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Generation and propagation of stick-slip waves over a fault with rate-independent friction

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Earthquakes generated at faults are either produced by rapid (sometimes supersonic) propagation of shear cracks/ruptures along the fault or originated in the stick-slip sliding over the fault. In some cases, supersonic (faster than the shear wave velocity) propagation of earthquake-generating shear ruptures or sliding is observed. This gave rise to the concept of supersonic shear crack propagation, much researched in the literature.

Here we consider another mechanisms of supersonic sliding propagation. We concentrate on the stick-slip sliding as the earthquake mechanism. It is conventionally assumed that the mechanism of stick-slip lies in intermittent change between static and kinetic friction and the rate dependence of the friction coefficient. However the accumulation of elastic energy in the sliding plates on both sides of the fault can produce oscillations in the velocity of sliding even if the friction coefficient is constant. These oscillations resemble stick-slip movement, but they manifest themselves in terms of sliding velocity rather than displacement. Furthermore, over long faults the sliding exhibits wave-like propagation.

We developed a model that shows that the zones of non-zero sliding velocities propagate along the fault with the velocity of p-wave. The mechanism of such fast movement is in the fact that sliding of every element of the rock at the fault surface creates normal (tensile/compressive) stresses in the neighbouring elements (normal stresses on the planes normal to the fault surface). The strains associated with these stresses are controlled by the Young's modulus rather than shear modulus resulting in the p-wave velocity of propagation of the sliding zone. This results in the observed supersonic (with respect to the s-waves) propagation of the apparent shear rupture.

Keywords: Stick-slip, Rate-independent friction, Supersonic propagation.