Università degli Studi di Brescia

WORKSHOP:

NUMERICS AND MODELLING OF SMALL-SCALE PLASTICITY

Lunedì 26 Ottobre
Facoltà di Ingegneria di Brescia, via Branze 38-43
Aula Consiliare

PROGRAMMA

11.00 – 12.15
Krishna Garikipati (University of Michigan, USA) – **A discontinuous Galerkin method for an incompatibility-based strain gradient plasticity theory**

12.15 – 14.00 **Pausa pranzo**

14.00 – 15.15
Christian F. Niordson (Technical University of Denmark) – **Aspects of numerical modeling in some recent strain gradient plasticity theories**

15.15 – 15.30 **Pausa caffè**

15.30 – 16.45
Javier Segurado (Universidad Politécnica de Madrid, Spain) – **Size effects in plasticity using Dislocation Dynamics**

Modalità di adesione:

La partecipazione è gratuita previa iscrizione tramite email, da inviare all'indirizzo: **lorenzo.bardella@ing.unibs.it**

Krishna Garikipati – A discontinuous Galerkin method for an incompatibility-based strain gradient plasticity theory

We consider a recent strain gradient plasticity theory based on incompatibility of plastic strain due to the nature of lattice distortion around a dislocation (Gurtin, J. Mech. Phys. Solids, **52**, 2545-2568, 2004). The key features of this theory are an explicit treatment of the Burgers vector, a microforce balance that leads to a classical yield condition, and the inclusion of dissipation from plastic spin. The flow rule involves gradients of the plastic strain, and is therefore a partial differential equation. We apply recently-developed ideas on discontinuous Galerkin finite element methods to treat this higher-order nature of the yield condition, while retaining considerable flexibility in the mathematical space from which the plastic strain is drawn. In particular, despite the higher-order continuity apparent in the yield condition, it is possible to use plastic strain interpolations that are discontinuous across element edges. Two distinct approaches are outlined: the Interior Penalty Method and the Lifting Operator Method. The numerical implementation of the Interior Penalty Method is discussed, and a numerical example is presented.

Javier Segurado – Size effects in plasticity using Dislocation Dynamics

There is compelling experimental evidence that size effects in the resistance to plastic flow appear in metals when the dimensions of the specimen or of the zone subjected to plastic deformation are in the range of µm. Classical models of phenomenological/crystal plasticity have neglected these size effects and this contribution has been addressed recently using strain gradient plasticity models, which introduce a length scale in the analysis. From the theoretical point of view, it is still not easy to find a physical meaning to this characteristic length that is fundamental to the model and, also, it is very difficult to measure, experimentally. Because of this, Discrete Dislocation Dynamics arises as an ideal tool to model the plastic deformation of metals at the micron scale because the size effects are obtained in a natural way with the length of the burgers vector. A 2D dislocation dynamics framework based on the model developed by Needleman and Van der Giessen (Modelling Simul. Mater. Sci. Eng., **3**, 689-735, 1995) will be presented. The current model accounts for the effect of dislocations leaving the crystal through a free surface in the case of non-convex domains, in which the intersection of the slip plane with the domain is not a continuous segment. The new method incorporates the displacement jumps across the slip segments of the dislocations that have exited the crystal within the finite element analysis carried out to compute the image stresses on the dislocations induced by the finite boundaries. This is done in a computationally simple and efficient way by embedding the discontinuities in the finite element solution. Several problems of interest will be presented: a cantilever single crystal beam, a crystal strip submitted to shear loading, and the analysis of the void growth inside a square single crystal. The effect of the sample size in the mechanical response will be analyzed for all the cases.

Christian F. Niordson – Aspects of numerical modeling in some recent strain gradient plasticity theories

Aspects of some recent strain gradient plasticity theories will be presented, with special emphasis on numerical implementation in finite elements. Both visco-plastic models (e.g. Gudmundson, J. Mech. Phys. Solids, **52**, 1379-1406, 2004) and time-independent models (e.g. Fleck and Willis, J. Mech. Phys. Solids, **57**, 161-177, 2009) will be discussed. In metals, strain gradient hardening leads to significant strengthening on the micron scale. Experimental investigations on size-effects in metals have been carried out for different materials and under different loading conditions such as bending, torsion, and indentation. Effects of passivation layers on thin films, suppressing the movement of dislocations, have been quantified, and it has been found that wherever large strain gradients appear, whether it is due to non-homogeneous loading or due to constraints on plastic flow, additional material hardening arises. These experimental findings have led to the formulation of a number of strain gradient plasticity theories that include constitutive length parameters and hence can model size-dependent plastic deformation. Different ways of introducing constitutive length parameters lead to different kinds of loading and unloading response. This will be exemplified through a study of the cyclic shear response using a higher order strain gradient visco-plasticity theory (Gudmundson, J. Mech. Phys. Solids, **52**, 1379-1406, 2004) accounting for both dissipative and energetic gradient hardening. Numerical investigations of the response under cyclic pure shear and shear of a finite slab between rigid platens have been carried out. It is shown for elastic-perfectly plastic solids how dissipative gradient effects lead to increased yield strength, whereas energetic gradient contributions lead to increased hardening as well as a Baushinger effect. For linearly hardening materials it is quantified how dissipative and energetic gradient effects promote hardening above that of conventional predictions. Usually, increased hardening is attributed to energetic gradient effects, but here it is found that also dissipative gradient effects lead to additional hardening in the presence of conventional material hardening. Furthermore, it is shown that dissipative gradient effects can lead to both an increase and a decrease in the dissipation per load cycle depending on the magnitude of the dissipative length parameter, whereas energetic gradient effects lead to decreasing dissipation for increasing energetic length parameter. For dissipative gradient effects it is found that dissipation has a maximum value for some none zero value of the material length parameter, which depends on the magnitude of the deformation cycles. Finally, the problem of lack of consistent loading and unloading criteria in some recent time-independent strain gradient plasticity theories will be discussed.

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