Crystals and polycrystals as standard generalized materials(*)

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A SIMPLE, phenomenological description of plastic behaviour of crystals and polycrystals is proposed. A problem of lattice rotations, which are caused by large plastic strains, is under consideration.

A polycrystal is assumed to be composed of grains of the same kind, but with a different initial lattice orientation. Each grain is treated as an elastic-ideally plastic material with internal variables (three Euler angles), which describe a current lattice orientation. The polycrystal is regarded as a standard generalized material with the set of internal variables: $\varphi_k^{(1)}, \ldots, \varphi_k^{(N)}$ $(k = 1, 2, 3)$, where N is a number of differently oriented grains. A set of generalized forces: $f_k^{(1)}, \ldots, f_k^{(N)}$ $(k = 1, 2, 3)$, is introduced.

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A single crystal is a special case of the considered material. Its free energy is composed of two parts: an elastic one and that which is stored due to change of the lattice orientation. For large plastic strains, the elastic part may be assumed to be independent of the lattice rotations. According to the theory of standard generalized materials, the free energy of the crystal is a potential for the stress tensor σ_{ij} and the generalized forces f_k. On the other hand, a plasticity condition for the crystal, expressed in terms of the conjugated forces, is a potential for the plastic rate tensor d_{ij}^p and rates of the lattice rotations $\dot{\varphi}_k$.

The plasticity condition is assumed as a quadratic approximation of the classical Schmid's law (von Mises criterion). The criterion is expressed in terms of the stress acting on the crystal and a tensor of plastic anisotropy, which describes a geometry of slip systems. This tensor depends on the internal variables φ_k.

A free energy of a polycrystal is a sum of free energies for each of the grains. A plasticity condition for the aggregate is expressed in terms of the global stress tensor and a mean tensor of plastic anisotropy. In this way, the reasoning for the monocrystal is transferred to the polycrystal.

An interesting lattice behaviour of grains with two slip systems under plane strain conditions, is analysed in details. For a single crystal with one slip system, the obtained results are identical with the classical ones.

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