The experiments of dynamic pressure surge in a fluid-filled fracture as a possible earthquake triggering due to passing seismic waves

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The geological environment is always interacting with different physical fields. It has been established in observation seismology that a tiny dynamic stress perturbation can trigger the earthquake with the participation of fluids. The underlying cause of this dynamic triggering is still not well understood. A possible mechanism for the dynamic earthquake triggering could be the pressure amplification in the fluid-filled fractures in the earth crust in response to a transient seismic wave. We call this the Transient Pressure Surge Effect. We have conducted low-frequency experiments to detect the pressure surge under controlled laboratory conditions based on the numerical modeling prediction showing that the PS effect occurs in the low-frequency regime (Zheng, 2018). We found the evidence of significant fluid pressure amplification in the fracture (Jin et al., 2021).

In our laboratory experiments, we made a fracture model by stacking two Plexiglass blocks on top of each other. The thickness of each one is around 8 cm. The length of the fracture was 120 cm and the width 36 cm. Both blocks were immersed in the water tank. The thicknesses of water layer above and under the model were the same, around 40 cm. The space between two Plexiglass blocks was filled by water as the fluid-filled fracture. The aperture was adjustable and varied from 0.2 mm to 9.2 mm. We sealed three sides of the fracture and kept the side facing the seismic source open. Because the PS effect appears at low frequencies, we made a low-frequency source (X-Frac-S) which was installed in fixed distance from the model and immersed in water. The source can vibrate to produce adjustable single-frequency sinusoid pressure waves in water from $\sim$ 10 to 70 Hz. There were difficulties in finding a miniature sensor for the dynamic pressure measurements in the thin fracture. We designed and made a disk-shaped thin pressure transducer (X-Frack-H) of $\sim$0.2 mm in thickness.

To qualitatively measure the PS effect, we defined Pressure Surge Factor (PSF) as the ratio between the wave amplitude inside the fracture and that of the incident wave, as a function of incident wave frequency. We observed that PSF depends on fracture geometry, size, aperture, and the incident wave frequency. We achieved the maximum pressure surge factor (PSF) 25.2 at frequency about 29 Hz in the fluid-filled fracture with aperture 0.95 mm. Extrapolating to the field scale (100 m fracture) we anticipate observing large PSF ($>$100) at frequency around 0.1 Hz or lower. The Pressure Surge effect can drastically increase the pore fluid pressure, which enables the Coulomb failure and leads to the fault rupture. The laboratory verification of transient pressure surge phenomenon is a critical step in understanding the mechanism of dynamic triggering of earthquakes.

References.

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