Linear Solid/Fluid Seismic Model for Heavy-Oil Related Media

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Abstract

The existing approaches to modeling seismic waves in attenuative media are based on time-dependent moduli and the quality factor (Q). In numerical algorithms, these properties are usually implemented by the Generalized Standard Linear Solid (GSLS), which is often illustrated by combinations of elastic and damping mechanical elements arranged in 'Maxwell's bodies'. However, although the concepts of Q and GSLS are usually thought to be very general, neither of them covers all cases of practical importance. In particular, the GSLS appears inadequate for fluids, fluid/solid mixtures, saturated porous rocks, and generally cases of low Q and transitional solid-fluid behaviour, such as bitumen-rich rocks.

Here, we propose a broader class of rheologies that we call the General Linear Solid (GLS). The GLS is rigorously described by using the macroscopic continuum Lagrangian mechanics. Conventional spring-dashpot diagrams can be used to represent the structure of the Lagrangian model. The GLS rheology includes viscous solids, fluids, fluid-saturated porous rocks as well as the GSLS and numerous more complex cases. The model also offers straightforward extensions, such as to thermoelasticity and nonlinear elasticity, viscosity, and plasticity. GLS equations of motion take the form of differential matrix equations, and finite-difference schemes can be readily derived for numerical simulations in such media. The model is illustrated by modeling recent observations of low-frequency P-wave viscoelasticity in bitumen sands.

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