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A New Compositional Model for Hydraulic Fracturing With Energized Fluids

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Abstract

Traditional fracturing models regard fracturing fluids as a single-component, single-phase fluid. This assumption is clearly incorrect for energized fluids, where phase changes and mass transfer between phases play important roles in controlling fluid rheology, leak-off, and fracture geometry. A model is developed to simulate hydraulic fracturing with energized fluids. Compositional balances allow us to track the changes in phase behavior and fluid properties such as rheology and multi-phase leak-off. An energy balance is implemented in order to consider temperature changes during fracturing. Phase behavior has been taken into account through an equation of state formulation. These compositional and phase behavior effects are coupled with a geo-mechanical model for fracture propagation.

It is shown that phase behavior and leak-off can significantly change the composition and fluid rheology in the fracture. This has a dramatic effect on the fracture geometry. Phase behavior changes are closely coupled to the temperature and pressure changes in the fracture. The temperature, phase behavior, and partitioning of components in the liquid and gas phases have a significant effect on fracture dimensions. For example, shorter and wider fractures can be obtained by foaming an energized fluid. With the model presented, these temperature, pressure, and composition changes can now be accurately modeled and incorporated into the fracture growth and geometry.

Introduction

A hydraulic fracturing process can be energized by the addition of a compressible, sometimes soluble, gas phase into the treatment fluid. When the well is produced, the energized fluid expands and gas comes out of solution. This, coupled with the high mobility of the fluid in the fracture, results in a rapid cleanup of the fracturing fluid as it is blown out of the well by the liberated gas phase.[1]

Energized fluid fracturing can be utilized for many reasons, but its common applications are in reservoirs that have a low fluid pressure,[1] or when the formation is sensitive to water.[2,3] When the reservoir pressure is low, the viscous forces applied to the trapped liquid phase (usually water) may not be sufficient to overcome the capillary pressure of the fracturing fluid in the formation; this results in little or no flowback. With energized fluids, the creation of a free gas phase in the rock matrix allows the gas relative permeability to increase as soon as the pressure is reduced. Energized fluids also minimize or eliminate the use of water when water causes fines migration or clay swelling problems in the formation.

Energized fluids can use CO_2,[2,4] N_2,[5,6] methanol,[7] or any combination of gases.[8] They can be pumped solely as an energized fluid[3,9] or can be mixed with an external phase, such as a cross-linked gel or hydrocarbons.[10] CO_2 and N_2 added to a traditional, aqueous based fluid is common and can be beneficial at high volume fractions because foam is created. Foam has all the same advantages as other energized fluids with similar composition, but has higher viscosities than single-phase fluids.

In traditional hydraulic fracture modeling, fracture dimensions are estimated and propagated over time by coupling rheological fluid flow models and fracture mechanics. The fluid is assumed to be incompressible, causing balances to be performed by volume conservation. Traditional fracturing fluids are single-phase and do not require that compositional effects be taken into account. The process is also assumed to be isothermal; the fluid properties are evaluated at reservoir temperatures. The reader is referred to Nordgren[11] for an example of a model with these assumptions.