Identification of a viscoelastic substitute model for seismic attenuation in heterogeneous poroelastic media by numerical homogenization

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ABSTRACT

Seismic attenuation in partially saturated porous rocks is of enormous scientific and economic interest. Especially at low seismic frequencies, oil and gas reservoir rocks frequently exhibit high P-wave attenuation and dispersion. Attenuation analysis can, therefore, be used for the interpretation of seismic data in order to assess the degree of pore fluid saturation or quality of reservoir rock. The present contribution studies in detail the wave-induced fluid flow caused by pore pressure differences between mesoscopic heterogeneities at frequencies f<100 Hz. The partially saturated rocks are approximated on the mesoscale by a poroelastic medium with regions fully saturated by one fluid and other regions fully saturated by another fluid (patchy saturation). However, mesoscopic heterogeneities may also occur in the material properties of the solid frame representing regions with different elastic moduli. Passing seismic waves lead to pore pressure gradients and induce seepage. Due to the viscous fluid flow, part of the wave energy is dissipated. The poroelastic mesoscale is modelled using Biot's equations of linear consolidation neglecting body and inertia forces. The pore pressure diffusion is interpreted as a local phenomenon. That is, the mesoscopic diffusion problem is restricted to a length scale much smaller than the observable scale. Under these circumstances, the resulting homogenized model substituting the heterogeneous coupled problem can be understood as a (viscoelastic) Cauchy continuum, see [1]. Due to the low wave frequencies, inertia effects can be ignored and only transient poroelastic initial value problems have to be considered on the level of a mesoscopic representative volume element. In the present contribution, we establish a computational homogenization framework for the transition from a heterogeneous poroelastic to a homogeneous viscoelastic medium, see [2, 3]. Periodic boundary conditions for the coupled problem are used on the level of mesoscopic volume elements. We show how to identify an orthonormal basis for the local pore pressure field that evolves during transient loading. Taking into account the linearity of the poroelastic model, we may use the superposition principle for computing the response variables. The proposed method will be validated in terms of numerical experiments.

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