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A general framework for the modeling of porous ferrogels at finite strains

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Abstract

Porous ferrogels are a new class of magneto-active composite materials that deform and alter their material characteristics under the influence of magnetic fields. In the future such materials could find a wide range of application in biomedicine and microfluidics. In this work we present a theoretical and computational framework for the macroscopic, continuum-based modeling of porous ferrogels at finite strains. Departing from the balance laws of continuum mechanics, we derive a thermodynamically consistent model based on Biot's consolidation theory. Regarding constitutive modeling we limit our attention to isotropic materials. Furthermore we discuss details of the numerical implementation of the coupled three field problem within a nonlinear finite element algorithm. The modeling capabilities and algorithmic performance are demonstrated by means of two representative initial boundary value problems.

Keywords: Magneto-active materials, Porous ferrogels, Magneto-poro-mechanics, Porous media, Magnetoelasticity, Large deformations, Finite element analysis

1. Introduction

Porous ferrogels are a new class of smart materials consisting of a polymer matrix with dispersed micro- or nano-sized magnetizable particles. The polymeric matrix is permeated by an interconnected network of pores, which are filled with liquid. Based on the arrangement of the magnetic particles within the polymer matrix one can distinguish between isotropic and anisotropic ferrogels. In isotropic ferrogels the magnetic particles are randomly distributed throughout the matrix while in anisotropic ferrogels the particles are aligned in chain-like structures. Such particle arrangements are realized by the synthesis of the ferrogel under the presence of a magnetic field. In this paper we focus on the isotropic category. Due to their fast responsiveness and large volumetric

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