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Hydraulic fracture crack propagation in heterogeneous rock materials: Efficient numerical solution

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An infinite elastic medium with a planar crack is considered. The crack is subjected to pressure of fluid injected inside the crack at a point of its surface. Description of the crack growth is based on the lubrication equation; the elasticity equation for crack opening caused by fluid pressure, Poiseuille equation related the fluid flux with crack opening and the pressure gradient and the criterion of crack propagation of linear fracture mechanics. The crack growth is simulated by a series of discrete steps. Each step consists of 3 stages: Increasing the crack volume by a constant crack size, crack jump to a new size defined by the fracture criterion and filling the new crack configuration by the fluid presented in the crack. The problem is ill-posed and requires specific methods for numerical solution. The proposed method is based on an appropriate class of approximating functions for fluid pressure distributions on the crack surface. The analysis of evolution of the crack boundary is based on an original method of fast numerical solution of the integral equations of the crack problem of elasticity. The method allows constructing the crack boundary at discrete time moments for media with varying elastic properties and fracture toughness. The model allows accounting filtration of the injected fluid in the medium. Evolution of the crack boundary in the process of fluid injection, time dependence of pressure distributions and crack openings are presented for examples of hydraulic fracture crack growth in layered heterogeneous media. The medium has young modulus 15 GPa, Poisson ratio 0.2, the fluid with viscosity 0.01 Pa.sec is injected with the rate 0.1 m3/sec, fracture toughness of the low half-space is 1 MPa.m1/2 and upper half-space is 1.5 MPa.m1/2, the point of injection is 20 m from the upper half-space.

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