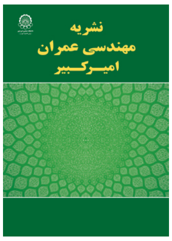

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Study of Permeability Coefficient and Inflow Rate Effects on Hydraulic Fracturing in Saturated Porous Media

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ABSTRACT: In this paper, a finite element model is developed for the fully hydro-mechanical analysis of hydraulic fracturing in saturated porous media. The model is derived within the framework of generalized Biot theory. The fracture propagation is governed by a cohesive fracture model. The flow within the fracture zone is modeled considering the lubrication equation. In order to describe the fracture in the saturated porous media, momentum equation and mass balance equation with Darcy law are employed. The standard Galerkin method and Newmark scheme are used for discretization in space and time, respectively. Finally, the effects of permeability and rate of injection on the hydraulic fracture propagation are studied. It is observed that an increase in permeability leads to slower crack propagation. In addition, increasing flow rate leads to a faster crack propagation. When permeability increases by 3.3 times, CMOD and crack length decreases by 43.8% and 20%, respectively after 1 second and decreases by 29.4% and 15.9%, respectively after 6 seconds. In addition, when flow rate increases by 2, 3, and 4 times, the crack length increases by 30.5%, 55.9%, and 76.3% after one second.

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1- Introduction

Modeling of hydraulic fracturing in a porous medium is an important problem because it has practical applications in a broad range of engineering areas. Hydraulic fracturing is a commonly used method in petroleum engineering to enhance reservoir permeability and performance.

2- Methodology

The saturated porous medium is modeled as a mixture of solid skeleton and water (as wetting phase). In order to describe the behavior of saturated porous media, the linear momentum balance and fluids mass balance equations are used. The mass balance equation for each fluid phase is combined with the general form of Darcy's law to describe the flow behavior of the porous medium under the influence of solid skeleton deformation [1].

For numerical solution, the main equations are discretized in space by Galerkin method and in time by Newmark scheme.

The fracture propagation is governed by a cohesive fracture model. The main concept of cohesive zone is based on the fact that in the cohesive zone, called fictitious process zone (FPZ), the stress can be transferred through the fictitious crack sides. In this model, if the crack tip stress reaches the tensile strength of material, the fictitious crack grows. By opening the crack, the crack surface does not become stress free, but its stress decreases by increasing the crack width according to a cohesive law. In this study, a bilinear cohesive law, which was originally proposed by Espinosa and Zavattieri [2] is used.

In order to perform the finite element model for fracture media, equilibrium equation is implemented for the fractured media.

3- Results

In order to demonstrate a part of the wide range of problems that can be solved by the present approach and to illustrate the performance of the computational algorithm in the modeling of porous media problem, the hydraulically driven fracture propagation problem is solved. To evaluate the accuracy of the finite element solution of crack growth in statured porous media a horizontal section plane strain model is considered. An analytical solution for this problem was obtained by Spence and Sharp [3] and used here for comparison. Then, the effects of permeability and rate of injection on the hydraulic fracture propagation are studied. It is observed that an increase in permeability leads to slower crack propagation. In addition, increasing flow rate leads to a faster crack propagation. When permeability increases by 3.3 times, CMOD and crack length decreases by 43.8% and 20%, respectively after 1 second and decreases by 29.4% and 15.9%, respectively after 6 seconds. In addition, when flow rate increases by 2, 3, and 4 times, the crack length increases by 30.5%, 55.9%, and 76.3% after one second.

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