of aluminium through direct dies without use of lubricant. For uniform and rectilinear outflow of metal from die aperture usually are applied pockets (prechambers) of the complicated cross-section, which make the passage from the container to die aperture more smooth. Except assigning pocket sizes, metal flow smoothing realizes with the help of working pocket, making their length and angle variable on a perimeter of the aperture [1]. The modern techniques of the definition of these parameters have a brightly expressed empirical character and are based on realisation of numerous experiments.

The intensive development of aluminium extrusion branch in Ukraine and abroad has led to arising a great number of mini-factories for production of aluminium shapes. For such a production the realisation of a lot of experiments for implementation of a new shape reduces competitiveness of a firm. Thereby a problem of extrusion process computer simulation with the complex considering of three-dimensionality of flow, real rheological properties of metal, friction and thermal processes in the deformation zone is actual.

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## MATHEMATICAL MODELLING

In studies [2, 3] the development and the testing of a mathematical model based on a solution of the three-dimensional task of flow of nonlinearly viscous incompressible medium during shapes extrusion is carried out with the help of a finite element method.

Except some modifications concerning free surfaces, the model is based on the Euler approach. For obtaining solution of the function of a Markov variable principle [4] is used

$$J = \frac{1}{2}\int_V \mu H^2 \, dV + \int_V \sigma\varepsilon_0 \, dV - \int_S \sigma_\tau u_\tau \, dV \, ;$$

where $\mu$ - conditional viscosity of metal, determined under the formula:

$$\mu = T(H, \Lambda, \Theta)/H \, ;$$

$T(H, \Lambda, \Theta)$ - shear stresses intensity $T$ depended on shear strain rate intensity $H$, shear strain $\Lambda$ and temperature $\Theta$; $V$ - deformed volume; $\varepsilon_0$ - is average strain rate; $\sigma$ - average stress; $\sigma_\tau$ and $u_\tau$ - friction stress and velocity of sliding of metal on the tool; $S$ - area of a contact surface of metal with the tool.

The nonlinearity of rheological properties of metal is taken into consideration with the help of hydrodynamic approximation method. The connected of thermo-viscous-plasticity task is solved.

The discretization of deformed metal volume and velocities field approximation is carried out with the help of the 15-nodes prismatic final elements with a triangular base. The automatic generator of a three-dimensional grid is based on an "extrusion" from two-dimensional triangular grids. Input data for automatic generation of a three-dimensional grid are the graphic files with an image of outlines of the shape, pocket, container and transitional outlines in case of fillet on the die aperture entrance. At generation of two-dimensional grids the algorithm of grid generation in a closed loop is used. This algorithm is included into a structure of a popular system of the stamping process simulation Qform, presented by Quantor Soft (Moscow), within the limits of joint researches.

## THE USE OF THE SYSTEM FOR EXTRUSION DIES DESIGN

Let us consider application of an automated system of three-dimensional computer simulation for the task of die design for extrusion the shape of window-door system TECNO produced by YOUGCHERMET (Ukraine, Dnipropetrovsk). The drawing of the shape is shown at Figure 1..

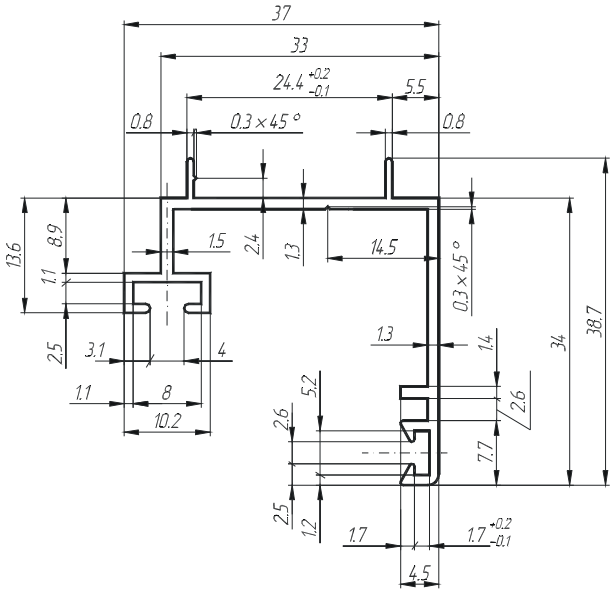


Figure 1. **Window - door system shape**
Slika 1. **Profil sustava prozor - vrata**

Disposition and form of the aperture and pocket are shown at Figure 2.. The definition of these parameters is carried out on a basis of computer simulation of a series of

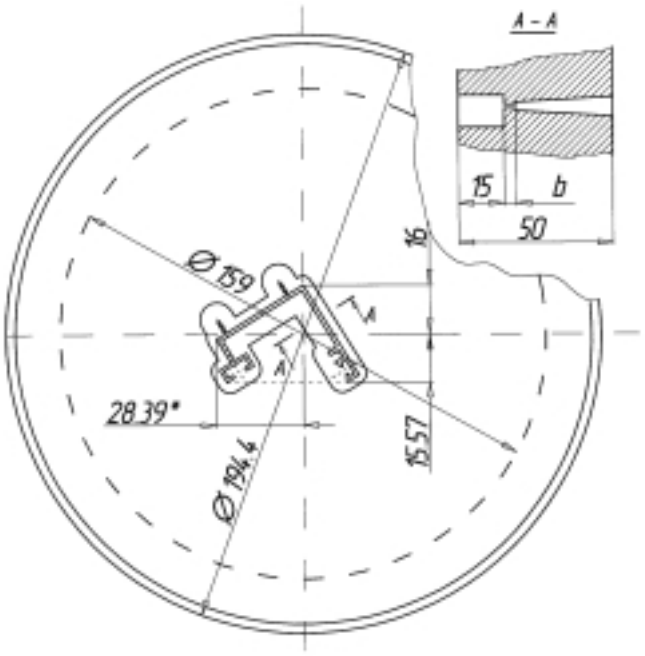


Figure 2. **Disposition and form of the aperture and pocket**
Slika 2. **Raspored i oblik aperture i džepa**

trial variants. The conditions of simulation corresponded to the production conditions of these shapes by YOUGCHERMET: velocity of extrusion - 4 mm/s, temperature of heating of billet and die 450 °C, factor of friction by

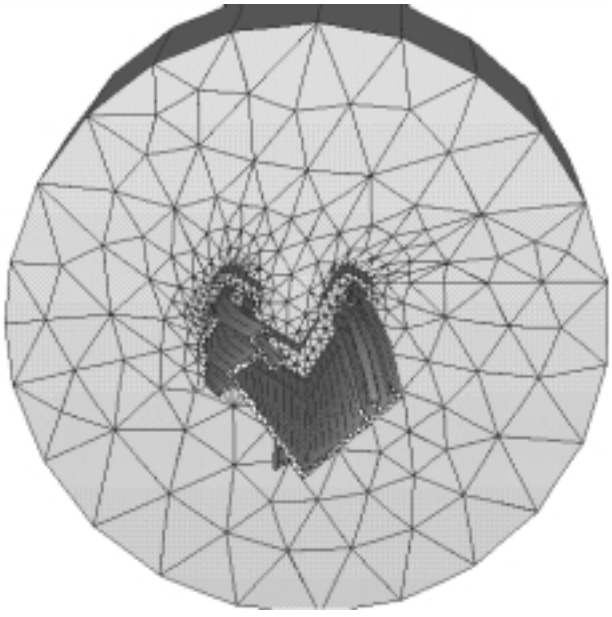

Figure 3. **The rezult of metal flow simulation (first variant)**
Slika 3. **Rezultati simulacije tečenja metala (prva varijanta)**

results of precomputations is taken as 0.8 (extrusion is carried on without greasing). The diameter of the container is 159 mm. The variant represented at Figure 2. was accepted as basic.

Outcomes of metal flow simulation for the given disposition of aperture is shown at Figure 3.. The depth of a pocket was 15 mm, bearing length was constant along a perimeter of the aperture and was 5 mm. By results of simulation the bending of the shape was 8.6 mm/m and torsion 192.9 °/m.

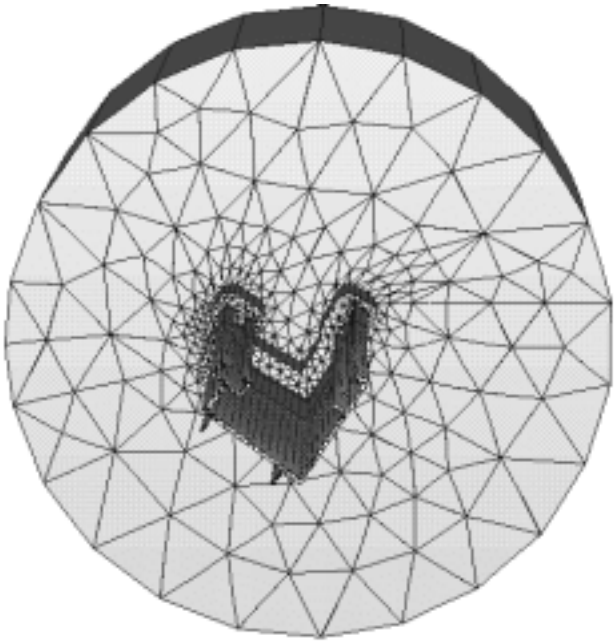

Figure 4. **The rezult of metal flow simulation (final variant)**
Slika 4. **Rezultati simulacije tečenja metala (završna varijanta)**

A further correcting of the die was fulfilled by modification of distribution of bearing lengths along a perimeter of the shape and metal flow simulation for the taken form of the die. The outcomes of metal flow computations for variant of the die, which was recognised final, are shown at Figure 4.. As a result the bending of the shape was 0.4 mm/m and it torsion was 16.2 °/m. The distribution of bearing lengths, corresponding to the given computation variant is shown at Figure 5..

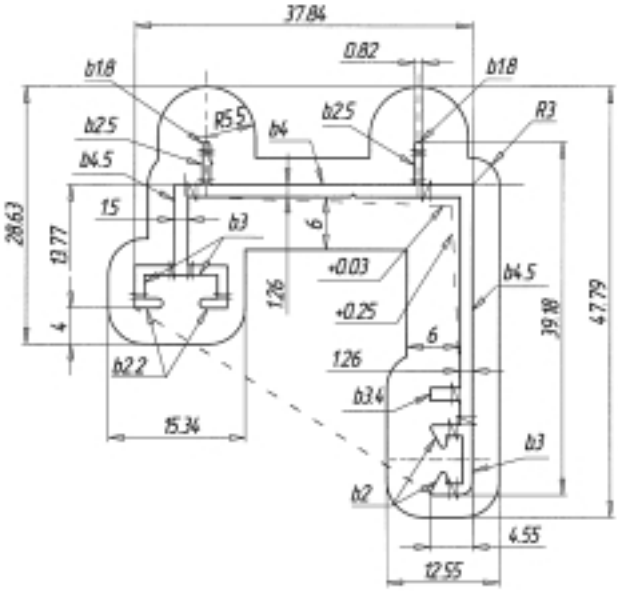


Figure 5. **The distribution of bearing lengths**
Slika 5. **Raspored nosivih dužina**

## CONCLUSION

The opportunity of use of the developed mathematical model of three-dimensional metal flow is shown for designing of extrusion dies. The mathematical model based on a finite element method, is realised as software ready for use at the enterprises.

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