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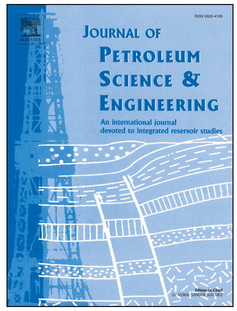

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Modeling method for a rock matrix with inclusions distributed and hydraulic fracturing characteristics

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Abstract

A permeability-based hydraulic fracturing (PHF) model based on a smeared approach is presented in this paper to study fracture propagation. This model is based on the elasto-plastic behavior of a rock-fluid system. The coefficient for the permeability modification of the rock is assumed to be a function of the mean effective stress via a hyperbolic tangent function. Level set method (LSM) is used to track the material interfaces between inclusions and matrix. The transition of interfaces between matrix and inclusions can be described by mathematical functions such as a jump function, linear function and hyperbolic tangent function. Numerical cases are carried out to study the influence of mesh of the traditional finite element method (FEM) and method using the LSM. Results show that coupling the LSM to the FEM is a good way for keeping the mesh unchanged for various rock samples. The propagation characteristics in a rock matrix with regularly distributed inclusions are classified according to the relative position when the fracture tip reaches the inclusions. We observe that the fracture propagation features in a rock matrix with inclusions randomly distributed can be well simulated via the PHF model combined with the LSM. Finally, fracture zone development, fracture opening, and the pore pressure of the observation points in a rock sample with irregularly distributed inclusions are studied by using the presented method.

Keywords: Hydraulic fracturing; level set method (LSM); permeability-based hydraulic fracture model (PHF); smeared approach; finite element method; ABAQUS.

1. Introduction

Hydraulic fracturing is an important technique for oil/gas production. The first experiment was performed in Grant County, Kansas, in 1947 by Stanolind Oil, with the first industrial use being in 1949 (Clark, 1949; Montgomery and Smith, 2010). Various mechanical models have been developed since this technique was proposed to study, for example, the dimensions of a fracture zone. The first two-dimensional fracture model is developed for plane strain conditions in horizontal planes by Khristianovitch and Zheltov (1955). To improve the first model, Geertsma and de Klerk (1969) developed the KGD fracture model, which has a constant and uniform height and rectangular cross-section. A second fracture model is developed based on assumptions of plane strain condition in vertical planes (Perkins and Kern, 1961). Nordgren (1972) further develops this model (PKN fracture model) to accommodate the fracture shape being elliptical (Economides and Nolte, 1989). There are also other versions of those models, such as KGD-C and PKN-C (Valko and Economides, 1995). For three-dimensional analysis, a representative model is the P-3D-C model (Adachi et al., 2007; Rahman and Rahman, 2010), which is based on the pseudo-three-dimensional (P-3D) models (Simonson et al., 1978; Settari and Cleary, 1986; Warpinski and Smith, 1989) by incorporating Carter solution of material balance.

There are numerous numerical methods for the simulation of hydraulic fracture, which can be classified as either discrete fracture approach or smeared approach. The former approach usually explicitly models the fracture during the whole propagation procedure. Popular models for the discrete fracture approach are based on: finite element method (FEM) (Wangen, 2011); cohesive zone model (Dugdale, 1960; Barenblatt, 1962; Sarris and Papanastasiou, 2011); distinct element method (DEM) (Fatahi et al., 2016); extended finite element method (XFEM) (Lecampion, 2009; Mohammadnejad and Khoei, 2013) and meshfree (meshless) method (Nguyen et al., 2016).

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