Phase transition in the fracture process of heterogeneous materials under unloading

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Abstract

We investigate the fracture of heterogeneous materials which emerges under unloading from a constant sub-critical load. Based on a fiber bundle model we show that depending on the rate of unloading the system has two phases, i.e. at slow unloading the gradual accumulation of damage leads to global failure giving rise to a finite lifetime of the sample, while rapid unloading results in partial failure with an infinite lifetime. Analytical calculations revealed that the transition between the two phases occurs at a critical unloading rate analogous to continuous phase transitions where the surviving intact fraction of the sample plays the role of the order parameter.

We show by computer simulations that fibers break in sudden burts generating crackling noise which can be registered experimentally by the acoustic emission technique. At the onset of unloading the stress relaxation is accompanied by a decreasing rate of bursts characterized by a power law functional form analogous to Andrade creep. In the regime of finite lifetime the initial slow down is followed by an acceleration towards global failure. We demonstrate that the increasing rate of bursts obeys the Omori law of earthquakes which has been found to describe the aftershock sequence after major events.

Analysing the correlation of the lifetime of the sample and of the time where the minimum burst rate is reached we pointed out a relation which can be exploited for the forecasting of the imminent gobal failure of the system.

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