Dynamic Aspects of Rupture Propagation at a Subsonic but Near-Rayleigh Wave Speed

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In seismology, instead of using the terminology "Doppler effect" referring to frequency variations in observed waves, waves radiated from moving seismic sources are usually evaluated in light of change in radiation pattern, directivity or the finiteness factor, despite the fact that the variation in the wave field related to seismic pulses radiated from sources propagating at certain speeds is a straight outcome of the Doppler effect (Douglas, Hudson and Pearce, *BSSA*, 1988; Uenishi, *IUGG*, 2019). Here, dynamics of rupture propagation is briefly described in view of this Doppler effect or wave field that changes with the relative rupture propagation speed, namely, the Mach numbers. It is indicated that if the speed of rupture propagation is in a supershear or supersonic range exceeding one or both of the body wave speed(s), Mach front(s) and accompanying intense seismic oscillations can be induced (e.g. Uenishi, *Ph.D. thesis*, 1997, Uenishi, Rossmanith and Scheidegger, *BSSA*, 1999). The physical phenomena can be visibly depicted by taking into account an energy source (line load) steadily moving at a constant speed V over an isotropic, homogeneous linear elastic half-space, with longitudinal and shear wave speeds being V_P and V_S, respectively. The characteristics of the solution to this problem are governed by the two Mach numbers M_P and M_S or V/V_P and V/V_S, respectively, and three cases (a) supersonic ($1 < M_P < M_S$ or $V_S < V_P < V$), (b) transonic or supershear ($M_P < 1 < M_S$ or $V_S < V < V_P$) and (c) subsonic ($M_P < M_S < 1$ or $V < V_S < V_P$) can be recognized. While the isochromatic fringe pattern (contours of the maximum in-plane shear stress) or wave field for the (a) supersonic case is composed of only two singular lines or Mach fronts, in the (b) supershear case there is one single Mach front due to the shear wave and the longitudinal wave information is widely spread in the asymmetric wave pattern. In the case of (c) subsonic energy source propagation, the fringe patterns are symmetric like static ones although the source is dynamically traveling. However, unlike sound propagation in the air, even in the subsonic case, at the Rayleigh wave speed ($V = V_R$), the stresses become infinite (Rossmanith, Uenishi and Kouzniak, *Fragblast*, 1997; Uenishi and Rossmanith, *Fragblast*, 1998). That is, rupture propagation at a near-Rayleigh speed can cause very severe, resonance-like seismic motion. Thus, dynamically, in order to have strong seismic motion, the fault rupture need not be supershear. It can be still subsonic. This viewpoint is reinforced by the theoretical investigation of the stress field around a dynamically propagating rupture, as described by both singular elastic crack models and slip-weakening rupture models (Poliakov, Dmowska and Rice, *JGR*, 2002) where the rupture speed V, especially that close to V_R, is shown to play a crucial role in the prediction of the change of the size of damage regions around a rupturing fault. However, this resonance or the generation of larger damage regions due to dynamic rupture at a near-Rayleigh wave speed, or some 90 percent of the relevant shear wave speed, seems to be nearly ignored, even though such a speed in the subsonic range is frequently assumed in kinematic seismic inversions.

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