Supershear growth of tensile cracks enabled by geometric non-linearities

David Kammer*[1], Mohit Pundir[1], and Mokhtar Adda-Bedia[2]

[1]Institute for Building Materials, ETH Zurich – Switzerland
[2]Laboratoire de Physique de l'ENS Lyon – CNRS, University of Lyon – France

Abstract

Linear elastic fracture mechanics (LEFM) theory has long postulated that the speed of crack growth is constrained by the Rayleigh wave speed. While numerous experimental and numerical studies have generally supported this prediction, some exceptions have raised questions about its validity and the underlying factors influencing dynamic crack behavior. In this work, we present new numerical results showing that tensile (mode I) cracks can surpass the Rayleigh wave speed and exhibit propagation at supershear velocities. The key to this finding lies in incorporating geometric non-linearities into the material model. While such non-linearities are inherent in most materials, their effects on dynamic fracture growth have been largely overlooked in previous work. Our results reveal that accounting for geometric non-linearities is sufficient to enable supershear crack propagation. In addition, we show that these non-linearities induce modifications in the crack-tip singularity, leading to unconventional crack-tip opening displacements, cohesive zone behavior, and altered energy flow dynamics toward the crack tip. These observations suggest that the elastic fields and energy budgeting in the vicinity of the crack tip of geometrically non-linear materials have a completely different behavior than that of linear elastic materials, which is commonly assumed in LEFM theory. Consequently, this provides a novel perspective on dynamic crack growth that challenges existing theoretical frameworks.

*Speaker