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Reflection, radiation and attenuation of Stoneley guided waves in fluid-filled fractures

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We study the reflection, radiation and attenuation of Stoneley guided waves in fluid-filled fractures in elastic rocks. Stoneley guided waves have been considered in the literature, for example, to explain long-period volcanic tremor signals or to propose methods for determining the fluid properties in fractured rocks. We use the finite element method (FEM) to model two-dimensional wave propagation in an elastic rock with an elliptically shaped finite crack (aspect ratio of length to thickness is 333) filled either with a viscous or inviscid fluid. The fluid in the crack is elastic in its bulk deformation behavior but viscous in its shear deformation behavior. Therefore, only P-waves are able to propagate within the crack, which are dispersive and attenuated. The crack geometry, especially the crack tip, is resolved in detail by the applied unstructured finite element mesh using 7-node triangles. The presence of a fluid-filled crack in the elastic rock gives rise to a so called Stoneley guided wave that is bound to and propagates along the crack walls with a much smaller velocity than all other waves in the system. At the tip of the crack the Stoneley guided wave is reflected. The reflection coefficient at the crack tip for cracks filled with common natural fluids (water, oil, hydrocarbon gas, magma) is around 0.8. The reflection coefficient depends on the crack shape. For example, the reflection coefficient of a rectangular crack is significantly smaller. Part of the Stoneley guided wave energy is converted and radiated at the crack tip as P- and S-waves. We also present results of Stoneley guided waves in rocks with two intersecting fractures and in fractures filled with two different fluids.

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