Dynamic fault weakening and fracture energy in a fault zone governed by thermal
pressurization

M. Cocco, A. Bizzarri

We model the traction evolution during the dynamic propagation of earthquake
ruptures governed by different friction laws with thermal pressurization of
pore fluids. The adopted numerical procedure allows us to perform 3 - D
simulations in which the heat generated during sliding raises the pore
pressure and reduces fault friction. The goals are to understand how
dynamic traction varies with slip and the physical mechanisms controlling
dynamic weakening during slip episodes. These features have important
implications on the estimate of fracture energy as well as on the size
of the characteristic slip-weakening distance (Dc). We have performed
different numerical experiments varying the thickness of the slip zone as
well as the hydraulic diffusivity. Our results show that the thickness of
the slip zone and the hydraulic diffusivity value modify the shape of the
traction versus slip curves. Numerical simulations performed with different
constitutive formulations reveal that the evolution law strongly affects the
traction dependence on slip. For particular configurations, the traction

evolution shows a gradual and continuum weakening with increasing slip for
which the definition of Dc might become rather meaningless. Our results
confirm that breakdown stress drop is inversely proportional to fault
thickness and to hydraulic diffusivity. A similar relation has been found
for the characteristic slip - weakening distance Dc. The increase of Dc
caused by thermal pressurization is relevant: we have found that values
larger than 0.6 m are measured for a hydrated fault zone, while the
resulting value for a dry fault is equal to 0.09 m. We observe that,
if diffusivity is comparable or slightly larger than laboratory values,
the breakdown stress drop (i. e., the difference between the minimum and
the yield stress values) is very large. This suggests that earthquake
stress drop might be nearly complete. The estimated fracture energy
values are consistent with those inferred seismically.