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Borehole Guided Wave Analysis With Poroviscoelastic Model Based On Effective Biot Theory

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In borehole sonic logging dispersion analysis, classical Biot theory is normally used to describe the formation media (Norris, 1989)). However, the classical Biot theory ignores all wave-induced flow at the mesoscopic scale, and when applied to a homogeneous medium cannot explain the high level of attenuation observed in natural porous media over the full seismic frequency range. This problem has been successfully solved in effective Biot theory. Therefore, we investigated the dispersion behaviour considering the effects over the full frequency range by applying effective Biot theory with the moduli replaced with general Zener model (Liu et al,2016).
We first upscale the effective Biot theory to a poro-viscoelastic model with the recently developed method developed in Liu et al (2018). Here, the moduli of the poro-viscoelastic model are represented by the relaxation functions of the generalized fractional Zener model. Then, all the elastic moduli in the borehole logging dispersion equations are replaced with their corresponding generalized fractional Zener models for the dispersion calculation over the full frequency range.
The velocity dispersion characteristics of borehole guided waves were calculated to investigate the influences of attenuative borehole fluid, an attenuative solid frame of the formation, and an impermeable borehole wall. The results show that the intrinsic attenuation of the borehole fluid and that of the solid frame can both cause significant changes in the phase velocities of guided waves at higher frequency, especially for pseudo-Rayleigh waves. For example, the phase velocity of Stoneley waves in an elastic borehole fluid with an attenuative frame of formation can be higher than the constant velocity of the borehole fluid at the high frequency limit, whereas phase velocities of the pseudo-Rayleigh waves do not approach the velocity of the borehole fluid if it is attenuative. By contrast, in spite of an attenuative solid frame of formation, an impermeable borehole wall results in dispersion curves approaching the velocity of the elastic borehole fluid at high frequency as if the solid frame was elastic and non-attenuative. These new results strongly indicate the necessity to consider the influence of wave induced flow at the mesoscopic scale on the dispersion of borehole guided waves.
References
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