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Radiation efficiency during slow crack propagation: an experimental study.

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Creeping faults are known to host a significant aseismic deformation. However, the observations of micro-earthquake activity related to creeping faults (e.g. San Andreas Faults, North Anatolian Fault) suggest the presence of strong lateral variabilities of the energy partitioning between radiated and fracture energies. The seismic over aseismic slip ratio is rather difficult to image over time and at depth because of observational limitations (spatial resolution, sufficiently broad band instruments, etc.). In this study, we aim to capture in great details the energy partitioning during the slow propagation of mode I fracture along a heterogeneous interface, where the toughness is strongly varying in space.We lead experiments at laboratory scale on a rock analog model (PMMA) enabling a precise monitoring of fracture pinning and depinning on local asperities in the brittle-creep regime. Indeed, optical imaging through the transparent material allows the high resolution description of the fracture front position and velocity during its propagation. At the same time, acoustic emissions are also measured by accelerometers positioned around the rupture. Combining acoustic records, measurements of the crack front position and the loading curve, we compute the total radiated energy and the fracture energy. We deduce from them the radiation efficiency, η_R, characterizing the proportion of the available energy that is radiated in form of seismic wave. We show an increase of η_R with the crack rupture speed computed for each of our experiments in the sub-critical crack propagation domain. Our experimental estimates of η_R are larger than the theoretical model proposed by Freund, stating that the radiation efficiency of crack propagation in homogeneous media is proportional to the crack velocity. Our results are demonstrated to be in agreement with existing studies which showed that the distribution of crack front velocity in a heterogeneous medium can be well described by a power-law decay function above the average fracture front speed, $\langle v \rangle$, and then establishing a relation of the type $\eta_R \propto \langle v \rangle^{0.55}$. These observations suggest that the radiation efficiency in heterogeneous media is defined by a power law involving a lower exponent value than the one predicted for a homogeneous media, but is sensitive to the shape of the velocity distribution of the heterogeneous interface. Finally, when studying the case of similar events observed in natural conditions, such as seismic swarms associated to slow slip along a fault, we notice a good agreement between our results and the radiation efficiency computed for these field data.