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Shock Wave Theory for Rupture of Rubber

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The rupture of rubber differs from conventional fracture. It is supersonic, and the speed is determined by strain levels ahead of the tip rather than total strain energy as for ordinary cracks. Dissipation plays a very important role in allowing the propagation of ruptures, and the back edges of ruptures must toughen as they contract, or the rupture is unstable. In this talk I will review the experimental evidence for these claims. I will present several levels of theoretical description of the phenomenon: first, a numerical procedure called mesoscopic particle modeling, which is capable of incorporating large extensions, dynamics, and bond rupture; second, a simple continuum model that can be solved analytically, and which reproduces several features of elementary shock physics; and third, an analytically solvable discrete model that accurately reproduces numerical and experimental results, and explains the scaling laws that underly this new failure mode. Rupture speeds compare well with experiments, although opening angles of the rupture are not captured especially well. Some additional interesting topics that may be encountered along the way include the question of how to model sound dissipation in disordered solids, and a numerical instability that is suggestive of the phenomenon of strain crystallization.