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KINEMATICS OF FLOW AND STRUCTURE FORMATION OF A METAL UNDER SEVERE PLASTIC DEFORMATION

Methods of severe plastic deformation are applied to processing of ultrafine-grained, in particular, nanocrystalline bulk materials

The efficiency of strain mechanical refinement provided by such methods is attributed to their kinematic features affecting value and modes of deformation important for nanocrystalline materials. The equal-angular channel pressing was considered in order to estimate the role of shear and rotation deformation components of structure transformation and their contribution to the strain value of the samples.

Three versions of evaluation are used to calculate the strain value of a mass point (particle) during its movement along specified strain paths. In the first version, a strain path is selected according to M. Segal and corresponds to the scheme of simple shear. In the second version, it is in the form of current flow in a strongly curved (bent) deformation core. In the third version, physically substantiated path of mass transfer has been selected in accordance with G. Lagrange concept. According to G. Freidel, an involute curve occurs in a bent zone of such a path.

It has been shown that in the case of the first version, there occurs a singular strain rate growth that prevents evaluation of accumulated strain in situ in a mass point at its movement along the strain path. Moreover, such conception does not agree with experiments since after ECAP, no features of structure and phase transformation typical to deformations performed at high strain rates and values are observed in metals. The strain value was evaluated using well known equations derived by comparing geometric characteristics of the initial mass point sample with the transformed mass point image after shear deformation. The value of the accumulated strain in the mass point made by the second version is half of that in the first case.

The value of the accumulated strain calculated by the third version is higher than in the first case by almost twice. In this case, the contribution of both rotation and shear strain components were taken into account as well as interfragment shear contribution.

The analysis of strain values of ECAP calculated by the mentioned three versions allows concluding that the most plausible strain value is determined by the third version. In this case the strain path agreed with notions of continuous systems relating large deformations. Moreover, the kinematics of mass point flow by the third version correlates with the transformation of structure resulting in formation of microbands and the role of linear crystal lattice defects in deformation and structure formation (in particular, disclinations responsible for rotation strain component and the accumulation of angular misorientations of forming areas of disorientation).

Keywords: mass point, strain path and value, rotation and shear strain component, non-monotonic deformation, distortion, banded structures, microbands

Fig. 1. Deformation scheme at ECAP by the variant 1. The material point before the shift is labeled as *abcd* square, and that after the shift is labeled as $a'b'c'd'$ parallelogram

Fig. 2. Deformation scheme at ECAP by variant 2. Hatched area is the stagnation zone

Fig. 3. Deformation scheme at ECAP by variant 3. The field velocity of material point M in deformation region $ABCD$: DMB – evolvent, $OM = \mathbf{R}_v$ – radius vector, $OD = ON – R$ –

evolvent parameter (radius of the circle around which the billet is bend), R_e – curvature of the evolvent

Fig. 4. Scheme of deformation caused by shift between microstripes