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An Experimental Study of Penny-shaped Fluid-driven Cracks in an Elastic Matrix

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When a pressurized fluid is injected into an elastic matrix, the fluid generates a fracture that grows along a plane and forms a fluid-filled disc-like shape. For example, such problems occur in various natural and industrial applications involving the subsurface of Earth, such as hydraulic fracturing operations. We report a laboratory study of such a fluid-driven crack in a gelatin matrix, study the crack shape as a function of time, and investigate the influence of different experimental parameters such as the injection flow rate, Young's modulus of the matrix, and fluid viscosity. We find that the crack radius increases with time as a power law, which has been predicted both for the limit where viscous effects in the flow along the crack opening control the rate of crack propagation, as well as the limit where fracture toughness controls crack propagation. We vary experimental parameters to probe the physical limits and highlight that for our typical parameters both effects can be significant. Also, we measure the time evolution of crack shape, which has not been studied before. The rescaled crack shapes collapse at longer times, based on an appropriate scaling argument, and again we compare the scaling arguments in different physical limits. The gelatin system provides a useful laboratory model for further studies of fluid-driven cracks, some of which we will mention as they are inspired by the physics of hydraulic fracturing. This work is part of the PhD thesis of Ching-Yao Lai and is a collaboration with Drs. Zhong Zheng and Jason Wexler (Princeton University) and Professor Emilie Dressaire (NYU).

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