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A phase-field approach embedded in the Theory of Porous Media for the description of dynamic hydraulic fracturing

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Abstract

Hydraulic fracturing is a big issue in the exploitation of oil and gas resources as well as in the production of heat in deep geothermal energy plants. Investigating hydraulic fracturing processes numerically by means of a finite-element analysis, one has to address the porous solid and its pore content within a fully coupled computational approach. For this purpose, the present article combines the well-established Theory of Porous Media with elements of fracture mechanics, especially, with the phase-field approach to fracture, which has proven as a successful tool for the computation of fracturing processes in the field of standard solid mechanics.

Although hydraulic fracturing is widely applied in practice, this procedure has not yet been investigated adequately by means of a full theoretical and computational framework on the basis of a multicomponent medium tackling a porous solid skeleton and its pore content with their mutual interaction of deformation and fracture, and fluid-driven processes both in the solid bulk and cracking domains. Addressing these features, the article concentrates on a permeable elastic solid skeleton, where the fracturing process is governed by brittle fracture driven either by a prescribed fluid pressure or by a prescribed fluid influx. Two- and three-dimensional numerical examples computed by use of the coupled solver PANDAS exhibit the possibilities of this approach.

Keywords: Phase-field theory; Theory of Porous Media; hydraulic fracturing

1. Introduction

Hydraulic fracturing in porous media came into play in the late 1940s and found its application in oil and gas industries, the exploitation of deep groundwater sources and deep geothermal energy plants. Only after 1990, it was also applied for the exploitation of unconventional oil and gas resources such as shale gas. Hydraulic fracturing, also known as "fracking", is a common technique in oil and gas industries. The key point

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