MM 62: Topical Session: Fundamentals of Fracture - Stochastic Aspects

Time: Thursday 17:15–18:45 Location: H4

Topical Talk MM 62.1 Thu 17:15 H4

Elasticity and disorder for fracture size effects — •Stefano Zapperi — IENI-CNR, Milano, Italy — ISI foundation, Torino,Italy

I will discuss the asymptotic properties of fracture strength distributions of disordered elastic media studied by combination of renormalization group, extreme value theory, and numerical simulation. We investigate the validity of the weakest-link hypothesis in the presence of realistic long-ranged interactions in the random fuse model. Numerical simulations indicate that the fracture strength is well-described by the Duxbury-Leath-Beale (DLB) distribution which is shown to flow asymptotically to the Gumbel distribution. We explore the relation between the extreme value distributions and the DLB-type asymptotic distributions and show that the universal extreme value forms may not be appropriate to describe the nonuniversal low-strength tail. Finally, we confirm numerically that the Weibull distribution, widely used in the past to fit failure statistics from experiments, only arises when the distribution of pre-existing disorder has a power law tail and is otherwise unstable due to interactions.

MM 62.2 Thu 17:45 H4

Time evolution of creep rupture due to thermally activated cracking in a fiber bundle model — •Ferenc Kun[1], Naoki Yoshioka[2], and Nobuyasu Ito[3] — [1]Department of Theoretical Physics, University of Debrecen, P.O.Box: 5, H-4010 Debrecen, Hungary — [2]Yukawa Institute for Theoretical Physics, Kyoto University, Kitashirakawa Oiwake-cho, 606-8502 Kyoto, Japan — [3]Department of Applied Physics, Graduate School of Engineering, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo, 113-8656, Japan

We study sub-critical fracture driven by thermally activated crack nucleation under a constant external load in the framework of fiber bundle models. We show that in the presence of stress inhomogeneities, thermally activated cracking results in an anomalous size effect, i.e. the average lifetime of the system decreases as a power law of the system size, where the exponent depends on the external load and on the temperature.

On the microlevel, thermal fluctuations trigger bursts of breakings which proved to have a power law size distribution. Focusing on the waiting times between consecutive bursts we show that the time evolution has two distinct forms: at high load values the breaking process continuously accelerates towards macroscopic failure, however, for low loads and high enough temperatures the acceleration is preceded by a slow-down. Analyzing the structural entropy and the location of consecutive bursts we show that in the presence of stress concentration the early acceleration is the consequence of damage localization.

MM 62.3 Thu 18:00 H4

Failure Prediction in Silicon Nitride based on a Probabilistic Micromechanical Approach — •Yamen Othmani and Thomas Böhlke — Chair for Continuum Mechanics, Institute of Engineering Mechanics, Karlsruhe Institute of Technology (KIT), Kaiserstrasse 10, 76131 Karlsruhe, Germany

Silicon nitride ceramics are prime structural materials for several challenging assignments and applications. This is due to their outstanding high stiffness, high-temperature strength and, especially, their high fracture toughness. However the structural use of these materials is restrained because of the occurrence of damage phenomenon under severe working conditions. Many approaches, including fracture mechanics, could be adopted to predict the failure of silicon nitride. Nevertheless, the strengths of such materials are statistical in nature and the damage progression is stochastic. Therefore, the application of statistical methods to evaluate the failure of ceramics is a versatile approach. In the present work, multivariate weakest link approach is developed and used in conjunction with a stochastic analysis of the local elastic fields to determine the failure probability of sintered silicon nitride. The originality of the work is reflected by the employment of second-order estimates in the analysis of elastic field fluctuations. The following assumptions have been taken into consideration: The constitutive phases of silicon nitride are considered to be isotropic and linear elastic. The strain field is compatible which implies a vanishing distribution of eigenstresses.

MM 62.4 Thu 18:15 H4

Thermally Activated Fluctuating Dynamics of Dislocations in a Low-Stress Zone — •Thomas Swinburne — EURATOM/CCFE Fusion Association, OX14 3DB — Department of Physics, Imperial College London, SW7 2AZ

A crack is an intense dislocation source, and the propagation of the crack is controlled by the mobile dislocations forming the atmosphere extending into the far-field low stress zone. The mobility of dislocations is believed to control brittle to ductile transition [Hirsch, Roberts and Samuels 1989, Hartmaier and Gumbsch 1999].

To explore the transition from brittle to ductile fracture it thus becomes essential to investigate dislocation mobility under vanishing applied stress, a regime typically considered inaccessible to atomistic simulation of bcc metals due to the kink limited motion of screw dislocations. This is overcome through specially adapted large-scale atomistic simulations which enforce the existence of individual kinks on a dislocation line. The temperature dependence of the resultant kink motion contradicts decades of theoretical work and leads to new conclusions on dislocation friction.

A stochastic line model is capable of quantitatively capturing the diverse range of temperature dependent effects seen in atomistic simulation providing the line is crystallographically discrete, introducing a new length scale into thermally activated plasticity. The model, fully parametrised from atomistic simulation, is used to predict the thermally activated response of mobile dislocations to vanishing applied stress.

MM 62.5 Thu 18:30 H4

The low temperature deformation properties of thermally active bulk metallic glasses — •Peter Derlet — Condensed Matter Theory Group, Paul Scherrer Institut, Switzerland

Despite significant atomic-scale heterogeneity, bulk metallic glasses well below their glass transition temperature exhibit a sharp transition to plasticity with a reproducible yield stress. Under tension, limited ductility is observed with the materials often exhibiting brittle fracture. Because of the high reproducibility of the yield stress such mechanical failure is not flaw based (as in a ceramic) but rather an intrinsic property of the structural glass. The present work investigates these issues via a thermal activation model which assumes the number of available irreversible structural transformations scales exponentially with an internal heterogeneous length scale. It is found that a distinct low temperature deformation regime exists which is dominated by the statistics of kinetic freezing, giving an approximately linear increase in yield stress as a function of decreasing temperature. This result is discussed in terms of the onset of heterogenous plasticity and eventual macroscopic material failure.