Universität Karlsruhe (TH)
Forschungsuniversität · gegründet 1825

Institut für Technische Mechanik
Prof. Dr.-Ing. habil. Thomas Böhlke
Prof. Dr.-Ing. Carsten Proppe
Prof. Dr.-Ing. Wolfgang Seemann
Prof. Dr.-Ing. Dr. h.c. Jörg Wauer
Institut für Mechanik
Prof. Dr.-Ing. Karl Schweizerhof

Mechanik-Seminar

Referent: **Prof. Dr. Khanh Chau Le**
Lehrstuhl für Allgemeine Mechanik, Ruhr-Universität Bochum

Datum: Donnerstag, 24. Januar 2008
Uhrzeit: 15.45 Uhr
Ort: Hertz-Hörsaal, Geb. 10.11, Raum 126

Thema: "**Continuum dislocation theory and size effect in crystal plasticity**"

Abstract

When polycrystals deform plastically, newly formed dislocations pile up near obstacles giving rise to the size-dependent material strengthening. Dislocations appear in the crystal lattice to reduce its energy. Motion of dislocations yields the dissipation of energy which, in turn, results in a resistance to the dislocation motion. Any plasticity theory aiming at predicting plastic yielding, work hardening, and hysteresis must therefore take the nucleation and motion of dislocations into account. The continuum description of dislocations is dictated by the high dislocation densities accompanying plastic deformations, in the range of 10^8-$10^{14}m^{-2}$, as well as the complexity of the dislocation network. Although the framework of continuum dislocation theory has been laid down long time ago by Nye [1], Kondo [2], Bilby *et al.* [3], Kröner [4], Sedov and Berdichevsky [5], and Le and Stumpf [6,7], among others, the applicability of theory became feasible only in recent years [8,9] thanks to the progress in statistical mechanics and thermodynamics of dislocation network [10,11]. In [12] the analytical solution of the anti-plane constrained shear problem for single crystals was found. The interesting features of this solution are the energetic and dissipative yielding thresholds, the Bauschinger translational work hardening and the size effect. The dislocation nucleation admits a clear characterization by the variational principle for the final plastic states.

In this presentation we are dealing with the plane-strain constrained shear of a single and bicrystal strip [13,14]. For the single crystal strip we consider the single and double slip systems oriented at different angles to the direction of shear. For bicrystal strip the main assumption is that each crystal layer has only one active slip system. These slip systems are oriented differently with respect to the direction of shear. We also assume that both crystal layers are elastically isotropic and have the same elastic moduli. At the grain boundary the displacements and the tractions must be continuous. Besides, the dislocations cannot penetrate the grain boundary. The problem is to determine the displacements and the plastic distortion as functions of the given overall shear strain.

Our aim is twofold. First, we are going to find the solution in closed analytical form for the single crystal with one active slip system and with symmetric double slip systems, and for the bicrystal in the symmetric case (twins). If the dissipation can be neglected, then dislocations appear to minimize the total energy of crystal. Due to the specific form of the energy of dislocation network which is proportional to the dislocation density for small densities, we show that there is an

energetic threshold for the dislocation nucleation. If the shear strain exceeds this threshold, geometrically necessary dislocations appear and pile up near the grain and phase boundaries leading to the material hardening. From the obtained solution we can compute the contribution of the geometrically necessary dislocations to the energy of grain and phase boundaries. If, in contrary, the dissipation due to the resistance to the dislocation motion is essential, the energy minimization should be replaced by the flow rule. The solution exhibits the dissipative threshold for dislocation nucleation, the Bauschinger translational work hardening, and the size effect. Our second aim is to develop the numerical procedure for the solution of this problem in the case where the active slip systems are not symmetric. The agreement between the numerical and analytical solution for the special case of symmetry will justify the correctness of developed numerical procedure. Short discussion will be given as how to apply this kind of theory to TWIP-alloys.

References

1. Nye J.F. (1953) Some geometrical relations in dislocated crystals. Acta Metall. 1:153-162
2. Kondo K. (1952) On the geometrical and physical foundations of the theory of yielding. In: Proc. 2 Japan Congr. Appl. Mech., pp. 41-47
3. Bilby B.A., Bullough R., Smith E. (1955) Continuous distributions of dislocations: a new application of the methods of non-Riemannian geometry. Proc. Roy. Soc. (London), A231:263-273
4. Kröner E. (1958) Kontinuumstheorie der Versetzungen und Eigenspannungen. Springer, Berlin
5. Berdichevsky V.L., Sedov L.I. (1967) Dynamic theory of continuously distributed dislocations. Its relation to plasticity theory. J. Appl. Math. Mech. (PMM), 31:989-1006
6. Le K.C., Stumpf H. (1996) Nonlinear continuum theory of dislocations, Int. J. Engng Sci. 34:339-358
7. Le K.C., Stumpf H. (1996) A model of elastoplastic bodies with continuously distributed dislocations, Int. J. Plasticity 12:611-627
8. Berdichevsky V.L. (2006) Continuum theory of dislocations revisited. Continuum Mech. Thermodyn., 18:195-222
9. Ortiz M., Repetto E.A. (1999) Nonconvex energy minimization and dislocation structures in ductile single crystals. J. Mech. Phys. Solids, 47:397-462
10. Berdichevsky V.L. (2005) Homogenization in micro-plasticity. J. Mech. Phys. Solids, 53:2457-2469
11. Berdichevsky V.L. (2006) On thermodynamics of crystal plasticity. Scripta Materialia, 54:711-716
12. Berdichevsky V.L., Le K.C. (2007) Dislocation nucleation and work hardening in anti-plane constrained shear. Continuum Mech. Thermodyn., 18:455-467
13. Le K.C., Sembiring P. (2007) Analytical solution of plane constrained shear problem for single crystals within continuum dislocation theory. Arch. Appl. Mech. DOI 10.1007/s00419-007-0178-1
14. D. Kochmann, Le K.C. (to appear) Plastic deformation of bicrystals within continuum dislocation theory. Math. Mech. Solids.

Alle Interessenten sind herzlich eingeladen.
Prof. Dr.-Ing. habil. Thomas Böhlke