Abstract

The Stroh formalism provides a strict and structured framework of investigating anisotropic continuum systems, discovering natural symmetries and simplifying compact first-order models that are needed to study wave propagation and coupled-field interactions. This makes it a good starting point of generalizing classical elasticity to more multiphysics models due to its versatility. This thesis constructs a unified Stroh-Hamiltonian framework for modeling reversible multiphysics processes in anisotropic porous solids, with a focus on poroelastic and thermoporoelastic interactions. Inspired by structural similarities between classical Stroh sextic formalism of anisotropic elasticity and canonical Hamiltonian systems, the work generalizes this analogy to a family of coupled solid-fluid-thermal systems based on the Biot theories. The first part of the thesis defines a Hamilton representation of incompressible poroelasticity under perfectly drained conditions, and thus explains how incompressibility and the lack of the pressure gradients reorganize the canonical variables and put constraints on the dynamics that are reversible. This formulation sheds new light on the energy conjugate relationships determining the solid deformation and fluid induced effects.

Based on this foundation, the second part introduces a generalized reversible framework for anisotropic thermoporoelasticity, developed from the Duhamel–Neumann constitutive relations, and expressed through a Lagrangian density formulated to reflect both mechanical, hydraulic, and thermal variations. By recasting the governing equations in canonical form, the thesis highlights intrinsic symmetries, clarifies the coupling mechanisms among stress, temperature, pore pressure, and seepage displacement, and provides a systematic platform for analyzing wave propagation and boundary-value problems in multiphysics media.

The last contribution generalizes the methodology of Stroh-Hamiltonian to the special case of thermoporoelasticity when the solid constituents are incompressible. The expression narrows the set of acceptable pairs of dual variables and provides a brevity of first-order form that takes on reversible thermo-fluid-structure interactions with incompressible restrictions, thus offering a serious path of analysis to the investigation of strongly coupled processes in anisotropic fluid-saturated materials.

Collectively, the thesis not only advances the theoretical basis of reversible coupled field modeling, but also introduces a systematic canonical formalism that can be used throughout the poroelastic, thermoporoelastic regimes and provides a basis on which dissipative processes, heat conduction and nonlinear material behaviour can be incorporated.