Thermoelastic constitutive relations for initially-stressed elastomers: Application to the pore expansion of kerogen under in-situ stresses

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Abstract

With the breakthrough of hydraulic fracturing and in-situ conversion technologies in exploiting unconventional energies, more attention has been paid to modeling the non-linear deformation of organic matter under in-situ stresses and thermal fields. As a generalization to Ogden's invariant formulations and Hoger's multiplicative decomposition, new thermoelastic constitutive theories for initially stressed elastomers are required to describe the change of underlying mechanical responses triggered by the required temperature variation.

This study develops a general thermoelastic constitutive relation for soft elastomers with initial stresses. We first reveal the initial temperature dependence of conventional thermoelastic models. This property attributes the alteration of the underlying thermoelastic response to free thermal expansions. Then, a compatibility-breaking-compensation framework is established based on thermoelasticity. Specifically, a free thermal expansion is generated to eliminate the Riemannian curvatures of the virtual stress-free configuration derived from the isothermal stress release. Once the conventional thermoelastic model without initial stress is specified on the natural configuration, the desired initially-stressed constitutive relation can be constructed using the intrinsic embedding method of initial states.

By carrying out comparative analyses of the pore expansion of kerogen under in-situ stresses between the current constitutive relation and the existing theories, the influences of adopting distinct background residual stresses, the performance of the non-local effect, and the availability of the new constitutive relation are presented. Our approaches may shed some light on the theoretical modeling of multi-field coupling problems.