

ICF -14 Distinguished Lecture

Using Sub-Rayleigh and Super-shear Laboratory Earthquake Ruptures to reveal the structure of Dynamic Friction

Ares J. Rosakis (presenter)

*Theodore von Kármán Professor of Aeronautics and Professor of Mechanical Engineering
California Institute of Technology, Pasadena, CA, USA*



Abstract:

Friction plays a central role in how ruptures propagate along faults in the earth's crust and release waves that cause destructive shaking. Yet the detailed nature of the dynamic frictional law which operates on such faults is one of the biggest uncertainties in earthquake science. This presentation will discuss unprecedented measurements of evolving local, on-fault, friction recorded dynamically during spontaneous mini-earthquakes in the laboratory, enabled by our novel ultra-high-speed full-field imaging technique. This is a new way of inferring friction directly from transient rupture events without involving assumptions of uniform sliding along a frictional interface. In our laboratory, earthquakes are mimicked by dynamic rupture propagating along an inclined frictional interface between two quadrilateral Homalite plates prestressed in compression and shear. The diagnostics previously employed in this setup included temporally accurate but spatially sparse laser velocimetry measurements as well as a short sequence of full-field photoelastic images. These measurements have been successfully employed to capture important rupture features but they do not give enough information to quantitatively characterize the full-field evolution of the deformation. The newly developed imaging technique quantitatively captures, for the first time, the full-field evolution of particle velocities, strains, and stresses of both sub-Rayleigh and supershear ruptures. The technique combines pattern-matching algorithms with ultra-high-speed photography and highly tailored analysis to obtain full-field time histories. Dynamic imaging of particle velocities, strains stresses and transient surface tractions during rupture enables unique observations of key rupture features as well as detailed analysis of dynamic friction.

Our measurements do not support classical slip weakening as the operant frictional law. Instead they show that friction is strongly velocity dependent and has a complex (history dependent) evolution, qualitatively consistent with a rate-and-state frictional law, supplemented with flash heating. This study develops a novel approach for measuring local evolution of dynamic friction and has important implications for earthquake physics.

Biographical Sketch:

B.A. & M.A. (1978), Engineering Science, Oxford University, U.K. M.S. (1980) & Ph.D. (1983), Solids and Structures, Brown University. Assistant (1982-'88), Associate (1988-1993) and Full Professor (1993-); Theodore von Kármán Professor of Aeronautics and Mechanical Engineering, California Institute of Technology, 2004-, and F. Otis Booth Leadership Chair, 2013-2015. Director, Graduate Aerospace Laboratories, GALCIT (2004-2009); Chair (Dean), Division of Engineering and Applied Science (2009-2015), California Institute of Technology. Distinguished Visiting Professor, École Normale Supérieure, Paris (2005). Astor Visiting Professor, Oxford University, U.K. (2007).

Professional awards include: NSF Presidential Young Investigator, The U.S. White House (1985). R. Kingslake Medal and Prize, SPIE (1989). Hetenyi (1992 & 2008), Lazan (1996), Frocht (2003), Murray (2005), Harting (2007) and Theocaris (2013) Awards from the Society for Experimental Mechanics (SEM). Fellow, American Society of Mechanical Engineers, ASME (1995). Fellow, SEM (2009). Engrg. Alumni Medal, Brown University (2010). R.H. Thurston Award, ASME (2010). A.C. Eringen Medal, Society of Engineering Science, SES (2011). P.S. Theocaris Award, SEM (2013), the Sia Nemat-Nasser Medal, SEM (2015), and the Theodore von Karman Medal, American Society of Civil Engineers, ASCE (2016).

Rosakis was inducted into the National Academy of Sciences, (NAS), National Academy of Engineering (NAE), the American Academy of Arts and Sciences, the Academia Europaea (AE), and the European Academy of Sciences and Arts (EASA). He is a Foreign Fellow of the Indian National Academy of Engineering (INAE), and Corresponding member of the Academy of Athens, and was made Commandeur dans l'Ordre des Palmes Académiques by the French Republic.