Cracking sheets: Oscillatory fracture paths in thin elastic sheets

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When a blunt cutting tool is forced through a thin elastic sheet that is held along its lateral boundaries, a strikingly regular wavy cut can be left behind, examples of which are presented in Fig. 1. The thin film is brittle, hence it undergoes negligible irreversible deformation besides fracture. For tools much wider than the film's thickness, the crack tip follows a highly reproducible nonsinusoidal oscillatory path.[1–3] Each single period of this path consists of two smooth curves separated by a kink, at which there is a sharp change in the direction of curvature. Propagation is primarily quasistatic, at a speed comparable to that of the cutting tool but is interrupted by periodic bursts of dynamic propagation immediately after each kink. By decreasing either the size of the cutting tool down to widths comparable to the film thickness or the tool's speed, the crack path eventually becomes straight.[1,3] These oscillatory patterns are strikingly robust and even doing the experiment by hand yields surprisingly regular patterns.

In Ref. 4 we have shown that the coupling of classical theories for elastic plates and for crack propagation can be reduced to a simple set of geometrical rules which explain this experimentally observed oscillatory crack behavior in thin brittle films. This was done by following a common approach in fracture theory: calculating the elastic energy of the system while taking into account the possible large out-of-plane deformations of the film induced by the cutting tool. Griffith's criterion for crack propagation was then applied. The principal ingredient of our 2D construction is therefore the coupling between crack propagation and large out-of plane deformations in the film. Geometry is, in general, known to play an important role in the theory of elastic rods, plates, and shells but, in the tearing of thin films, geometrical considerations acquire an unprecedented level of importance. This is a compelling example where a complex crack motion is entirely ruled by geometry.

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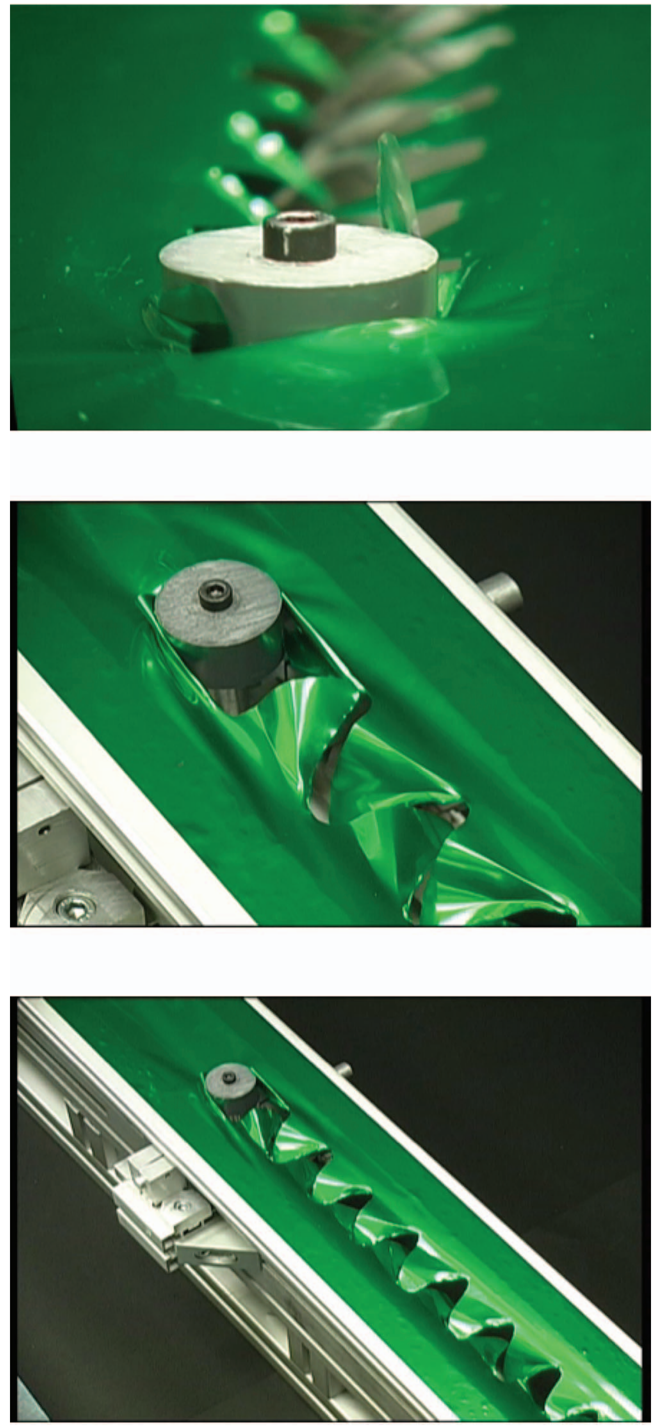

FIG. 1. (Color) Oscillatory fracture paths obtained when cutting a thin polymer sheet (mylar) with a blunt cylindrical cutting tool (36 mm diameter) (enhanced online).

