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Relaxation oscillations of slip and crack instabilities

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The source of earthquakes is commonly attributed to a frictional stick-slip instability occurring on a preexisting fault plane creeping steadily. This instability is characterised by long periods of "stick" where the stress builds up and which are divided by abrupt stress drops and fast sliding spikes accompanied by elastic radiation. Stick-slip originates from a Hopf bifurcation when the stiffness of the medium, that is the ratio of the elastic shear modulus by the medium thickness, is less than a critical value. When the friction force depends on the slip rate, as considered generally, this critical stiffness is proportional to the slope of the steady-state friction coefficient. However, stick-slip phenomena have also been observed in Fracture Mechanics in the sense that the crack propagation can be oscillatory. In both cases, these oscillations are produced when the friction law or the specific fracture energy show a velocity weakening. As a result, it is clearly of great interest to compare and contrast these two types of stick-slip as possible earthquake mechanisms.

In order to motivate development of theoretical models and measuring techniques of electromagnetic and acoustic emissions which would lead to the discrimination between these two oscillatory modes of failure in natural environments, we report on recent work devoted to relaxation oscillations arising in brittle systems for which the friction law or the specific fracture energy are spinodal (*i.e.* 'N-shaped') functions of the rate of failure propagation. Relaxation oscillations are indeed special kinds of periodic orbit characterised by slow and fast dynamics, the latter one most likely responsible of elastic radiation associated with large jumps in velocity.

First, in the context of rate-and-state friction, we concentrate on the frictional stick-slip of a single interface embedded in an elastic body of finite thickness. We show how

a relaxation oscillation regime is reached when the stiffness is small enough. Then, studying a spring-block system, the effects of inertia are emphasised in relation with the existence of three time scales which determine the evolution of the block velocity as the faster variable, the interfacial state as the medium variable and the spring force as the slowest variable. It is found that the main inertial effect is characterised by a double stress drop. The first one happens during the first phase of the fast dynamics associated with the acceleration of the block and the first velocity jump. A rapid stress build-up follows before the second stress drop which is slow and accompanied by the brutal stop of the block. Finally, we present comparisons with a model of stick-slip fracture for which the crack-tip motion is assumed to be inertia-dependent.