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THE MEASUREMENT OF DEFORMATION FORCE VARIATION BY USING STRAIN GAGES IN EXTRUSION TECHNOLGY

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ABSTRACT

The variation of extrusion pressure for backward extrusion processes with different punch shapes and lubricants is analyzed in this paper. The process parameters that are varied in experiment are: degree of deformation (three degrees), the punch shape (flat, conical and spherical punch) and the lubricant (zinc stearate and the mixture of zinc stearate and the oil SAE90). The finite volume method is used for calculation of extrusion pressure and the very good agreement with measuring data is obtained.
Key words*: Extrusion pressure, Punch shape, Finite Volume Method*

1. INTRODUCTION

The extrusion technology is a metal forming process used to produce large variety types of profiles. In the industrial application of the extrusion process, the tool design and process control are mainly based on empirical knowledge. This empirical knowledge is not well documented and is to a large extent only accessible through the experience of tool designers. In recent years a trend can be observed towards a more objective documentation of the empirical knowledge available at extrusion companies.
The development of automated design applications or expert systems can be seen as a part of this trend. The numerical methods like finite element method (FEM) [1-4] or finite volume method (FVM) [8-10] could bee the valuable tool in obtaining such knowledge, providing insight into the process that cannot easily be obtained in any other way. Because the analytical solutions don't exist, the experimental verification of these numerical models is the best way for verification and is necessary in many cases [6-7]. For obtaining the numerical results, the finite volume method is used in this paper.

2. THE EXPERIMENTAL EQUIPMENT

The experimental investigation were planed and performed by using the rules of multi factorial analyze of experiments. In the experiment, three process parameters were changed:

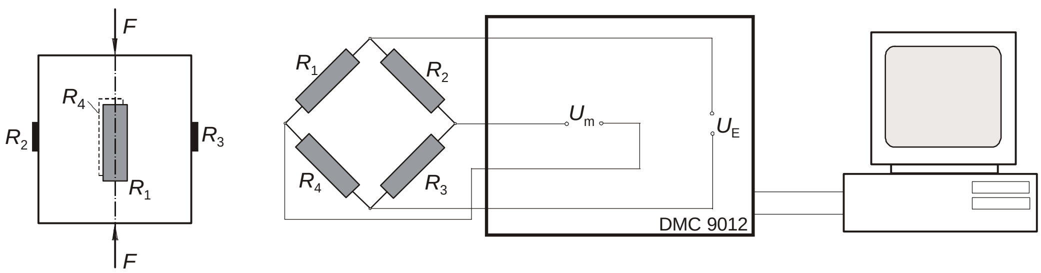
- The degree of deformation – three levels,
- The punch shape – three levels: flat, conical (with half cone angle α=15^0), and spherical (with radii r=12,5 mm) punch,
- The lubricant – two levels: the Zn-stearate and the mixture of Zn-stearate and the oil SAE90 in ratio 60:40.

During the testing the diameter of the die (D_0) was changed, while the punch diameter (d_1) was kept constant. The extruded material was technically pure aluminum, Al 99,5 with the hardness 20 HB. The basic experimental data are given in Table 1.

Table 1. The basic geometrical data of workpiece, extruded cans and the material properties.

	D_0 mm	d_1 mm	S mm	H_0 Mm	ε %	φ	k_f MPa	Extruded can high, H, mm Flat	Conical	Spherical
1.	28		1,5		79,7	1,37	160,9	45,4	41,0	37.0
2.	27	25	1	14	85,7	1,79	166,8	62,1	55,0	49,0
3.	26,5		0.75		89,0	2,09	170,4	78,7	69,6	62,1

For the measuring of variation of the extrusion pressure, the strain gages are used. Due to elimination of the eccentric forces and the temperature compensation, the full Wheatstone's bridge is used. The scheme of constructed transducer and the measuring is given in Figure 1.

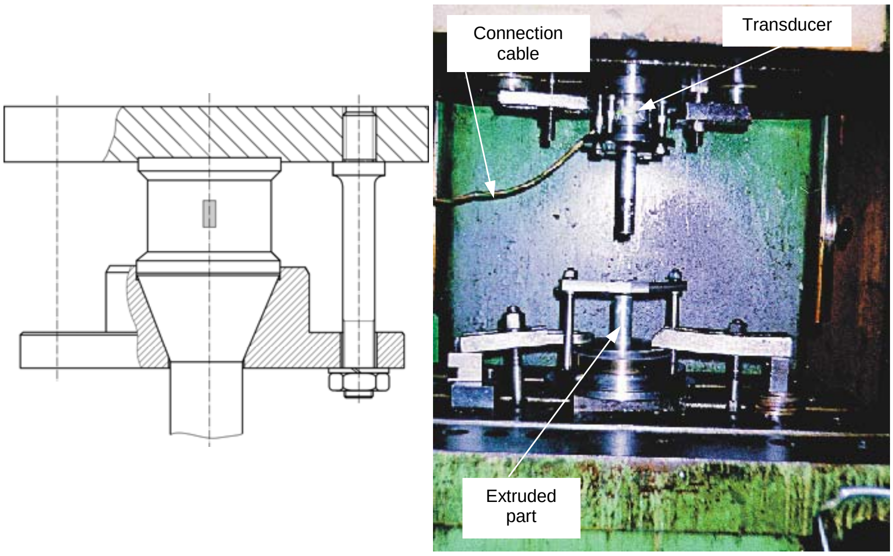


(a) (b)

Fig. 1. The scheme of transducer (a), and measuring principle (b).

For the measuring signal amplified, the amplifier HBM DMC 9012A with 24 measuring channels is used. Also, the HBM strain gages of the type 6/120LY11* with K-factor K=2,04 and the active length l = 9,57 mm are used. The measuring system ended with the Apple Macintosh computer with the BEAM software for analysis of experimental results, and the printer device.

The process of extrusion is performed on the hydraulic press with nominal force F=630 kN and the constant ram speed 15 mm/s. Assemble of the tool in working position and the drawing of the transducer position in tool is given in Figure 2.



(a) (b)

Fig. 2. The detail of extrusion tool with transducer (a) and the tool in working position (b).

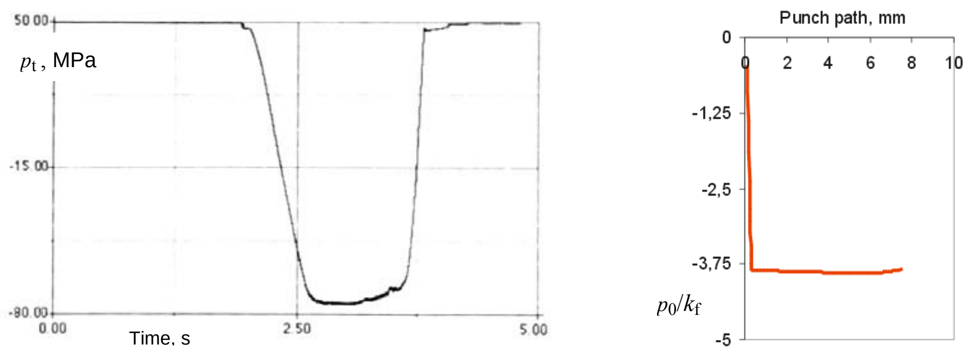
3. THE COMPARISON OF EXPERIMENTAL AND NUMERICAL RESULTS

After the experiment execution, the diagrams of working pressure variation with time are obtained. Some examples of extruded components with the different degree of deformations and punch shapes are given in Figure 3.

Fig. 3. Some extruded cans.

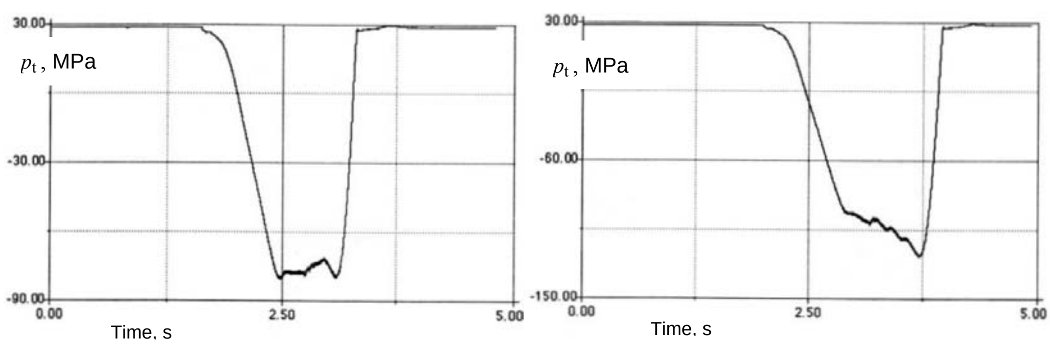
The typical pressure-times diagrams for the extrusion with flat, conical and spherical punch are given in Figure 4, Figure 5 and Figure 6 respectively. Note that the pressure given in Figs. 4, 5 and 6 are the pressure on the transducer p_t, and the extrusion pressure p_0 may be obtained by multiplying this pressure with the ratio D_t/D_0, where D_t is the transducer diameter.

The obtained pressure variation for the case of extrusion with flat punch and the degree of deformation ε = 89%, given in Figure 4a, are in good agreement with results obtained by FVM, Figure 4b. One can see that the extrusion pressure doesn't vary considerably in this case. This is not case for extrusion with conical and spherical punch, especially in the case of bigger degree of deformation, Figure 5 and Figure 6.



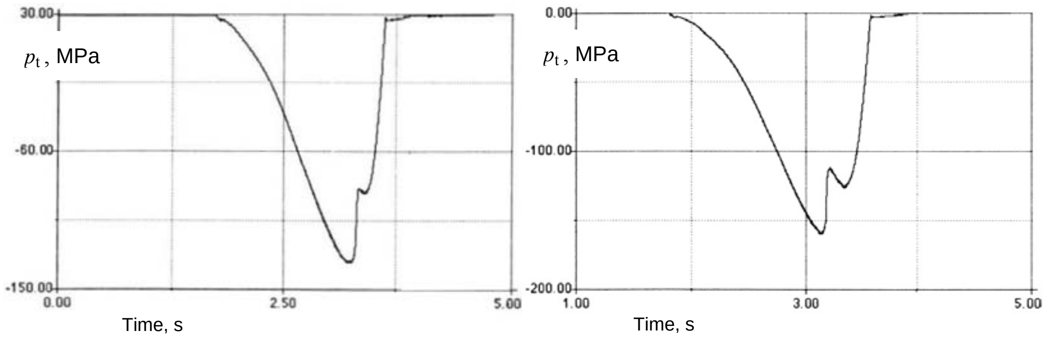
(a) Zn-stearate (b) Calculation by FVM

Fig. 4. The pressure – time diagram (a) and the p_0/k_f – punch path diagram (b), for the extrusion with flat punch and ε = 89%,.



(a) Zn-stearate (b) Zn-stearate+SAE90

Fig. 5. The pressure-time diagrams for the extrusion with conical punch and ε = 89%.



(a) ε = 85,7%, Zn-stearate+SAE90 (b) ε = 89%, Zn-stearate

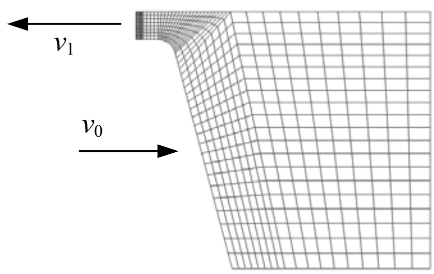
Fig. 6. The pressure – time diagrams for the extrusion with spherical punch.

In the numerical simulation by finite volume method, a rigid-plastic constitutive model is used to describe the material behavior. The elastic properties of material are neglected because they are small compared to the very large plastic deformations that occur during the process [5]. The Levy-Mises constitutive equations are used for the relation between the stress tensor and the strain-rate tensor.

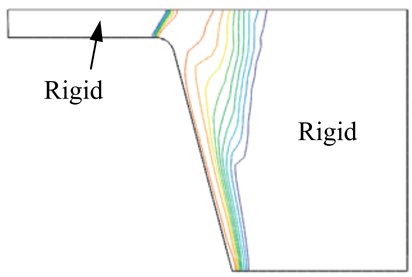
For the calculation, the Coulomb's friction model is used. The average friction factor on all contact surfaces was taken as μ=0,03. The calculation is done as a non-stationary, using Arbitrary Lagrange-Euler formulation (ALE), [8,9], firstly developed in fluid mechanic, and in the recent time, in the metal forming processes [11,12].

The examples of numerical meshes with 616 control volumes for the simulation of the backward extrusion with the conical punch and degree of deformation ε = 79,72% are given in Figure 7. The duration of real process is 0,35 s, and the punch during this period moves for Δx=5,25 mm. The number of time steps is 35, i.e. the used time step is 0,01 s.

(a) t=0 s, Δx=0 mm



(b) t=0,1 s, Δx=1,5 mm



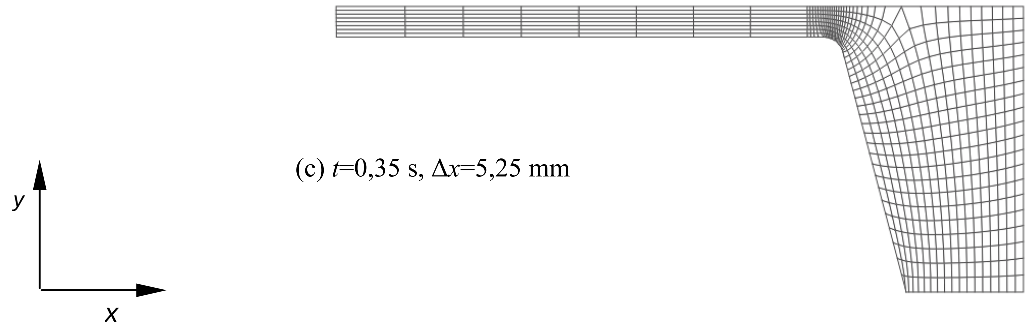
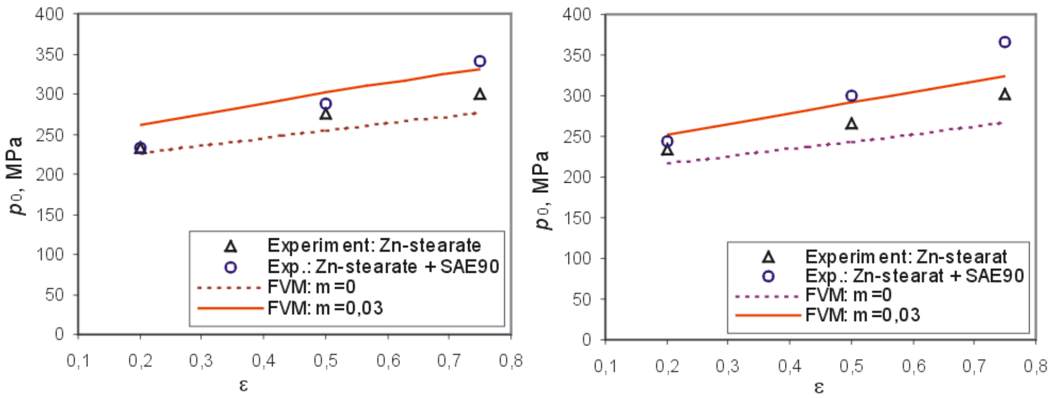


Fig. 7. The numerical grids for simulation of extrusion with conical punch in different time steps: (a) the initial grid, t = *0 s, Δ*x = *0, (b) the rigid-plastic zones distribution in* t = *0,35 s, and Δ*x = *1,5 mm, (c) the final grid after* t = *0,35 s and Δ*x = *5,25 mm.*

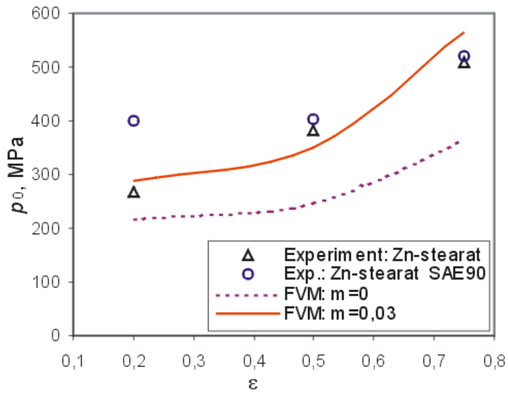
One can see on the Figures 6 that the extrusion pressure has decrease during the time and increase again by finishing of the deformation process. This variation is known as 'heat effect' that is appearing due to material properties changing (material softening), which is result of heat dissipation during deformation. This effect appears by increasing of degree of deformation and more often when the mixture of Zn-stearate and oil SAE90 is used as lubricant.

For the numerical simulation of this effect, it is necessary to have complete information about deformed material, i.e. the flow curve that is function of degree of deformation, strain rate and temperature i.e. $k_f = k_f(\varepsilon, \dot{\varepsilon}, T)$. Additionally, the complete information about friction factor (which is not constant in space and time) is also necessary. It is clear, that the numerical simulation and obtaining of curves like that given in Fig. 6. is, due to needed data, impossible. The used numerical method in every cases gives the approximately constant resulting pressure distribution in time, Fig. 4b.

The comparison between the experimental and calculated results for all punch shapes is given in Fig. 8. A good agreement is obtained. Some differences between numerical and experimental data exist in the case of extrusion by spherical punch. This may be due to the most intensive friction and material properties changing and non-valid information about friction distribution in space and time in the real process.



(a) Flat punch (b) Conical punch



(c) Spherical punch

Fig. 8. The comparison between experimental and calculated results.(a) flat punch, (b) conical punch and (c) spherical punch.

For the further comparison, the calculated results in the case of zero friction on all contact surfaces is also given in Figure 8. It can be seen that the friction has greatest influence on extrusion pressure in the case of extrusion by spherical punch. Also, comparing the frictional and non-frictional results, it is possible to conclude that the very good contact conditions are realized in the experiment.

4. CONCLUSION

The numerical simulation of the extrusion process has numerous advantages. It may be a powerful tool for the die designer and it is often treated as the universal support system in solving of metal forming technologies. But, the accuracy of the results of such simulation and their transfer onto the real processes depend highly upon the accuracy of input parameters. These parameters are primary material properties and the information about contact (boundary) conditions. The best way of verification is on real processes that can be expensive, time consuming, and sometimes, impossible.

An experimental analysis of variation of backward extrusion pressure shows a very big influence of thee lubricant on the process parameters. By increasing of the degree of deformation, the extrusion pressure variation in time is bigger. The experimentally obtained results are compared with the calculated, which are obtained by using the finite volume method, and the good coincidence is obtained. But, some effect, like the 'heat effect' cannot be simulated successfully.

5. REFERENCES

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MERENJE VARIJACIJE DEFORMACIONE SILE U PROCESU ISTISKIVANJA KORIŠĆENJEM MERNIH TRAKA

Hazim Bašić

REZIME

U radu je prikazana metoda merenja varijacije deformacione sile u procesu suprotnosmernog hladnog istiskivanja. Parametri procesa koji su bili varirani su: stepen deformacije (tri nivoa), oblik žiga (ravan, konični i sferični) i vrsta podmazivanja (cink stearat i mešavina cinkstearata sa uljem SAE 90). Za izračunavanje sile istiskivanja korišćen je metod konačnih zapremina (finite volume). Slaganje između izmerenih i izračunatih vrednosti sile bilo je veoma dobro.
Za merenje sile korišćene su merne trake HBM 6/120 LY11 sa K faktorom K=2,04 i aktivnom dužinom od l=9,57 mm. Trake su bile povezane u puniWheatsonov most, kako bi se eliminisao eventualni negativni uticaj ekscentričnog opterećenja. Signal sa mernih traka pojačavan je na 24-kanalnom pojačalu HBM DMC 9012A a zatim se obrada signala izvodila na Apple Macintosh računaru pomoću BEAM software-a.
Eksperiment je izveden na hidrauličnoj presi od 630 kM, sa konstantnom brzinom od 15mm/s.
Numerička simulacija procesa metodom konačnih zapremina izvršena je pod pretpostavkom kruto-plastičnog tela. Elastične deformacije su zanemarene obzirom da su one neznatne u odnosu na plastične. Levi-Misesove konstitutivne jednačine su korišćene za opis veze između napona i tenzora brzine deformacije. Coulombov zakon trenja (μ=0,03) je primenjen u proračunu. Eksperiment je ukazao na veliki uticaj vrste podmazivanja na promenu sile istiskivanja. Takođe se pokazalo da "toplotni efekat" nije mogao biti uspešno simuliran.