

SIMULATION OF THE EQUAL CHANNEL ANGULAR EXTRUSION TECHNOLOGY

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Abstract: This article shows the results of the simulation of the equal channel angular extrusion in parallel channels taking into account the radius of the channel conjugation.

KEYWORDS: EQUAL CHANNEL ANGULAR EXTRUSION, SHEAR STRAIN, RADIUS OF THE CHANNEL CONJUGATION, SPECIFIC PRESSING FORCE, INTERSECTION ANGLE OF THE CHANNELS

1. Introduction

Still in the early stages of the research channel angular extrusion proposed by V.M. Segal [1] as a way to achieve large strains workpieces without changing their shape cross-section, it was found that the unexpectedly small reduction in ductility is accompanied by a significant increase in strength. Cause of changes in the mechanical properties of metals is the ultrafine grinding grains to ultra small-grained state with a characteristic size of less than 1 micron.

Advance of the upper layers of the metal workpiece is the first shear deformation, and advance the lower layers - at the second shear deformation. At the same time the distortion of end sections of the workpiece minimizes.

Along with the traditional method of equal channel angular extrusion other schemes are used, for example the way channel angular extrusion in parallel channels designed by Ufa scientific school [2, 3].

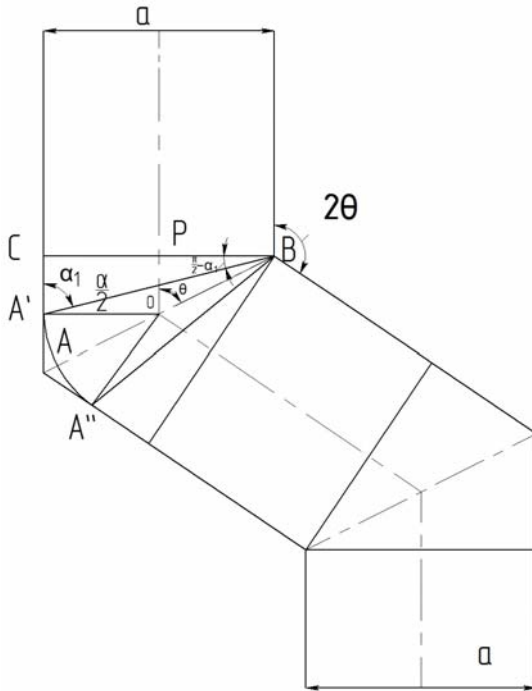


Fig.1 Plan of channel matrix

2. Prerequisites and means to solve the problems

According to the scheme (Fig. 1) implementation of a simple shift is in consecutive order in two areas in the deformation zone crossing channel matrices. After one cycle of treatment the value strain of the workpiece is $\epsilon \approx 2$, which reduces the number of passes required to obtain ultra small-grained structure in the semis.

Kinematics of flow and stress-strain state depends on the angle of intersection of channels 2θ and center distance of parallel channels Z [4]. You must not ignore the force parameters that affect performance stamping equipment and selection of hardware. The aim is determining the power process parameters of equal channel angular pressing in parallel channels (ECAPPC) with the radius of the interface channels. Attempts accounting radius interface

channels in the calculation of power parameters is taken for the limiting case of equal radius interface width of the channel [5, 6].

3. The solution of the problem

We divide on the blocks the area of plastic deformation of one of the centers. We consider the process of plastic deformation at ECAPPC for statistical analysis of the metal flow as a result of relative motion of rigid blocks 1, 2, 3, 4, in which a 5 - is incompressible zone (tool, Fig. 2).

Material is ideally rigid-plastic, for which the intensity of the stress is $\sigma_i = \sigma_s$ and constant of plasticity $k = \frac{\sigma_s}{\sqrt{3}}$. We accept the

assumption that the friction force is proportional to the resistance of deformation σ_s , the friction force is constant and independent of the stress state, the rate of deformation. Tangential stresses obey Siebel's law

$$\tau_k = 2mk = \frac{2m\sigma_s}{\sqrt{3}}, \quad (1)$$

where m - friction factor (from 0 to 0.5).

For the assumed decomposition of deformation zone in the hard blocks power balance equation of internal and external forces is given by [4]:

$$P \cdot av_1 = k(l_{12} \cdot v_{12} + l_{23} \cdot v_{23} + l_{34} \cdot v_{34} + l_{25} \cdot v_{25} + l_{35} \cdot v_{35}) + 4mk \left(\frac{a}{2} \operatorname{ctg} \theta \right) v_1, \quad (2)$$

where l_{ij} - length of the boundary of the adjacent blocks i, j ;

v_{ij} - rate of their relative movement;

According to Fig. 2a, we calculate the linear dimensions of the block boundaries for the lines discontinuity of velocity for the case when the radius of the interface channels is $R = A'O = \frac{a}{2}$.

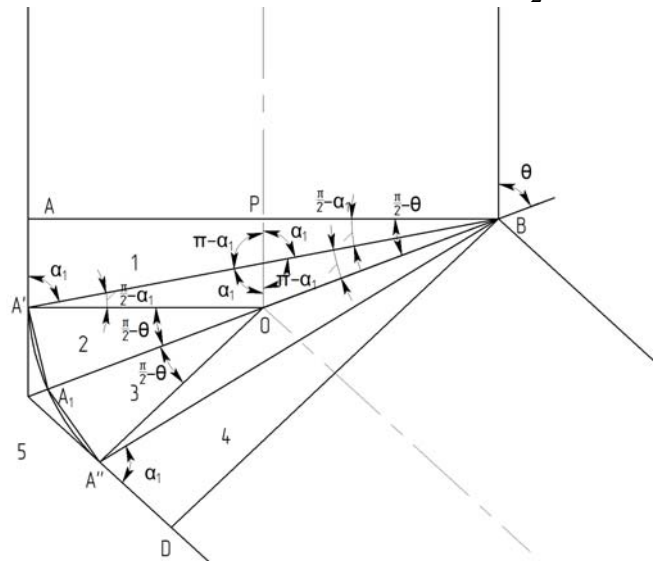


Fig. 2a Plan of partitioning of plastic area on the hard blocks

$$l_{12} = A'B = \frac{a\sqrt{3\sin^2\theta + 1}}{2\sin\theta}$$

$$l_{23} = \frac{a(1 + \sin\theta)}{2\sin\theta}$$

$$A_1C = OP = \frac{a}{2}\operatorname{ctg}\theta = A''D$$

$$l_{25} = l_{35} = \frac{a\sqrt{2}}{2}\sqrt{1 + \sin\theta}$$

Let us turn to Fig. 2b and calculate rates of the relative movement of blocks through the known rate of the tool V_1

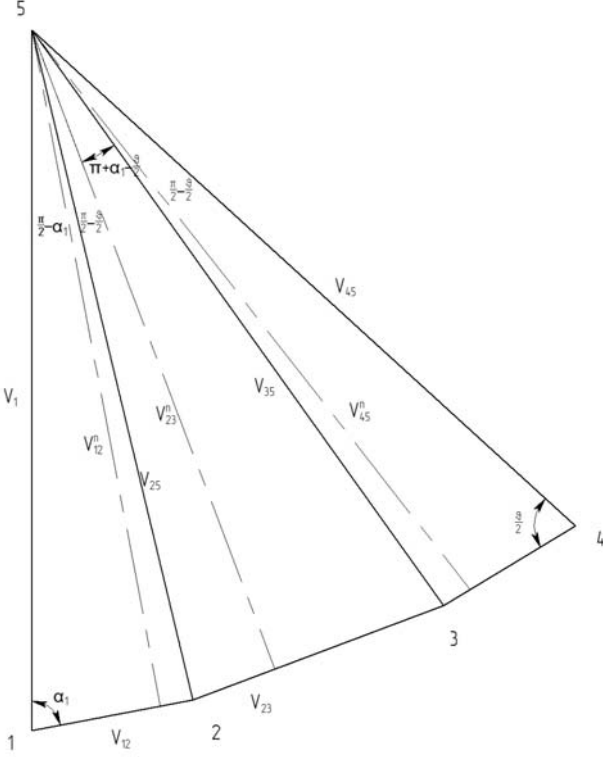


Fig. 2b Hodograph rate of travel

$$v_{12} = v_1 \left(\cos\theta - \sin\theta \cdot \operatorname{tg}\left(\frac{\pi}{4} + \frac{\theta}{2}\right) \right) = v_{34}$$

$$v_{12}^n = v_1 \frac{2\sin\theta}{\sqrt{3\sin^2\theta + 1}}$$

$$v_{25} = v_1 \sin\theta \cos\left(\frac{\pi}{4} - \frac{\theta}{2}\right) = v_{35}$$

$$v_{23} = v_1 \sin\theta \cos\left(\frac{\pi}{4} - \frac{\theta}{2}\right) \cdot \frac{1}{\cos\left(\frac{\pi}{4} + \frac{\theta}{2}\right)}$$

$$v_{23}^n = v_1 \sin\theta \cos\left(\frac{\pi}{4} - \frac{\theta}{2}\right) \sin\frac{\theta}{2}$$

After substituting in equation (2) of the known components and dividing by $v_1 k$, we get the relative specific effect in the form of:

$$\begin{aligned} \frac{p}{k} = & \sqrt{3\sin^2\theta + 1} \cdot \left(\operatorname{ctg}\theta - \operatorname{tg}\left(\frac{\pi}{4} + \frac{\theta}{2}\right) \right) + \\ & + (1 + \sin\theta) \frac{\cos\left(\frac{\pi}{4} - \frac{\theta}{2}\right)}{\cos\left(\frac{\pi}{4} + \frac{\theta}{2}\right)} + \sqrt{2}\sqrt{\sin^2\theta} \cdot \sin\theta \times \\ & \times \cos\left(\frac{\pi}{4} - \frac{\theta}{2}\right) + 2m\operatorname{ctg}\theta. \end{aligned} \quad (3)$$

The total shear deformation is defined [5]:

$$\gamma = \gamma_{12} + \gamma_{23} + \gamma_{34} = 2\gamma_{12} + \gamma_{23}, \text{ где } \gamma_{ij} = \frac{v_{ij}}{v_{ij}^n}$$

$$\gamma_{12} = \frac{v_1 \left(\cos\theta - \sin\theta \cdot \operatorname{tg}\left(\frac{\pi}{4} + \frac{\theta}{2}\right) \right)}{v_1 \sin\theta} =$$

$$= \frac{\left(\cos\theta - \sin\theta \cdot \operatorname{tg}\left(\frac{\pi}{4} + \frac{\theta}{2}\right) \right) \cdot \sqrt{3\sin^2\theta + 1}}{2\sin\theta}$$

$$\gamma_{23} = \frac{v_1 \cdot \sin\theta \cdot \cos\left(\frac{\pi}{4} - \frac{\theta}{2}\right)}{\cos\left(\frac{\pi}{4} + \frac{\theta}{2}\right) \cdot v_1 \sin\theta \cdot \cos\left(\frac{\pi}{4} - \frac{\theta}{2}\right) \cdot \sin\frac{\theta}{2}} =$$

$$= \frac{1}{\sin\frac{\theta}{2} \cos\left(\frac{\pi}{4} + \frac{\theta}{2}\right)}$$

$$\gamma = \frac{\left(\cos\theta - \sin\theta \cdot \operatorname{tg}\left(\frac{\pi}{4} + \frac{\theta}{2}\right) \right) \cdot \sqrt{3\sin^2\theta + 1}}{\sin\theta} +$$

$$+ \frac{1}{\sin\frac{\theta}{2} \cdot \cos\left(\frac{\pi}{4} + \frac{\theta}{2}\right)} \quad (4)$$

$$\varepsilon = \frac{\gamma}{\sqrt{3}} = \frac{1}{\sqrt{3}} \left[\frac{\left(\cos\theta - \sin\theta \cdot \operatorname{tg}\left(\frac{\pi}{4} + \frac{\theta}{2}\right) \right) \sqrt{3\sin^2\theta + 1}}{\sin\theta} + \frac{1}{\sin\frac{\theta}{2} \cos\left(\frac{\pi}{4} + \frac{\theta}{2}\right)} \right]$$

4. Results

In Fig. 3 we show a plot of the specific force of the friction factor m for different angles of intersection of channels θ . As the angle of intersection of channel specific force is reduced, and the more the value of the friction factor, force deformation is the more specific.

Research the function (3) on the extremum allowed to plot function $f'(\theta)$ changes, depending on the angle of intersection of channels. Reduction θ leads to the asymptotically approximation of the function to 0. Given the range of the shear strain γ (Fig. 4), we can

say that, in practice, the values of angles should be $\frac{1}{2}\theta$ in the

range $50^\circ \leq \frac{1}{2}\theta \leq 65^\circ$. At an angle $\frac{1}{2}\theta = 65^\circ$ value of the total shear

strain is $\gamma = 2$, at a value is $\frac{1}{2}\theta = 50^\circ$ is $\gamma = 7.5$. It should be

noted that the value of the derivative $f'(\theta) \approx 0$ at the angle of the recommended range.

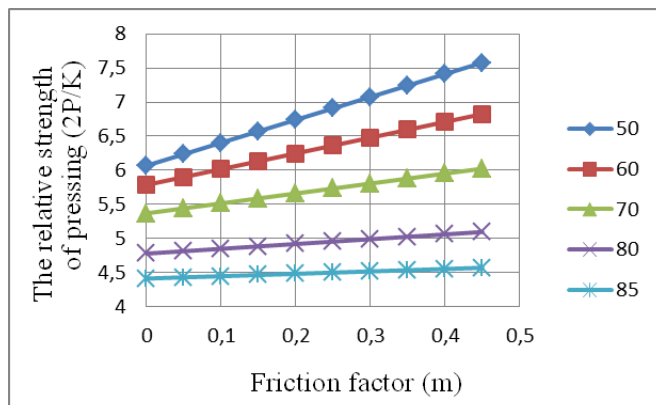


Fig. 3. Dependence of the specific pressing force of friction factor at different angles of intersection of channels $\frac{\theta}{2}$.

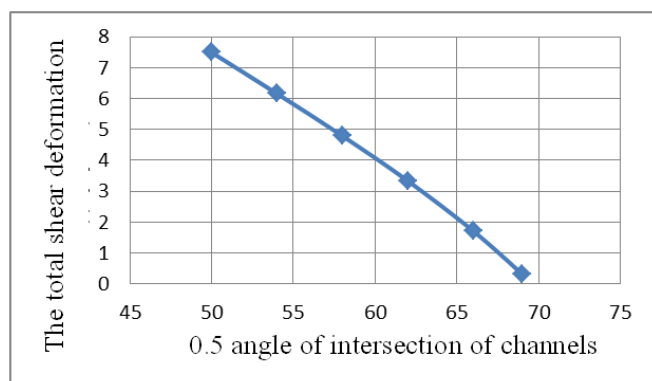


Fig. 4. Change of shear strain.

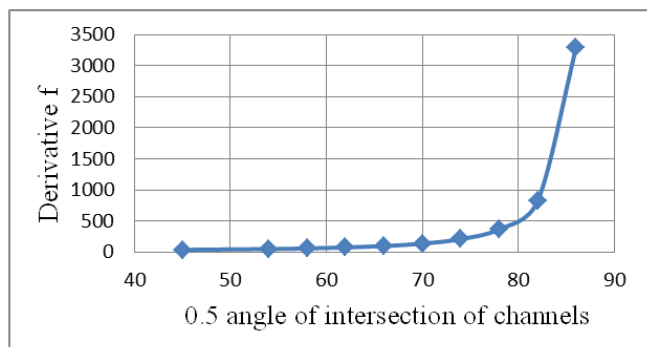


Fig. 5. Research of the function (3) of extremum.

5. Resume

A theoretical research of power parameters equal channel angular pressing in parallel channels using hard blocks allowed to determine the nature of changes the specific strength of the friction factor for different angles of intersection of channels, as well as determine the effect of the value of the angle of intersection of channels in the total amount of shear deformation.

Recommend the range of variation of the angle of intersection of channels in which the specific pressing forces close to the minimum.

6. Literature

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