

PROPERTIES OF INTERFACE CRACKS IN DISORDERED MEDIA: CRACK NUCLEATION AND CRACK PINNING.

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We discuss the influence of structural disorder on the failure of interfaces between a thin elastic films and a disordered substrate. In particular, we investigate the two problems of (a) crack nucleation and (b) crack pinning, and discuss transitions between different failure modes that occur in a pre-cracked sample if the degree of structural disorder is increased.

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Criticality of fracture precursors

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March 20, 2009

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Abstract

We present statistical analysis of acoustic emission (AE) from tensile experiments on paper sheets. We study loading mode I with ordinary copy paper.

Acoustic emission (AE), stress waves produced by sudden redistribution of stress in the material, is measured by using continuous data acquisition with piezoelectric sensors. Integrating a squared amplitude one obtains the released elastic energy during the experiment. Post-processing the amplitude signal, we find discrete sequence of events with corresponding energies E_i and arrival times t_i .

We performed 100 experiments on copy paper using intact samples and 70 experiments with 10mm initial edge notch. Total number of observed acoustic emission events in all experiments were 800921.

We analyze time series by creating windowed time series of event energies and event rates and average the data over large set of experiments. Different methods to average the data are studied and averaging method is shown have an effect to the interpretation of results.

We show that the characteristic behaviour of the energy rate \dot{E} in intact samples is different from the event rate \dot{n} . The behaviour of the event rate $\dot{n}(t_c - t) \sim t^{-\beta}$ implies criticality, when t_c is chosen to be the time at the maximum of the event rate. The event rate increases more like exponential fashion. We show that the maximum of the event energy rate \dot{n}_{max} corresponds time which is observed after the maximum of the stress σ_c . When event rate increases, average event energy increases at non-trivial manner. $P(E)$ is power law with a cutoff where cutoff depends on ϵ/ϵ_c .

Deformation and strain rate during successive fatigue cycles

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Abstract

We study here the evolution of the deformation on a quasi 2D paper sample during cyclic creep experiments. The goal is to find if it is possible to predict the break. We perform tensile creep tests on normal copy paper samples; loading procedure consists in 30s creep under constant weigh of circa 6kg and 30s unloading to let relaxation occurs. We use two methods to obtain the z-axial deformation: on the first hand, we calculated it from mechanical data of the vertical displacement, measured thanks to a laser sensor, and on a second hand, we used digital image correlation with pictures taken each 2s from a camera. We will first see first that there is a huge disparity on the break cycle number and that it is difficult to define reproducibility because lot of parameters influence the paper mechanical behaviour like humidity and history [1]. We are then interested in deformation field and strain rate during creep phases. The increase of deformation with creep time fits quite well with a power law and the exponent decreases with the number of cycles. Moreover it seems that a limit before break exists for the deformation added during each creep phase and for the strain rate.

[1] Alava, M.J. and Niskanen, K.J., Physics of Paper, Reports on Progress in Physics 69, 669-724 (2006)

Triggering failure in an intact rock sample: analysis of the role of temperature, seismic waves and fluid

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We investigated the role of temperature in triggering failure during uniaxial tests on different lithologies (basalts, sandstones, clays), representative of stratigraphic succession at Mt. Etna volcano, the most active volcano in Europe. Rocks have been loaded under constant strain rate of $0.75 \mu\text{m/s}$ at temperatures of 25 and 300 °C, respectively. Results evidence as higher temperatures have different influences on the mechanical strength of the investigated materials. Thermal weakening and its consequent failure trigger is strongly dependent on the mineralogy and fabrics of each lithology, which might have a main role in volcanoes instability processes.

The analysis of the effect of triggering seismic waves on failure has been carried out by using a triaxial cell operating at ENS, Paris. Water saturated Fontainebleau samples of sandstone (porosity=7%) have been loaded at constant strain rate at 10^{-6} s, $P_c=30$ MPa, $P_p=15$ MPa to the failure. Small stress perturbations of ± 1 MPa at 0.02 Hz have been imposed during the progressive loading. A positive correlation between positive perturbations and AE rate has been found, indicating that small overpressures do enhance crack growth and propagation. A quantitative textural analysis of acquired images is also elucidating the spatial size and shape relations within the fault zone.

AE triggered during rapid fluid decompression through the damage/shear zone have been statistically compared to the AE generated during the deformation stage. Analysis of first motion and spectrograms allows to qualitatively identify high and low frequency events, from the two experimental stages respectively. Here, we present a new and independent analysis, aiming to quantitatively classify 'families' of AE events belonging to the same experimental stage without prior knowledge. We then test this method using the AE catalogue for verification, which is not possible with field data.

Strain Fluctuations During Primary Creep

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Abstract

Deformation of disordered material is studied by examining the 2D-strain from paper creep experiments and discrete dislocation dynamics (DDD) simulations.

In experiments a quasi 2D paper sample is loaded under constant load. The deformation of the sample is recorded with digital camera to a series of images with time interval of 10 seconds. The 2D-strain is then obtained using digital image correlation between sequential images [1].

In DDD simulations [2] the positive and negative edge dislocations move under internal shear stresses and a constant external stress. The average dislocation movement is considered as strain of the material. The average strain rate obeys the Andrade scaling ($t^{-0.7}$) and the standard deviation scales as $t^{-0.5}$. In the experiments the exponents are similar but a bit higher (-0.8 and -0.55, respectively). The results indicate that the role of fluctuations increase during primary creep.

The strain results exhibit a data collapse typical of the integrated order parameter in absorbing state phase transitions. This is true for both experiments and simulations, for which the strain distribution verifies a scaling function collapse [3].

[1] J. Kybic, and M. Unser, Fast Parametric Elastic Image Registration, IEEE Trans. Image Process. 12, 1427 (2003)

[2] M.-C. Miguel, A. Vespignani, M. Zaiser, and S. Zapperi, Dislocation Jamming and Andrade Creep, Phys. Rev. Lett. 89, 165501 (2002)

[3] R. Dickman, M.A. Munoz, Interface Scaling in the Contact Process, Phys. Rev. E. 62, 7632 (2000)

PLASTICITY AT THE MICRO-SCALE

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Recent advances in experimental methodology awoke a lot of interest on plasticity size effect in micron- and submicron-sized materials. The experimental phenomenology is briefly reviewed and a simple cellular automaton for interacting dislocation is proposed. We reproduce numerically a compression test under stress control and we show that the probed systems strengthen as the system size is decreased. Moreover we are able to reproduce experimentally observed staircase-like behavior of the stress-strain curve. Analysing it we get that the strain avalanches are scale-free and that the stress increments follow a Weibull distribution.

VARIATION OF THE AFTERSHOCK RATE DECAY IN SPACE AND TIME.

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The definition of the aftershocks sequence is still a debated topic. We here propose the study of the spatial and temporal variation of the daily earthquake number decay. For this purpose several main earthquakes have been selected on the basis of magnitude and all subsequent events are stacked to calculate the mean rate. Stacking increases the number of data allowing to analyze changes over time interval and distance from the main shock. The appearing decay domain depends on the threshold magnitude of the catalog and is characterized by smooth variations in space probably due to the merging of several sequences. A similar behavior is found in acoustic emissions of a rock sample during failure.

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INVESTIGATING GRANULAR FLUIDISATION THROUGH VIBRATION

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We perform experiments on a granular medium confined to a circular channel. The medium is excited both by the shearing action of a forced annular overhead plate and by vertical excitation. The vibration naturally causes the granular structure to lose rigidity and here we attempt to quantify what level of energy input is necessary to weaken the granular material. The results indicate that an extremely low level of vibration is sufficient to completely destroy the solidified state of the GM, though we find that one requires a much larger vibration to significantly reduce the viscosity of the resultant granular fluid.

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SUPPRESSION OF FRICTION BY MECHANICAL VIBRATIONS

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Mechanical vibrations are known to affect frictional sliding causing sometimes a drastic reduction of the frictional force. This issue is relevant for applications in nanotribology and to understand earthquake triggering. We study the dynamics of a granular lubricant confined between a horizontally driven top plate and a vertically oscillating bottom plate. Our numerical results show a suppression of the high dissipative stick-slip regime in a well defined range of frequencies that depends on the vibrating amplitude, the normal applied load, the system inertia and the damping constant. We propose a simple theoretical explanation of the numerical results and derive a phase diagram indicating the region of parameter space where friction is suppressed.

FROM STICK-SLIP TO STABLE SLIDING THROUGH INTERFACE AGEING: TOWARDS GEOPHYSICAL GLIDE?

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In the earth crust, and more specifically in shallow dipping subduction zones, a variety of disparate slip patterns have been revealed by seismic and geodetic monitoring. These include regular earthquakes, slow slip events, and silent quakes. Noting that the present understanding of these slip patterns is based upon numerical simulations, we investigate slip patterns using a friction lab-scale experiment. In particular, we are curious to see how cumulative slip changes frictional and acoustic patterns in a lab-scale subduction zone. We find that as the contact interface between plates ages, energy is released through a progression of shallow loud earthquakes, medium-depth slow earthquakes, deeper silent quakes, and the deepest steady state creep. This progression of seismic signals, from strong earthquake events to smaller-amplitude and longer-duration signals similar to those seen for nonvolcanic tremor, indicates that all motion appears as different aspects of a more holistic process that combines motion, aging, and displacement. Implications for slip instabilities in the earth crust, earthquake slips and landslide are discussed.

TRIGGERING OF SNOW SLAB AVALANCHES: FROM FRACTURE MECHANICS TO HAZARD MITIGATION?

J. Heierli¹ and M. Zaiser

We have recently shown that snow slab avalanches release by a particular fracture mechanism which can be termed an anticrack. We discuss the implications of this finding in view of the phenomenology of failure initiation and propagation, and analyze the efficiency of various local triggering mechanisms including skier loads. We also discuss the consequences of this new (?) paradigm of avalanche release for identifying the relevant research questions that need to be addressed in snow mechanics if we want to better understand and mitigate of avalanche hazard.

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SEISMIC MONITORING OF A HUGE ROCKSLIDE, SÉCHILIENNE, FRENCH ALPS

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In the French Alps, the Séchilienne rockslide is one of the natural phenomena presenting the higher potential combined risk in terms of socio-economical outcomes. The failure of this huge landslide (3 to 30 millions of m³) is likely to form a natural dam, which would block the Romanche river, its subsequent rupture could have devastating consequences downstream for people and facilities. This area has been extensively instrumented since 1988 using a displacement network (discrete GPS, laser, radar, extensometers) and a meteorological station. More recently, a seismic network is in use since May 2007. During one year, several thousands seismic events have been recorded. We record both very long events (several minutes long), which are likely due to rockfall avalanches, and much shorter events, probably associated with fracturing or crevasse opening. The seismic activity is very variable, from a few events per day to more than 100 events per day during seismic crisis. Most peaks are associated with precipitations, with almost zero time delay between rain and triggered seismic events. Seismic crisis are also often associated with periods of accelerated deformation. However, there is no simple and systematic relation between precipitations, microseismic activity and displacement.

For more information see OMIV web site at <http://www-lgit.obs.ujf-grenoble.fr/observations/omiv>.

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