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DETERMINATION OF KINEMATICS STATE BY PHYSICAL DISCRETIZATON METHOD AT BULK METAL FORMING

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ABSTRACT

Kinematic state of a working-piece at bulk metal forming of axial-symmetrical pieces has been determined in this paper. Strain rate tensor components are determined by the known theory, as partial strain rate component devivations. Displacement rate points of meridial section are basic for kinematic state determination. As non-stationary deformation process is concerned, it is necessary to determine initial and final points displacements when a relatively short observed interval is constant. Point displacements are determined by known geometry of groove-like plates before deformation and measured coordinate points out of digitalized picture of meridial section after deformation. Measure meuts are done by setting the lines with sufficient number of points. At the end, a graphic interpretation of the obtained results is given, their analysis and conclusions are made.

Key words: Bulk Metal Forming, Open Die, Finite Element Method (FEM), Deformation, Strain, Strain Rate, Displacement, Displacement Rate, Forming Velocity.

1. INTRODUCTION

The importance of knowing the kinematic state of a working-piece in deformation process is pointed out by a hypothesis on similarity and coaxiality of deviators of stress tensor and strain rate tensor growth, being the base of Levy-Mises's theory of plastic yield [1].

Determining kinematic state is a quantitative determination of kinematic parameters in the form of components of strain rate tensor in all the points of the piece section. To reach the research goal, appropiate pieces were developed. After several trials, more or less successful ones, there resulted the idea of making pieces in segments of groove-plate forms. Plate grooves practically represent finite elements physical discreeted, and this method is called Physical Discretization Method (PDM).

By a suitable mechanical and chemical forming after deformation, it is possible to get a deformed image of meridial section. First, a part of the piece till its symmetry axis, i.e. meridial section is removed by cutting. Then the surface is finely polished and chemically immersed into NaOH solution, after which deformed contours of groove plates become visible by a naked eye. The section is scanned and its digital version is obtained, being suitable for further computarization.

2. STRAIN RATES

To define strain rate displacement velocity is defined first as an expression of time displacement. Strain rate, in its general sense, represents the expression of time forming, or the ratio of strain rate of two pints displacement to the distance of this points, when the distance tends to be zero.

For axis-symmetrical stress state of strain rate tensor components in cylindrical coordinate system are [2]:

$$\left.\begin{aligned} \dot{\varepsilon}_r &= \frac{\partial v_r}{\partial r} & \dot{\gamma}_{r\theta} &= 0 \\ \dot{\varepsilon}_\theta &= \frac{v_r}{r} & \dot{\gamma}_{\theta z} &= 0 \\ \dot{\varepsilon}_z &= \frac{\partial v_z}{\partial z} & \dot{\gamma}_{zr} &= \frac{\partial v_r}{\partial z} + \frac{\partial v_z}{\partial r} \end{aligned}\right\} \tag{1}$$

Effective strain rate or intensity strain rate is a quantitative velocity change measure, expressed by [6]:

$$\dot{\varepsilon}_e = \frac{2}{\sqrt{3}}\sqrt{I_2(T_{\dot{\varepsilon}})} = \frac{\sqrt{2}}{3}\sqrt{(\dot{\varepsilon}_r - \dot{\varepsilon}_\theta)^2 + (\dot{\varepsilon}_\theta - \dot{\varepsilon}_z)^2 + (\dot{\varepsilon}_r - \dot{\varepsilon}_z)^2 + \frac{3}{2}\dot{\gamma}_{rz}^2} \,. \tag{2}$$

With unsteady processes such as bulk forming at open dies, kinematics and stress fields in an immovable space point where the forming originates are changed in the course of time. In such processes, an analysis of a forming growth can not illustrate kinematics and stress fields during the whole process, only the observed growth can be clear. Thus, it is necessary to determine an interval (step), at the end of which the stress state in the working piece volume could be determined.

Kinematics field is found by virtue of the known parameters of meridial cross-section point displacement and interval duration. Displacement velocity components are expressed by:

$$\left.\begin{aligned} v_r &= \frac{r_0 - r}{\Delta t} = \frac{\Delta r}{\Delta t} \\ v_z &= \frac{z_0 - z}{\Delta t} = \frac{\Delta z}{\Delta t} \end{aligned}\right\} . \tag{3}$$

The hypothesis for such a velocity determination is the constant forming velocity.

If you know the kinematics field, i.e. displacement velocity arrangement, it is possible to determine forming velocities to the cross-section meridial points (1), where partial derivates are determined for sufficiently small values of Δr, Δz and Δt, using these expressions [3]:

$$\left.\begin{aligned} \frac{\partial v_r}{\partial r} &= \frac{\Delta v_r}{\Delta r} \\ \frac{\partial v_z}{\partial z} &= \frac{\Delta v_z}{\Delta z} \\ \frac{\partial v_r}{\partial z} + \frac{\partial v_z}{\partial r} &= \frac{\Delta v_r}{\Delta z} + \frac{\Delta v_z}{\Delta r} \end{aligned}\right\} . \tag{4}$$

3. EXPERIMENTAL RESEARCHES

There have been adopted two levels of height from the upper side and one level of height from the low side of the die plane [4,5,6].

Research works are carried out on a real material in laboratory conditions and are adjusted in the way to be as much similar to real (production) conditions being present in direct industrial environment. As the investigated material there has been used an aluminum alloy AlMgSi0,5, which is very often used in processes of bulk metal forming, above all in extrusion processes and bulk metal forming in open dies. Experiment is carried out at temperatures of hot forming of the mentioned alloy, namely at t=440 [°C]. Deformation is realized by constant deformation velocity: v=2 [mm/s]. Process is carried out by graphite grease lubrication, being applied in production conditions.

To determine kinematics state, compression of two working-pieces of h_{va}=3 [mm] wreath height and final h_{vb}=h_v=1 [mm] is done. An optimal forming interval at the end of forming process for tool stroke growth Δz=2 [mm] is chosen. These values are ensured by non-deformable steel rings. Otherwise, it is necessary for this interval to be little enough to maintain a real state of displacement velocities, but not too much little as to avoid the influence of anisotropy forming. The parameters at the end of the interval observed are marked with index **b**, whereas initial one is marked with **a**.

The process of preparing cross-section working-piece surface, and the image digitalization of deformed mesh in the meridial cross-section are described in the introductory part and papers [4,5]. The treated surface of the meridial cross-section with initial and final radial and axial lines are given in Fig.1.-Fig.4.

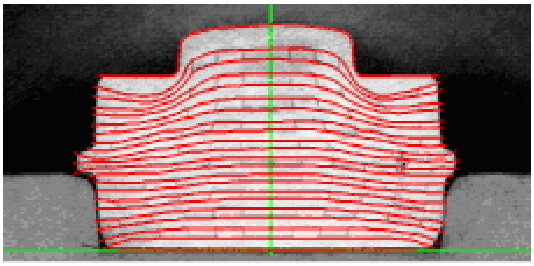

Figure 1. Initial interval radial lines

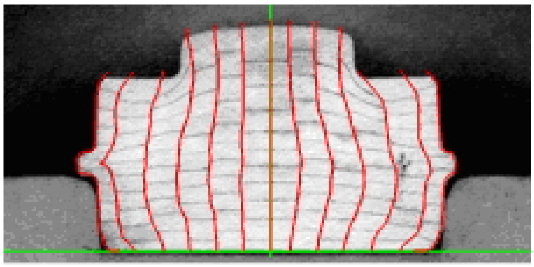

Figure 2. Initial interval axial lines

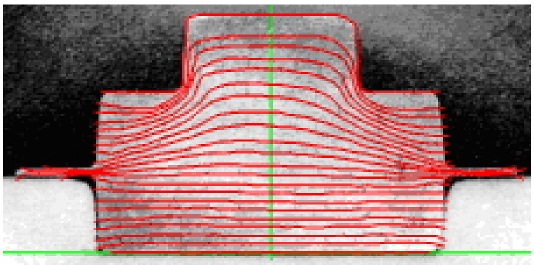

Figure 3. Final interval radial lines

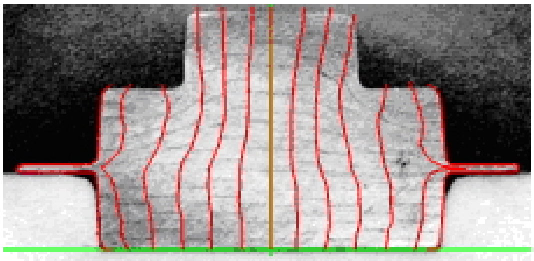

Figure 4. Final interval axial lines

4. RESULT PROCESSING

A program for complete kinematics analysis is made in MATLAB, input data are the values of coordinate points of deformed both radial and axial mesh. This program automatically determines node points of the deformed mesh, namely cross-section points of the deformed radial and axial lines, i.e. points whose displacement is determined.

The displacement growth in the node points of deformed mesh is determined as a displacement difference at the beginning and end of the observed interval:

$$\left.\begin{aligned} \Delta u_r &= u_{rb} - u_{ra} = r_{pb} - r_{pa} = \Delta r \\ \Delta u_z &= u_{zb} - u_{za} = z_{pb} - z_{pa} = \Delta z \end{aligned}\right\}. \tag{5}$$

By expression (3) it is possible to determine displacement velocities in the node points of the deformed mesh. Displacement velocity values in other points are approximated by the cube interpolation, thus a continual displacement velocity function in the meridial plane of the working-piece in function of radius and height coordinates are practically are obtained.

For the known displacement velocities of cross-section points, it is possible to determine partial expressions of velocity displacements per radius and height (4), to obtain forming velocities (1). The tangential strain rate component is not determined by partial derivate of displacement, the division result of radial displacement velocity and radius (1). Effective strain rate is obtained by expression (2).

Using cube interpolation radial, axial, tangential and shear components of strain rates and effective strain rate whose change in the meridial cross-section of the working-piece are given in the for of 3D diagrams in the function of radius and height of the working-piece in Fig.5.-Fig.9

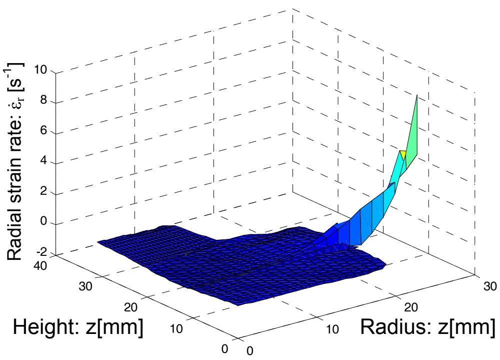

Figure 5. Radial strain rate

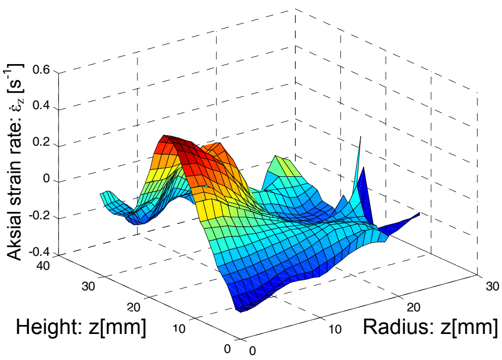

Figure 6. Aksial strai rate

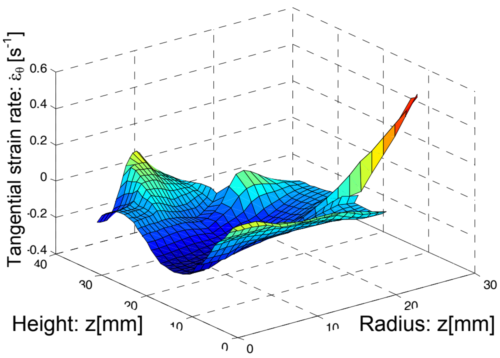

Figure 7. Tangential strain rate

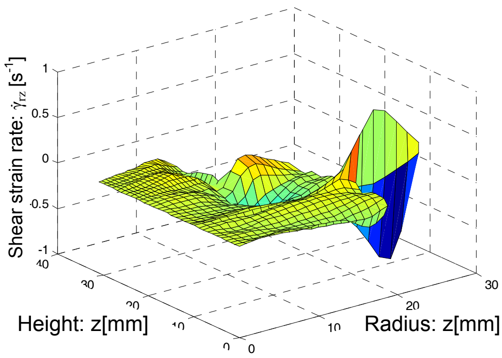

Figure 8. Shear strain rate

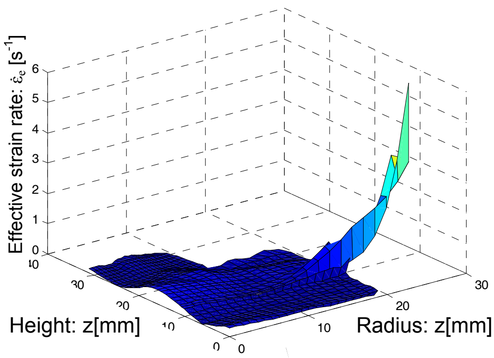

Figure 9. Effective strain rate

5. CONCLUSION

Using the Physical Discretization Method, it is possible to successfully obtain all the components of strain rates tensor and effective determination of meridial cross-section of axis-symmetrical working-piece formed in open dies.

With all components of strain rates, a zone is discreeted clearly and it corresponds to the inner part of the die and wreath zone.

Radial and effective strain rates have an equal, very low absolute value in die zone whereas their extreme value is of the same size order and is in the end of the wreath. Tangential and axial strain rates have a less extreme value of the given components and are at the end of the wreath.

With shear strain rate extreme values are obtained for the middle wreath zone.

An expressive difference in the values of strain rates components in the die and wreath zones is due to the observing of final forming process when the material has filled a complete die engraving, which is not deformed any longer, if not distinguished in the wreath.

6. REFERENCES

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