The Fundamental Physics of the Onset of Frictional Motion: How do laboratory earthquakes nucleate?

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Abstract

Recent experiments have demonstrated that rapid rupture fronts, akin to earthquakes, mediate the transition to frictional motion. Moreover, once these dynamic rupture fronts (”laboratory earthquakes”) are created, their singular form, dynamics and arrest are well-described by fracture mechanics. Ruptures, however, need to be created within initially rough frictional interfaces, before they are able to propagate. This is the reason that ”static friction coefficients” are not well-defined; frictional ruptures can nucleate for a wide range of applied forces. An important open question is, therefore, how the nucleation of rupture fronts actually takes place. We experimentally demonstrate that rupture front nucleation is prefaced by extremely slow, aseismic, nucleation fronts. These nucleation fronts, which are often self-similar, are *not* described by our current understanding of fracture mechanics. The nucleation fronts emerge from initially rough frictional interfaces at well-defined stress thresholds, evolve at characteristic velocity and time scales governed by stress levels, and propagate within a frictional interface to form the initial rupture from which fracture mechanics take over. We will briefly describe a new theoretical description of the nucleation process obtained by means of a nontrivial extension of fracture mechanics. This theory quantitatively describes all of the experimentally observed features of the extremely slow nucleation process and merges seamlessly with the accepted fracture mechanics description of rapid dynamic ruptures. In addition, this new theory provides a mechanical explanation for what are considered as slow ‘creep’ processes that often take place prior to fracture. These results are of fundamental importance to questions ranging from earthquake nucleation and prediction to processes governing material failure.

References

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