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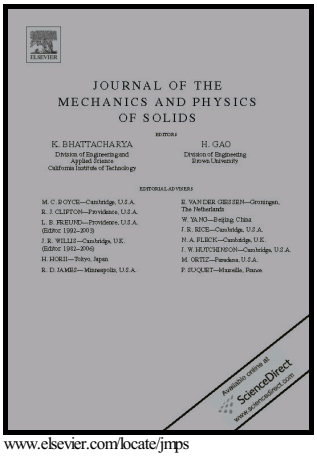

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On the Thermodynamics of Smooth Muscle Contraction

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Abstract

Cell function is based on many dynamically complex networks of interacting biochemical reactions. Enzymes may increase the rate of only those reactions that are thermodynamically consistent. In this paper we specifically treat the contraction of smooth muscle cells from the continuum thermodynamics point of view by considering them as an open system where matter passes through the cell membrane. We systematically set up a well-known four-state kinetic model for the cross-bridge interaction of actin and myosin in smooth muscle, where the transition between each state is driven by forward and reverse reactions. Chemical, mechanical and energy balance laws are provided in local forms, while energy balance is also formulated in the more convenient temperature form. We derive the local (non-negative) production of entropy from which we deduce the reduced entropy inequality and the constitutive equations for the first Piola-Kirchhoff stress tensor, the heat flux, the ion and molecular flux and the entropy. One example for smooth muscle contraction is analyzed in more detail in order to provide orientation within the established general thermodynamic framework. In particular the stress evolution, heat generation, muscle shorting rate and a condition for muscle cooling is derived.

Keywords. Continuum thermodynamics; smooth muscle cell; contraction; kinetic model; constitutive equation; entropy inequality; Gibbs free energy