THE STRUCTURE OF SLIP-PULSES AND SUPERSHEAR RUPTURES DRIVING SLIP IN BIMATERIAL FRICTION

H. Shlomai[1], J. Fineberg[1]
[1] *The Racah Institute of Physics, The Hebrew University of Jerusalem, Givat Ram, Jerusalem Israel*

Friction | bimaterial interface | rupture structure | slip-pulse | supershear ruptures

Frictional motion occurs when the contacts composing the interface connecting two bodies together detach via propagating rupture fronts. Most studies of frictional sliding have considered homogeneous systems, sliding bodies composed of the same material. The most common frictional motion in nature, however, involves *bimaterial* interfaces, when the contacting bodies possess different elastic properties. Important examples include natural faults that are bordered by different rock types [1]. The existence of a *bimaterial* interface can bring about qualitative differences in how contact points detach [2-3] as coupling between slip and normal stress variations, unique to bimaterial interfaces, has long been expected.

We study rupture dynamics in bimaterial system composed of PMMA (polymethylmethacrylate) and polycarbonate. Using high-speed simultaneous measurements of slip velocities, real contact area and near-interface stresses we will explicitly demonstrate the existence of both bimaterial coupling and its role in determining different classes of rupture modes, each with its accompanying structure. These include slip-pulses, highly localized slip (*pulse-like* rupture) accompanied by large local reductions of the normal stress near the rupture tip. These pulses only propagate near the softer material's shear wave speed and continuously evolve with their propagation distance. Slip pulses are the dominant mode when ruptures propagate in the direction of motion of the softer material, called the positive direction. In the opposite negative propagation direction, we find that bimaterial coupling drives dominant supershear fronts that are characterized by extended slip (*crack-like* rupture).

The robustness of these structures suggests that, despite the complexity of natural faults, distinct bimaterial effects should emerge in earthquakes along bimaterial faults. They might explain field observations as directionality of earthquake ruptures and asymmetry of rock damage along natural faults as well as contribute to understanding the "heat paradox", the relatively low amount of heat generated by earthquakes.

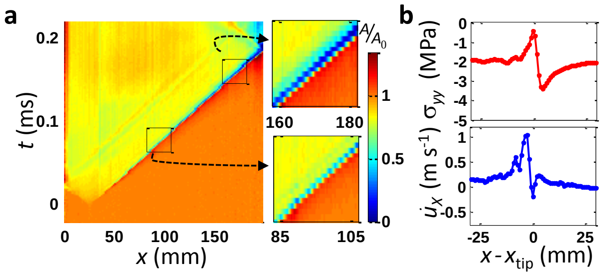

Figure 1. A slip-pulse rupture propagating in the positive direction in a bimaterial system. We reveal the structure of slip pulses using measurements of real contact area, $A(x,t)$ (**a**), normal stress, σ_{yy}, (**b**-top) and slip velocity, $\dot{u}_x$ (**b**-bottom). As the rupture tip approaches a measurement point, $A(x,t)/A_0(x)$ ($A_0(x) = A(x,t<0)$) is first compressed. With the tip passage, A drops dramatically to ~$0.1A_0$ (dark blue) for ~5mm and then heals to residual value of ~$0.8A_0$. σ_{yy} exhibits similar behavior. Initial compression is followed by a large release of normal stress for a short region of ~5mm. Then σ_{yy} is dynamically restored to its initial value. At the same time, the particle velocity adjacent to the interface, $\dot{u}_x$, is highly localized; non-zero values are only observed during the release in σ_{yy}. The correlation and synchronization of σ_{yy} and $\dot{u}_x$ provide clear evidence for slip-pulses (in the positive direction) driven by bimaterial coupling. Right panels (**a**) are close-ups of $A(x,t)$ in the denoted areas, showing both the continuous evolution of the slip pulse with propagation distance and highlighting the large reductions in real contact area surrounding the rupture tip.

References

[1] Dor, O., Rockwell, T. K. & Ben-Zion, Y. Geological observations of damage asymmetry in the structure of the San Jacinto, San Andreas and Punchbowl faults in Southern California: A possible indicator for preferred rupture propagation direction. *Pure and Applied Geophysics* **163**, 301-349 (2006).

[2] Weertman, J. Unstable slippage across a fault that separates elastic media of different elastic constants. *Journal of Geophysical Research* **85**, 1455-1461 (1980).

[3] Andrews, D. J. & Ben-Zion, Y. Wrinkle-like slip pulse on a fault between different materials. *Journal of Geophysical Research-Solid Earth* **102**, 553-571 (1997).