SPE 110845

A Novel Hydraulic Fracturing Model Fully Coupled With Geomechanics and Reservoir Simulator

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This paper was prepared for presentation at the 2007 SPE Annual Technical Conference and Exhibition held in Anaheim, California, U.S.A., 11–14 November 2007.

Abstract

Unconventional fracturing techniques, such as high rate waterfracs, waterflooding or steam stimulation, produced water and cuttings re-injection, CO_2 sequestration, N_2 , CBM stimulation etc., are difficult to model because of strong interactions among the fracturing process, geomechanical changes in the porous media, and reservoir fluid flow. The resulting strong poroelastic/thermoelastic effects, permeability/porosity changes, and possible rock failure (shear fracturing) make current conventional fracturing models inadequate in such circumstances. Therefore, it is necessary to develop new models which include all of these mechanisms and which are capable of integrated data analysis.

This paper presents a new fracturing model with all of these mechanisms included. The model fully couples fracture mechanics with reservoir and geomechanics simulation. This methodology allows us to model fracture initialization and propagation, post-frac multiphase cleanup in the reservoir and fracture, and pre- and post-frac well performance in a changing stress and pressure environment, all within the same system.

The model couples a three-dimensional (3-D) finite element geomechanics model with a conventional 3-D finite difference reservoir flow simulator. The geomechanics module implicitly models fracture propagation via displacements on the fracture face. The flow and geomechanics/fracturing are coupled in an iterative manner that is equivalent to full coupling of geomechanical modeling. The 3-D (planar) fracture geometry and pressure are the common dynamic boundary conditions for the flow and stress modules. The new iterative process yields smooth fracture propagation, and the model has been tested on classical fracturing problems.

A field example where we model a waterfrac stimulation performed in Bossier tight gas sands is presented to demonstrate the models' capabilities as well as the validity and advantages of the approach. The results show that the model is capable of matching a complex history of injections and calibrating the stress-dependency of formation permeability.

Introduction

Fracturing occurs both in conventional stimulation operations and in many other reservoir processes (unconventional fracturing applications), such as high rate waterfracs, waterflooding at fracturing pressure, produced water re-injection (PWRI), steam injection, or drilling cuttings re-injection. In contrast to conventional fracturing, these unconventional fracturing applications are usually characterized by high fluid leakoff velocity from the fracture into the reservoir, significant changes in stress, pore pressure, permeability and porosity, all possibly in a large region around the wellbore and fracture.[1,2] These phenomena are often manifested by interactions among geomechanical aspects of the porous media and reservoir fluid flow.[3] **Figure 1** is a schematic diagram illustrating these interactions. To properly account for all of these effects we model the fracturing processes by fully coupling the fracture mechanics with reservoir and geomechanics simulation. This allows us to better understand the physics associated with both conventional and unconventional applications.

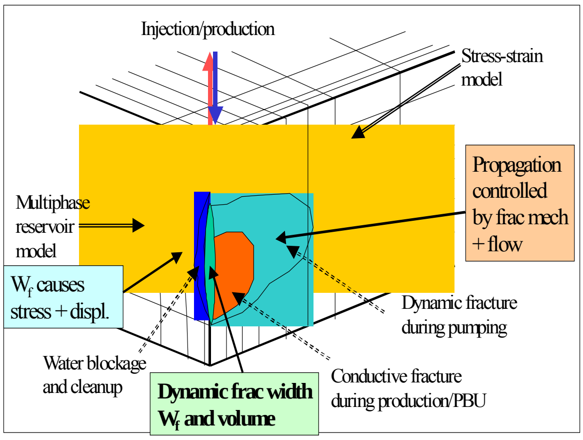

Fig. 1--Coupled geomechanical fracturing modeling system.

Coupled simulation of fracturing and reservoir flow was first proposed in early 1980s[4,5,6]. The essential idea of the coupled simulation is to use two sets of separate grid systems for fluid flow in the fracture and in the reservoir matrix, and numerically solve the fluid continuity equation for fluid flow