On the slip-weakening behavior in rate- and state-dependent constitutive laws

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The solution of the dynamic rupture problem requires the use of a constitutive law that relates the total dynamic traction to fault friction. In the literature different constitutive equations have been proposed, which can be grouped in two main classes: the slip dependent and the rate- and state-dependent laws. In this study we use a 2D in-plane solution of the elastodynamic equation adopting a finite diffence approach to compare these two constitutive laws for equivalent sets of the initial parameters. Our modeling results clearly show that the dynamic solution obtained by using a rate- and state-dependent friction law implies a slip dependence of the dynamic traction, as also previously observed by different authors either in laboratory experiments or in theoretical models. We emphasize, however, that the shape of the slip weakening curve obtained in this case is much more general: It shows a slip hardening phase preceding the traction drop (weakening phase) and an equivalent critical slip weakening distance (D_o^{eq}). It is important to point out that the characteristic length for scaling the dynamic parameters in the framework of rate- and state-dependent constitutive laws is the distance L, which has the meaning of a characteristic length controlling the state variable evolution. This implies that the nucleation patch depends on L and not on the equivalent critical slip weakening distance. Our simulations show that the adopted constitutive parameters A, B and L control the traction dependence on slip. In particular, we emphasize that for the same L value but using different B and A, the equivalent critical slip weakening distance as well as the slip-hardening phase changes considerably. Moreover, D_o^{eq} and the weakening rate depends on L. These results have important implications: They allow to explain large critical slip weakening distances ($D_o^{eq} \approx 1m$) as resulting from dynamic consistent waveform inversions, but small nucleation patches (if $L \approx 1mm$). Moreover, they provide a physical interpretation of the variation of the weakening rate and of the initial slope of the weakening curve, which have been recently proposed to control the nucleation duration.

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