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Analysis of attenuation and dispersion of Love waves in viscoelastic media by finite-difference modeling

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Rayleigh-wave exploration method, which is non-invasive, high-efficiency and high-resolution approach, has been used widely for estimation of Shear-wave velocities of near-surface materials by inverting dispersive Rayleigh-wave phase velocities. Love waves are the result of constructive interference of multiple reflections of SH waves at the free surface, and their particle motion is parallel to the surface but perpendicular to the direction of propagation. Like Rayleigh waves, Love waves are also one kind of surface waves. Nevertheless, unlike Rayleigh waves, the dispersive nature of Love waves is independent of P-wave velocity. This characteristic not only makes Love-wave dispersion curves simpler but also reduces the degree of non-uniqueness leading to more stable inversion of Love-wave dispersion curves. Therefore, Love-wave exploration method has received increased attention from the near-surface geophysics community interested in application to a variety of near-surface geological and geophysical problems. So far, Love-wave exploration method is still based on the theoretical framework of elastic media. However, the Earth has been recognized as the anisotropic-viscoelastic media with the significant effects on seismic-wave propagation, especially on surface waves. Thus, it is of great importance to study the characteristics of Love waves in viscoelastic media for further broadening the application field of Love-wave exploration method and guiding the practical exploration works.

In this study, the first-order SH velocity-stress wave equations of 2-D viscoelastic media in time domain, which are based on the viscoelastic theory of generalized Zener body (GZB), are used for modeling the propagation of Love waves. In order to obtain results with high accuracy, we adopt a standard staggered grid (SSG) finite-difference (FD) scheme, which incorporates the free-surface boundary condition of the stress image method (SIM) and the absorbing boundary condition of the multiaxial perfectly matched layer (M-PML). We also extend the generalized reflection and transmission coefficients method (GRTM) from the elastic media to the viscoelastic media, which can be used for demonstrating the accuracy of FD method by the analytical seismogram and verifying the correctness of modeling results by the theoretical dispersion curves. In a two-layer model, we analyze the characteristics of attenuation and dispersion of Love waves by comparisons of modeling results between elastic media and viscoelastic media in terms of synthetic seismograms and dispersive images, respectively. In addition, we also utilize three typical four-layer models to further analyze the characteristics of Love waves in the viscoelastic layered media.