Analysis of the relaxation time in subcritical rupture of heterogeneous materials

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Abstract

Predicting subcritical rupture of heterogeneous materials is an important subject in physics of materials. Subcritical rupture happens when a material is loaded at a constant force below its ultimate tensile strength for a long time. This process ends with the ultimate failure that defines the lifetime of the sample,
*tau*c. The lifetime is a scattered and hard to predict parameter. If we stop maintaining the target force before the final rupture, we observe a relaxation of the force in the sample. This relaxation can be fitted using a visco-elastic rheological model (1) which predicts a logarithmic decay of the force with a characteristic time
tau . The aim of our experiment is to measure the evolution of the relaxation time,
tau , during the subcritical rupture process. For this purpose, we use paper samples held in a tensile stress apparatus controlling elongation and we impose a constant force with a feedback loop. In addition to this constant force, we apply tiny force steps to probe the relaxation locally. The time between two steps is proportional to the characteristic relaxation time. Experimentally, for paper samples, we observe that this time
tau increases linearly, indicating a slowing down in the subcritical rupture dynamics, then fastly decreases at about 80% of the lifetime
*tau*c(2). This behavior can be qualitatively explained by the fiber bundle model (3) that describes the phenomenological rupture of a heterogeneous fibrous material. Considering the strain of our sample, we recover behaviors already observed in other soft materials such as protein gels (4). When a constant force is applied, the strain rate first decreases with a power law then increases sharply before the final rupture.

References
(1) Arthur Tobolsky and Henry Eyring. "Mechanical Properties of Polymeric Materials". In: Journal
of Chemical Physics 11.3 (Mar. 1943), pp. 125–134.
(2) Juha Koivisto et al. "Predicting sample lifetimes in creep fracture of heterogeneous materials". In:
Physical Review E 94.2 (Aug. 8, 2016), p. 023002.
(3) Jérôme Weiss and David Amitrano. "Logarithmic versus Andrade's transient creep: Role of elas-
tic stress redistribution". In: Physical Review Materials 7.3 (Mar. 13, 2023). Publisher: American
Physical Society, p. 033601.

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(4) Mathieu Leocmach et al. "Creep and Fracture of a Protein Gel under Stress". In: Physical Review
Letters 113.3 (July 15, 2014). Publisher: American Physical Society, p. 038303.