Possibilities of estimation of grain deformation in polycrystalline materials

Maroš Martinkovič and Stanislav Minárik

Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, J. Bottu 25, Trnava 91724, Slovak Republic

Mechanical working of polycrystalline materials leads to deformation of grains affected by deformation. Amount of grain surface (S_V) and grain edge (L_V) per unit volume are presented as the parameters for deformation description. Direction of grain boundaries orientation caused by deformation is the same as direction of deformation. If deformation scheme is known (there are only three principal schemes of elementary bulk deformation), grain boundaries can be decomposed into isotropic, planar and linear oriented components. Saltykov stereology methods with oriented test lines were used in case of grain surface S_V – common boundary of two grains, respectively stereology methods with oriented test planes in case of grain edge L_V – common boundary of three grains [1]. On metallographic cuts total specific surface area S_V of grains and planar and linear oriented part of specific surface area $(S_V)_{OR}$ of grains are estimated. Degree of grain boundaries orientation O can be estimated as $(S_V)_{OR}$ to S_V ratio. Similar total specific line length L_V of grains edges and linear oriented part of specific line length $(L_V)_{OR}$ of grains edges can be estimated too. From these results analytical formulas relating structure parameters and strain in each position inside the bulk sample can be developed. One of the methods using idealized tetrakaidehadreon shape of grain (mathematical description of real state shape of grain is quite impossible) is based on dependence of the ratio of specific surface area of grain boundaries in deformed state S_V and undeformed state S_{V0} (respectively specific length of edge L_V and L_{V0}) [2]. The method requires knowledge of the parameter of structure in case of zero value of initial deformation, which is unknown in most of cases, it is not the same in the whole volume of pieces and it depends on grain size. Our conversion method was based on analysis of orientation – deformation relation of a grain. Dependence of strain on orientation O was derived from three basic equations – definition of deformation, definition of degree of orientation and invariability of volume (initial volume is equal volume after plastic deformation). The solution of the system includes one free parameter – grain size. Solution of the system of equations for used idealized grain shapes is independent on the initial dimension of grain – strain depends only on shape of grain and it does not depend on its dimension. Due to it the method enables estimation of local plastic deformation from estimation of microstructure anisotropy in arbitrary place of body with arbitrary state of initial deformation.

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[2] J.Y. Chae, R. Qin, H. K. D. H. Bhaeshia, Topology of the Deformation of a Non-uniform Grain Structure, ISIJ International 49 (2009) 115–118.