Journal for Technology of Plasticity, Vol. 28 (2003), Number 1-2

VELOCITY PROFILES AT THE OUTLET OF THE DIFFERENT DESIGNED DIES FOR ALUMINIUM EXTRUSION

J.Caloska, J. Lazarev, Faculty of Mechanical Engineering,
University "Cyril and Methodius", Skopje, Republic of Macedonia

ABSTRACT

Uniforming of the exit velocities profile in the process of Al-extrusion is a very complex problem, which cannot predict before making and testing the tool.
The group of a Russian scientists (G. R. Gun, V. I. Rkovlev, B.A. Prudkovskii) investigated profile of the exit velocities in laboratory and real production conditions.
The investigated pieces were rectangular Al and Pb profiles. The dies were divided on segments because they wanted to measure the differences of the exit velocities in the different parts of the profile.
The obtained diagrams present the profile of the exit velocities in every segments of the die. This paper present the comparation between the exit velocities obtained experimentally by the mentioned scientists, and exit velocities obtained numerically with model created by FLUENT. The Al extrusion process is treated as steady state laminar fluid flow with high viscosity. The treated material is aluminum alloy AlMgSi0,5 .
The paper shows that there are differences between the exit velocities for segmental and continual exit of the dies.

Key words: *Al-extrusion, die design, exit velocity profile*

1. INTRODUCTION

The aluminium extrusion process is a technology, which has been used in commercial aims almost 60 years. During the extrusion process, the heated billet is extruded under the high pressure through the outlet of the die. The extruded profile has the same form as the outlet of the die (Figure 1.1).

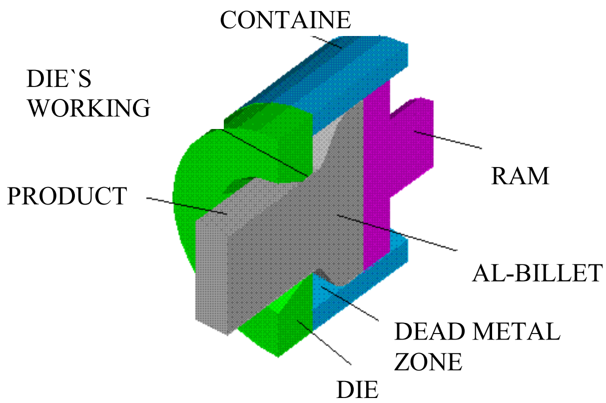


Fig. 1.1 Extrusion process

Many theoretical and experimental investigations show that it is necessary to make thoroughly research of the influential factors on the exit velocity profile. To receive extruded profile with high quality it is necessary to know the arrangement of the velocity profiles at any zone at the outlet of the die. Practically it is impossible to predict the exit velocity profile before making and testing the tool. Different velocities in the different zones at the outlet of the die result with defects on the final extruded product (Figure 1.2).

Fig.1.2 Defects on extruded profiles

Using the conventional measuring techniques to analyze the influence factors on the exit velocity profile is very difficult, because the Al-extrusion is complex process, which is conducted under hard working conditions (high temperature and pressure).

By using the mathematical-numerical model for a simulation of flowing process through the tool, where Al-extrusion process is treated like steady state laminar Newtonian fluid flow with high viscosity, it is possible to obtain the exit velocity profile before the manufacturing of the die. This model gives us opportunity to make corrections on the tool in the phase of construction.

2. MATHEMATICAL-NUMERICAL MODEL

The mathematical model is based on the analogy between the process of extrusion and the fluid flow. The process of extrusion is occurred very slowly, the flow condition and deformation of Al-material would be treated as a steady state laminar flow. The viscosity and density of extruded material are considered to be constant during the whole process. Using these assumptions, the equations for conservation of momentum, mass and energy for fluid flow would be used for the process of aluminium extrusion.

In the process of Al-extrusion, the aluminium is treated closer to the fluid conditions by involving the following assumptions:

- The shear stress between Al-material and wall of a container is proportional to the pressure

$$\tau_n = \mu \cdot dF_n/dA = \mu\ p\ dA/dA = \mu\ p \qquad (2.1)$$

- The dynamic viscosity in the numerical simulation has a value with the same range as the shear stress between the wall of the tool and the extruded material

Because the shear stress in the fluid mechanics is presented as a function of the viscosity

$$\tau_f = \mu_f \frac{dv}{dn},$$

by involving the assumption that the difference of velocity between the streamlines is very small, which means:

$$\frac{dv}{dn} \approx 1,$$

the following conclusion can be expressed: $\tau_f \approx \mu_f$ that mean "the shear stress and viscosity are of the same order".

- The viscosity is identical with the shear stress in the mean deformation zone (near the inlet of the die)

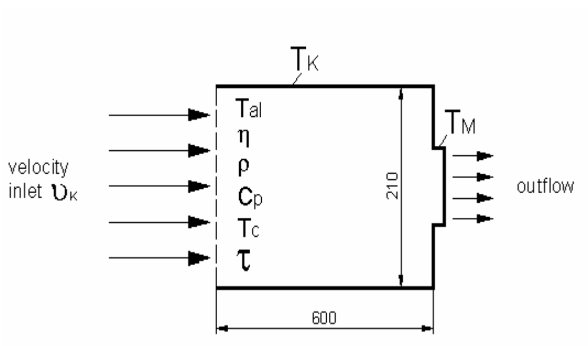
$$\eta \Rightarrow \tau_{k2} \approx \mu \cdot \sigma_{n2} \qquad (2.2)$$

where σ_{n2} is the normal stress in the zone of the mean deformation.

The numerical simulation is realized by using finite volume method and the following boundary conditions:

- wall temperature along the container is constant;
- wall temperature on the exit of the die is constant;
- constant inlet velocity in Z-direction;
- zero pressure gauge of outflow.

Figure 2.2 presents the inlet parameters, which are taken in the numerical simulation of the extrusion process.



Ram speed	0,0075 m/s
Container temperature	683 K
Die temperature	673 K
Billet temperature	773 K
Viscosity	$2x10^7$ kg/ms
Density	2405 kg/m^3
Spec. heat temp	1090 j/kgK
Heat transfer coef.	228,5 W/mK
Shear stress	$4x10^7$ Pa

Figure 2.2 Inlet parameters of the extrusion process

3. RESULTS AND DISCUSSION

The current (modern) numerical experiment is based on experimental results of other authors. The experimental costs in real production and laboratory conditions are decreased, by using the existing results. The group of Russian scientists [1] investigated the material flow kinematics of Aluminium and aluminium alloys.

Their aim was measuring the exit velocities in different points of the rectangular profile. The investigated profile (Fig.3.1) was divided on the five equal parts, and extruded material was aluminium alloy AD31 (GOST).

The container diameter was D_k=79 mm and the ram speed was v_k=11mm/s.

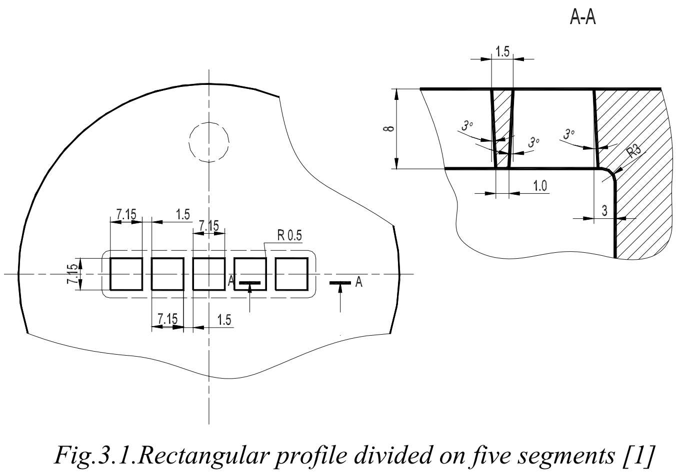


Fig.3.1.Rectangular profile divided on five segments [1]

The same model is numerically simulated by the authors of this paper [2], with the same experimental conditions (Fig.3.2).

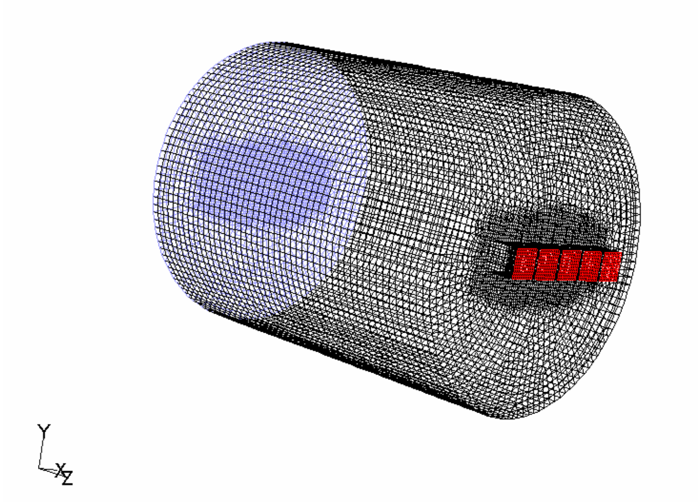


Fig.3.2. Model designed by using FLUENT

Figure 3.3 presents the velocities contours on the central plane of the container where the material flows faster then the material at the corner parts of the profile.

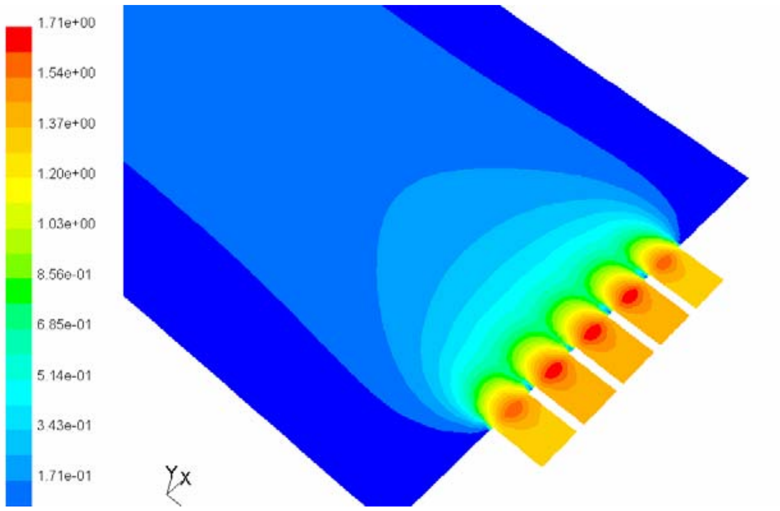


Fig.3.3. Velocity contours on the central plane of the container for segmental die

The divided model was made because it was the only way to measure the differences of the exit velocities in the different parts of the profile. So we created the rectangular model with continual exit of the die and analyzed the exit velocity profile.

The velocity contours shows the acceleration of the material flow in the center of the die and decreasing velocities at the corners of the profile, near the walls of the die (Fig.3.4).

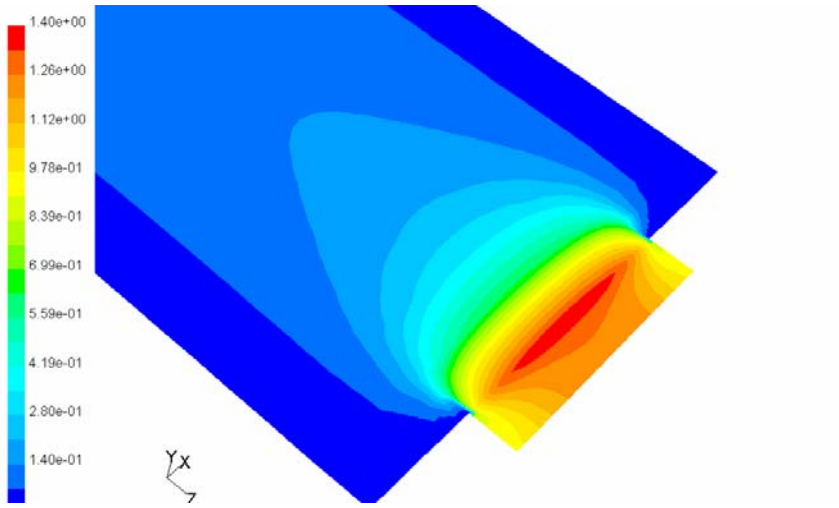


Fig.3.4. Velocity contours on the central plane of the container for continual die

The comparation analysis of the exit velocities shows the differences between the exits velocities profile obtained with segmental and continual dies (Fig.3.5).

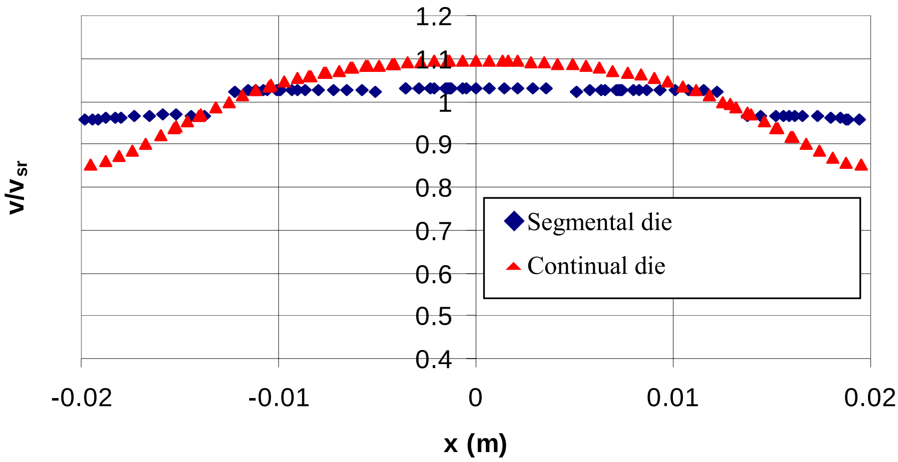


Fig.3.5. Comparation of the exit velocities profile for segmental and continual die

The higher differences exist at the parts of the profile, which are further of the center of the die, because of of the die's walls influence. The profile of the exit velocities presented on theFig.3.5 for die's model with segments is not conformed with the exit velocities profile for continual die's model. The reason is because of different influence of the die's walls and continuum of the material's flowing.

The central part of the continual model has a higher velocity than the same part of the segmental model. The parts near the corner of the profile have a lower velocity because of the increasing friction.

The experimental results are conformed to numerically obtained results for segmental die's model (Fig.3.6).

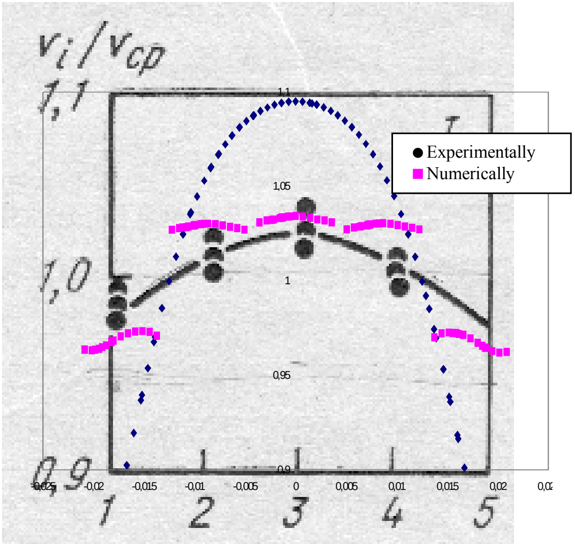


Fig.3.6. Exit velocity profile obtained experimentally (black points •) and numerically by using FLUENT(■)

This is not a case with continual die's model. The comparation on Figure 6. shows that model of segmental die is not very favourable, specially for measuring of the exit velocities at a different parts of the profile.

Figure 3.7a) presents the flow pattern of the material for central rectangular model, obtained experimentally [1], and the same model but numerically obtained by using Fluent (Figure 3.7b). The experiment was realized in the real production conditions and the material was Al-alloy. The presented flow pattern was obtained by cutting and meshing a bullet.

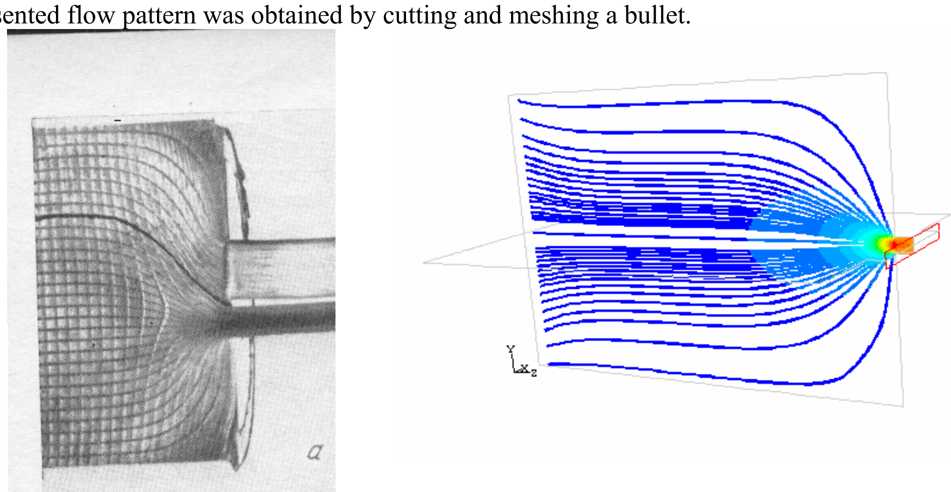


Fig.3.7. Flow pattern for central rectangular model a)experimentally b)numerically

Figure 3.8 shows the same flow pattern for decentral die's model.

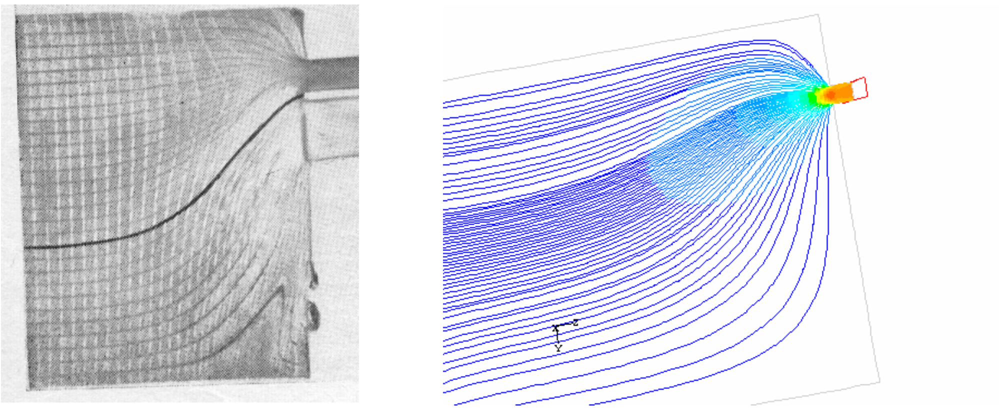


Fig.3.8 Flow pattern for decentral rectangular model a)experimentally b)numerically

4. CONCLUSION

The comparation analysis at the exit velocities profile of the Al-extrusion shows a differences between the exit velocities for segmental and continual die's model. Because the increasing friction near the die's walls, the material's velocity is decreasing.
So, the segmental die is not very suitable to measure the exit velocities on the different parts of the extruded profile.
The results of this paper give verification of the numerical model, created bu FLUENT to use the same for other future investigations.
By using the existing experimental results we can decrease the costs and time, which are spended for verification of the numerical model.

5. REFERENCES

[1] G. R. Gun, V. I. Rkovlev, B.A. Prudkovskii I dr., Pressovanie alnominievvih splavov, Metallurgir, Moskva, 1974

[2] J.Caloska, J. Lazarev, A. Nospal, V. Stojkovski,: Exit velocities profile at the extrusion process of aluminium square pipe, Southeastern Europe Fluent Users Group Meeting 2002, Thessaloniki, Greece, 2002

[3] J.R. Davis: Aluminum and Aluminum Alloys, Davis&Associates, 1994

[4] B.J.E.van Rens, W.A.M. Brekelmans, F.P.T.Baaijens:Boundary conditions for the 3D Numerical Simulation of Extrusion. ATP.Vol.III, ICTP,sept.1999

[5] M.Kiuchi,J. Yanagimoto, V. Mendoza: Extrusion of Restangular sections and Angeles. Institute of Industrial Science, University of Tokyo,1995

[6] T. Bundalevski: Mehanika na fluidite, MB-3, Skopje,1996

[7] L.D. Landau, E.M. Lifšić.: Mehanika neprekidnih sredina, Građevinska knjiga, Beograd

[8] FLUENT Manuals, Fluent Europe Ltd,1998

[9] GAMBIT Manuals, Fluent Europe Ltd,1998

[10] J. Caloska: Investigation of the kinematics of Al-profile`s extrusion, PhD thesis, University "Cyril and Methodius", Skopje, R. Macedonia, 2002

PROFILI BRZINA NA IZLASKU IZ ALATA RAZLIČITIH KONSTRUKCIJA KOD ISTISKIVANJA ALUMINIJUMA

J.Caloska, J. Lazarev

REZIME

Ujednačavanje (uniformisanje) izlaznih brzina profila u procesu Al istiskivanja (ekstruzije) je veoma kompleksan problem, koji se ne može egzaktno rešiti bez da se izradi i testira alat. Grupa ruskih naučnika je izučavala izlazni profil brzina u laboratorijskim uslovima kao i u proizvodnim uslovima.

Istraživani oblici su bili Al i Pb profili. Alat je bio segmentiran obzirom da je cilj bio da se odrede brzine na različitim segmentima profila.

U ovom radu daje se kritička analiza pomenutih istraživanja ruskih autora kao i komparacija sa istraživanjima autora ovog rada. Upoređen je profil izlaznih brzina i to eksperimentalno (ruski istraživači) i numerički, korišćenjem modela kreiranog u FE paketu FLUENT. Proces ekstruzije je tretiran kao stacionarni laminarni tok sa visokom viskoznošću. Posmatrani materijal je AlMgSi0,5.

U kreiranju matematičkog modela uvedene su neke pretpostavke:

- *tangencijalni napon između Al – materijala i zida kontejnera proporcionalno je pritisku:*
  $\tau_n = \mu \, dF_n/dA = \mu \, p$
- *dinamička viskoznost ima vrednost koja je istog nivoa kao i tangencijalni napon između zida alata i ekstrudiranog komada*
  $\tau_f = \mu_f \frac{dv}{dn}$ *tj. tangencijalni napon i viskoznost su "istog reda veličine"*
- *viskoznost je identična sa tangencijalnim naponom u glavnoj zoni deformacija*
  $\eta \Rightarrow \tau_{k2} \approx \mu \cdot \sigma_{n2}$

Numerička simulacija je realizovana metodom konačnih zapremina korišćenjem relevantnih graničnih uslova. Na osnovu dobijenih rezultatat moguće je zaključiti sledeće:

- *upoređenje izlaznih brzina Al – profila pokazuje razlike između segmentnog i kontinualnog alata. Zbog povećanog trenja u blizini zida alata, brzina materijala opada*
- *segmentni alat nije pogodan za merenje izlaznih brzina na različitim delovima istisnutog profila*
- *rezultati ovog rada je verifikovani numerički model, kreiran pomoću FLUENT-a*
- *korišćenjem postojećih eksperimentalnih rezultata mogu se redukovati troškovi i vreme za verifikaciju numeričkog modela*