Journal for Technology of Plasticity, Vol. 27 (2002), Number 1-2

EFFECT OF LUBRICATION ON THE STRAIN RATE DISTRIBUTION IN EXTRUDED MATERIAL

Leo Gusel, Miran Brezočnik
Faculty of Mechanical Engineering, Maribor, Slovenia

ABSTRACT

The visioplasticity method is used to find the complete stress and strain rate distribution in the deformation zone, according to the deformation grid lines marked on the surface of the workpiece. From the experimental data (the values of the flow function for the extrusion), the velocity, strain rate and stress fields can be calculated by the finite-difference method from the stream function, equilibrium and plasticity equations.

In this article strain rate components distribution in forward extruded specimens of copper alloy is analysed using the visioplasticity method. Comparison are made between strain rate distribution of the specimens extruded with two different coefficients of friction.

1. INTRODUCTION

Although the theory of plasticity provides a sufficient number of independent equations for defining the mechanism of plastic deformation , it is not possible to obtain a complete solution for a general forming problems without simplification and approximations in the deforming mechanism. A number of approximate methods has been developed for the analysis of metal forming problems.

Among them, the visioplasticity method gives the most realistic solution to various forming problems /1/. Furthermore, this method can be used as a means of examining the approximations of other solutions.

The visioplasticity method was developed by Thomsen /2/ and consists of obtaining the velocity field experimentally and calculating the complete strain rate, strain, and stress fields by considering the equilibrium and plastic equations.

2. CALCULATION OF THE STRAIN RATE BY VISIOPLASTICITY METHOD

Visioplasticity is a method of obtaining information on material flow by using experimentally determined displacement of velocity fields. Mostly square grids composed of line nets are used on longitudinally cut sections in bulk forming. The grid can be inscribed on the specimen by mechanical means of etching, by photographic methods or pressing /3/. The grid lines must be thin and sharp and the grid mesh should not split off, which would make the measurements difficult.
The material flow can be determined by comparing undeformed and deformed grids.

For steady-state flow problems in which the flow field does not vary with respect to time, it is possible to introduce a flow function θ by measuring the coordinates of the points located along grid lines after steady-state conditions are reached. In the steady-state axi -symmetric extrusion, the velocity field can be expressed by the flow function θ (r, z) as follows /1/:

$$v_z = \frac{1}{r} \cdot \frac{\partial \theta}{\partial r} \quad ; \quad v_r = -\frac{1}{r} \cdot \frac{\partial \theta}{\partial z} \tag{2.1}$$

where v_z and v_r are the velocity components in the z- and r- directions.

When the velocity components u and v are known at all points in the deformation zone, the strain rate components can be obtained according to:

$$\overset{\bullet}{\varepsilon}_r = \frac{\partial v_r}{\partial r} \quad ; \quad \overset{\bullet}{\varepsilon}_\vartheta = \frac{v_r}{r} \quad ; \quad \overset{\bullet}{\varepsilon}_z = \frac{\partial v_z}{\partial z} \quad ; \quad \overset{\bullet}{\varepsilon}_{rz} = \frac{1}{2} \cdot \left(\frac{\partial v_r}{\partial z} + \frac{\partial v_z}{\partial r} \right) \tag{2.2}$$

The effective strain rate is then calculated from its definition:

$$\overset{\bullet}{\varphi}_e = \sqrt{\frac{2}{3}\left(\dot{\varepsilon}_r^2 + \dot{\varepsilon}_\vartheta^2 + \dot{\varepsilon}_z^2 + 2\dot{\varepsilon}_{rz}^2\right)} \tag{2.3}$$

The total effective strain can be evaluated by numerical integration of effective strain rate along a flow line with respect to time:

$$\varphi_e = \int_0^{t1} \overset{\bullet}{\varphi}_e \cdot dt \tag{2.4}$$

where t_l is the time required for a point to be displaced along a flow line. Strain rate components can also be written as follows:

$$\begin{aligned} \dot{\varepsilon}_r &= \lambda \cdot (\sigma_r - \sigma_m) \\ \dot{\varepsilon}_z &= \lambda \cdot (\sigma_z - \sigma_m) \\ \dot{\varepsilon}_\vartheta &= \lambda \cdot (\sigma_\vartheta - \sigma_m) \\ \dot{\varepsilon}_{rz} &= \lambda \cdot \tau_{rz} \end{aligned} \qquad (2.5)$$

where: $$\sigma_m = \frac{\sigma_r + \sigma_\vartheta + \sigma_z}{3} \qquad (2.6)$$

$$\lambda = \frac{3 \cdot \varphi_e}{2 \cdot \sigma_f} = \text{coefficient of proportionality} \qquad (2.7)$$

σ_f = flow stress

3. EXPERIMENTAL WORK

In the experimental investigation rods of special copper alloy CuCrZr were used. The initial dimensions of specimens were Φ22 mm x 32 mm. 1 mm square grids were scribed on the meridian plane of one-half of a split specimen. The specimen was extruded trough a conical die having a 22,5 ^{0} half-cone angle and a 73 % reduction in area. Two different lubricants were used with different coefficient of friction ($\mu = 0,05$ and $\mu = 0,11$). Coefficient of friction for both lubricants were determined in ring test. The forward extrusion was carried out at a punch speed of 12 mm/s and the extrusion process was stopped when a sufficient length of specimen was extruded to ensure the establishment of a steady-state motion. The deformed grid after forward extrusion is shown in Fig.1.

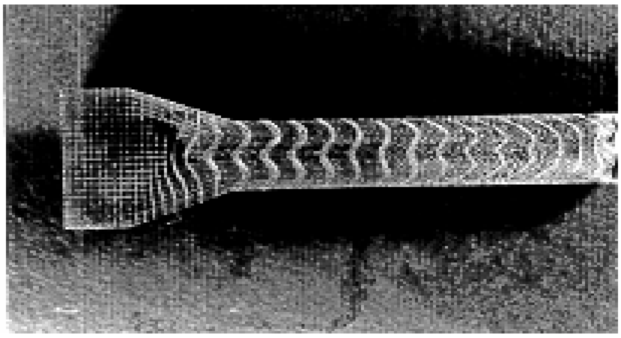


Figure 1: Deformed grid on the specimen after forward extrusion
(μ =0,05, v_{punch} = 12mm/s, R_{area} =73 %).

3. RESULTS AND DISCUSION

The position of every node of the deformed grid after forward extrusion (Fig.1) was measured by measuring microscope. These values were put in the special computer program for visioplasticity, developed in laboratory for material forming of Faculty of Mechanical Engineering Maribor, as well as every node of initial grid, distance between initial grid nodes, flow curve of the material to be formed and the punch speed.

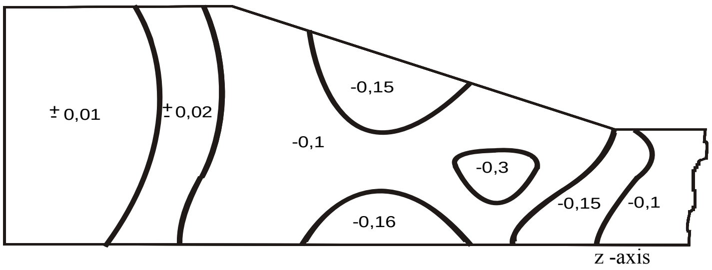
By measuring the difference between initial grid nodes and nodes on the deformed grid it is possible to calculate velocity of every point in r- and z- direction. The strain rates can be obtained from equations (2.2) to (2.7). The results of the distribution of strain rate components in the deforming region of the specimens are presented in diagrams in Fig. 2 to Fig. 5.

Figure 2 shows the contours of strain rate in radial direction ($\dot{\varepsilon}_r$). The largest value is reached at the end of the deforming zone while the smallest value is near the entrance. There is no significant difference in the contours when lubricant with coefficient of friction $\mu = 0{,}11$ was used except on the cone line where the strain rate for coefficient of friction $\mu = 0{,}11$ is 0,20 s^{-1} comparing to $\dot{\varepsilon}_r = 0{,}15 s^{-1}$ for $\mu = 0{,}05$.

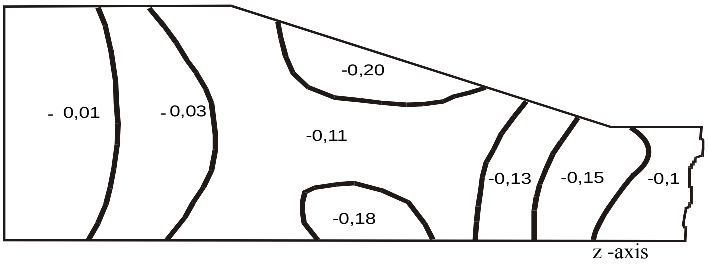
The largest axial strain rate ($\dot{\varepsilon}_z$) can be found at the exit of the deforming zone (Figure 3) and the effect of the lubricant on strain rate is noticeable on the cone line and on the exit of the deformation zone where the values are a bit higher for coefficient of friction $\mu = 0{,}11$.

Largest shear strain rate ($\dot{\varepsilon}_{rz}$) is at the outer side of the deforming zone exit (Figure 4). The difference of the strain rate values measured by two different lubricant coefficient of friction is from 0% (at the entering points) to nearly 15% on the exit of the deformation zone. There is also a slender discrepancy in shear strain rate contours shape for two different lubricators.

With better coefficient of friction ($\mu = 0{,}05$), lower radial, axial and shear strain rate values were reached over the whole extruded specimen.

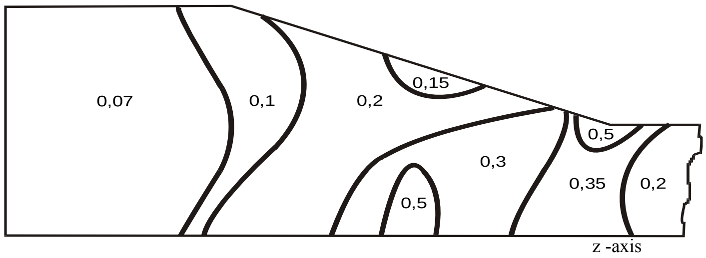


a) *coefficient of friction* $\mu = 0,05$

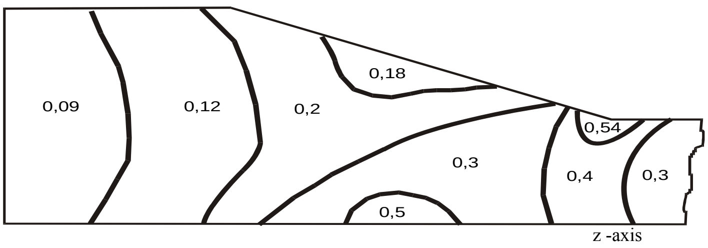


b) *coefficient of friction* $\mu = 0,11$

Figure 2: The contours of radial strain rate $\dot{\varepsilon}r$ (s^{-1}) (v_{punch} = 12 mm/s, R_{area} = 73%)

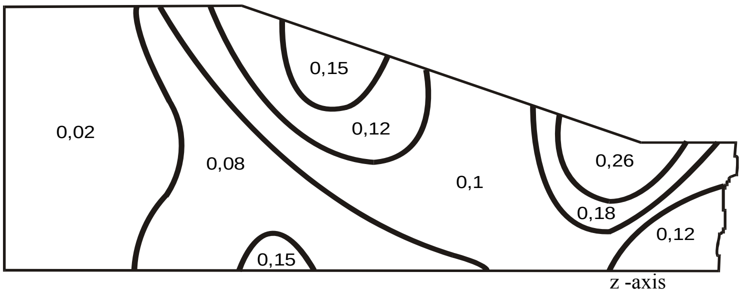


a) *coefficient of friction* $\mu = 0,05$

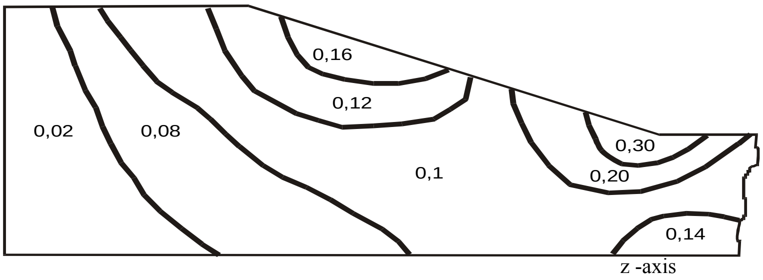


b) *coefficient of friction* $\mu = 0,11$

Figure 3: The contours of axial strain rate $\dot{\varepsilon}_z$ (s^{-1}) (v_{punch} = 12 mm/s, R_{area}= 73%)



a) *coefficient of friction* $\mu = 0,05$



b) *coefficient of friction* $\mu = 0,11$

Figure 4: The contours of shear strain rate $\dot{\varepsilon}_{rz}$ (s^{-1}) $(v_{punch} = 12$ *mm/s,* $R_{area} = 73\%)$

4. CONCLUSION

The choice of the right lubricant, its proper application and its influence on wear, forming force, friction, temperature, material and geometric properties is very important. In this article we've examined the effect of the lubricant on strain rate values in forward extruded copper alloy. Strain rate was determined by using visioplasticity method which is very useful in providing a detailed analysis of the distribution of the major field variables such as effective strain , strain rates and stress in any section within the plastically deforming region /4/.

Knowing the values of strain rates in plastic region of the material is very important for calculating stresses and prediction of specimen quality. The experiments have showed that the influence of the lubricant (with coefficient of friction $\mu = 0,05$ and 0,11) on the strain rate distribution in extruded specimens is slender in most measured regions, but can also be of greater importance in some critical regions such as cone line of the specimen and exit of the deforming zone .

4. REFERENCES

[1] Lange K.: Handbook of Metal Forming, McGraw Hill Book, New York 1991

[2] E.G. Thomsen: A new approach to metal - forming problems, ASME, 77 (1955) pg. 515;

[3] J.P.Wang, J.J. Wang, Y.H. Tsai: The dynamic analysis of visioplasticity for the plane upsetting process by the flow-function elemental technique, Journal of Materials Processing Technology 63,pgs.: 738-743, Elsevier 1997

[4] J.P. Wang, Y.T. Lin, Y.H. Tsai: The finite flow-line regions approach to visioplasticity in plane –strain extrusion, Journal of Materials Processing Technology 58, pgs. 308-313, Elsevier 1996

[5] P. Leš: Povezava med deformacijami, deformacijskimi hitrostmi in napetostmi v plastičnem področju za izotropne in nestisljive materiale, Strojniški vestnik 7-9, str. 165-168, LJ 1983

[6] W.R.D. Wilson: Tribology in Cold Metal Forming, Journal of Manufacturing Science and Engineering Vol. 119, November 1997, pp. 695 – 698;

UTICAJ PODMAZIVANJA NA RASPORED BRZINE DEFORMACIJE KOD ISTISKIVANJA

Leo Gusel, Miran Brezočnik

REZIME

Iako teorija plastičnosti pruža mogućnosti da se definiše proces plastičnog deformisanja, kompletno rešenje u opštem slučaju nije moguće dobiti bez uvođenja određenih pojednostavljenja i pretpostavki. Na takvim osnovama razvijan je jedan određen broj metoda analize procesa deformisanja. Jedna od najpoznatijih metoda u tom kontekstu je vizioplastičnost. Ta metoda često je korišćena od raznih autora. Metoda bazira na dobijanju brzinskog polja eksperimentalnim putem, a zatim se – korišćenjem odgovarajućih teoretskih postulata – dobija polje brzine deformacija i polje napona. Ovaj rad ilustruje primenu metode vizioplastičnosti u određivanju brzine deformacije u procesu istosmernog istiskivanja pripremaka od bakra. Varirana je veličina trenja (način podmazivanja).

U eksperimentu je primenjena CuCrZn legura. Pripremak je bio dimenzija: ϕ22x32mm. Na meridijalnoj ravni pripremka nanesena je mreža razmaka 1mm. Polu-ugao konusa matrice je 22,5^o a stepen redukcije 73%. Koeficijent trenja za dva razičita načina podmazivanja bio je određen u eksperimentu sabijanja prstena. Brzina žiga kod istosmernog istiskivanja bila je 12mm/s a proces je izvođen sve do trenutka kada se uspostavilo monotono deformisanje. Merenje mreže pre i nakon deformisanja vršeno je specijalnim mikroskopom. Specijalnim postupkom koji je razvijen na Univerzitetu Maribor izvršena je analiza deformisane mreže.

Eksperiment je pokazao da je uticaj trenja na raspored brzine deformacije (μ=0,05 i μ=0,11) relativno mali ali da u određenim uslovima i određenim zonama obratka (npr. konus, izlaz materijala iz zone deformisanja) može biti signifikantan.