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3D NUMERICAL MODEL OF HYDRAULIC FRACTURE PROPAGATION

Denis V. Esipov[1], Vasily N. Lapin[2] and Sergey G. Cherny[3]

[1] Institute of Computational Technologies SB RAS, 6 Acad. Lavrentjev avenue, 630090, Novosibirsk, esipov@ict.sbras.ru
[2] Institute of Computational Technologies SB RAS, lapdump@ngs.ru
[3] Institute of Computational Technologies SB RAS, cherny@ict.nsc.ru

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Hydraulic fracturing is the one of the powerful technique of oil and gas wells stimulation. Although the models of a hydraulic fracturing treatment are quite developed, there are still some gaps that require the attention of researchers. One of them is the understanding of the behaviour of the hydraulic fracture in the near wellbore area. In the early stage of propagation, it can be simulated only numerically in 3D statement because of geometrical complexity. Also, the first step in simulation of the near wellbore fracture propagation is fracture initiation modelling, which is necessary to predict the location, orientation and shape of a nucleated fracture.

The 3D numerical model of hydraulic fracture propagation which incorporates the model of fracture initiation is presented. The initiation model [1] is based on the maximum tensile stress criterion and the assumption that the local length of the nucleated fracture is a function of the difference between the rock strength and the maximum tensile stress at the corresponding point of the potential fracture front. The nucleated fracture used as an initial step in the model of fracture propagation.

The propagation model consists of three submodels: linear quasistatic stress state of isotropic rock near perforated wellbore and non-planar fracture, flow of Newtonian fluid in fracture cavity with variable fluid lag to the fracture front, step-by-step propagation of curvilinear fracture front with choosing direction of propagation obtained from maximum circumferential stress criterion. The rock stress state is governed by equilibrium equations which are solved by boundary element method (BEM). The fluid flow is governed by bearing equations which are solved by finite element method (FEM). Moreover, both methods use boundary and finite elements for approximation with identical shape functions. This allows to exclude interpolation errors at interface boundaries. The using of BEM drastically simplifies meshing and remeshing procedures. Each fracture front increment is approximated by a few layers of elements and some elements near the joint of increments with cavities are divided. Stress intensity factors (SIFs) needed by brittle rupture criterion is computed by applying interpolation formulae to displacement discontinuities near fracture tip. The magnitude of fluid lag is obtained using the distribution of fluid velocities at fluid front.

The coupled simulation of fracture propagation is represented by two coupled non-linear subproblems: subproblem of fracture propagation and subproblem of hydrodynamics – elasticity interaction. The first one defines the fracture front increments and for each step demands to solve many times the second one. The efficient method for simultaneously solving these subproblems is developed.

A thorough study of solution sensitivity to different parameters of model have been performed. It is showed that in-situ stresses, perforation direction to maximal in-situ stress and fluid viscosity play the key role in mechanisms of hydraulic fracturing. Particularly the influence to fracture trajectory and also width and pressure along have been investigated. The presented model and the performed sensitivity study is a necessary step toward a predictable and controllable hydraulic fracturing.

REFERENCES

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