Available online at www.sciencedirect.com

ScienceDirect

Procedia Structural Integrity 6 (2017) 228–235

Structural Integrity Procedia

www.elsevier.com/locate/procedia

XXVII International Conference "Mathematical and Computer Simulations in Mechanics of Solids and Structures". Fundamentals of Static and Dynamic Fracture (MCM 2017)

Time-Dependent Hydro-Geomechanical Reservoir Simulation of Field Production

Bazyrov I.[a]*, Glazyrina A.[b], Lukin S.[b], Alchibaev D.[b], Salishchev M.[b], Ovcharenko Yu.[b]

[a] *Saint-Petersburg Mining University, Department of oil and gas fields development and operation, Vasilievsky Island, 21st line,2, 199106 St Petersburg, Russian-Federation*

[b] *Gazpromneft Science & Technology Centre, Geomechanics Unit, 75-79 liter D Moika River emb., 19000, St Petersburg, Russian-Federation*

Abstract

In this paper pore pressure effects such as stress reorientation and faults reactivation are considered. Risk assessment of these effects is crucial for field development planning. Coupled 4D hydro-mechanical modelling was carried out to evaluate the prospects of well-candidates for repeated multistage hydraulic fracturing, particularly the repeated fracture geometry alteration. Furthermore, the factors influencing repeated fracture orientation were clarified. Influence of pore pressure on faults reactivation was considered in the context of fault permeability definition. Several methods for validation of numerical simulations have been reviewed.

Peer-review under responsibility of the MCM 2017 organizers.

Keywords: numerical simulation, geomechanics, hydraulic fracturing, refracturing, pore pressure, coupled simulation, principal stress reorientation, micro-seismic observation

Introduction

Development of oil and gas fields is a process of hydrocarbon production that occurs due to disequilibrium in a reservoir. The mechanical impact on a reservoir is the reason of volume changes and results in redistribution of pore

* Corresponding author. Tel.: +7-911-033-9958 (I.Bazyrov)

E-mail addresses: Ildarbazyrov@gmail.com (I.Bazyrov), Glazyrina.AE@gazpromneft-nct.ru (A.Glazyrina), Lukin.SV@gazpromneft-nct.ru (S.Lukin), Alchibaev.DV@ gazpromneft-nct.ru (D.Alchibaev), Salishchev.MV@gazpromneft-ntc.ru (M. Salishchev), Ovcharenko.YuV@gazpromneft-ntc.ru (Yu.Ovcharenko)

Peer-review under responsibility of the MCM 2017 organizers.
10.1016/j.prostr.2017.11.035

pressure in a near well bore zone and in a remote zone. Field development system is often constructed in such a way that the loss of reservoir energy is compensated by the waterflooding process. Rheological and chemical properties of the injection and production fluids differ significantly. Dynamic behavior of such agents causes the change in reservoir pressure.

Pore pressure dynamics causes the change in effective stresses, which mainly affect the wellbore stability, as well as other activities in the course of field development. Underestimation of pressure alteration can lead to crucial errors in new well trajectories planning, well azimuth selection, optimization of reservoir pressure maintenance process, selection of optimal hydraulic fracturing design and hydraulic fracturing modelling.

The reservoir four-dimensional geomechanical model is the result of the complexation of a finite-element geomechanical model with a hydrodynamic finite volume model. Earlier the construction of 1D / 3D geomechanical models [1] (including highly fractured rock [2]), as well as the effectiveness of the application of this approach [3,4] were discussed in detail. In this paper, 4D geomechanical modeling is considered as a tool for predicting the change in stress field and orientation of hydraulic fracturing cracks due to reservoir pressure dynamics.

To compare the results of 4D geomechanical modelling with real hydraulic fracturing crack geometry geophysical well logging before and after hydrofracturing (microimages and microscanners that estimate the orientation of the main stresses in the wellbore zone) as well as the radioactive proppant technology and surface micro-seismic monitoring are performed.

Methods of determining crack geometry parameters in various situations take different forms and the choice of method mostly depends on the budget of the project. However, the information derived from micro-seismic monitoring is actually the only method that has the potential to characterize and image both the induced and natural fractures enhanced by the hydraulic fracturing injection process.

Pore pressure alteration effect

One of the principal geomechanical concepts is to describe a reservoir as heterogeneous porous medium. The mass of overlying formation produces a load to significant depth, which is named overburden stress. Also in horizontal direction, the rock is subjected to non-uniform stresses that results in unequal magnitudes of maximum and minimum principal horizontal stress. Specific character of porous medium means that the total load is shared between rock mass and pore fluid.

To define the *coupled hydro-geomechanical reservoir model* we use the theory of linear poroelasticity in assumption that the model is an isothermal area. In quasi-stationary assumption the stress-strain condition of poroelastic medium is defined by the balance equation [5]:

$$\nabla \cdot \sigma(\boldsymbol{u}, p) = 0, \tag{1}$$

where σ is the total stress tensor, $\boldsymbol{u}$ is the displacement vector of porous medium, and p is the pore pressure.

The relation between stresses, initiated by material volume response on applied load, as well as the strains and pore pressure can be described in Terzaghi's effective stress principle [5, 6, 12]:

$$\sigma' = \sigma - \alpha p I = 2\mu\varepsilon(u) + \lambda\varepsilon_{Vol} I - \alpha\, p I, \tag{2}$$

where σ is the total Cauchy stress tensor, μ and λ are Lame moduli, α – Biot constant, p – pore pressure, I is the unite tensor.

The volumetric strain and the volumetric stress are $\varepsilon_{Vol} = \nabla \cdot \mathbf{u}$ and $\sigma_{Vol} = 1/3\ \mathrm{tr}\,\sigma$ respectively. So, following the generalized Hooke's law (2),

$$\sigma'_{Vol} = K\varepsilon_{Vol} - \alpha\, p \tag{3}$$

where K is the bulk modulus, is given as:

$$K = \lambda + \frac{2}{3}\mu = \frac{E}{3(1-2\nu)} \tag{4}$$

The pore pressure is proportional to the dilation of porous medium:

$$p = M(\zeta - \alpha\, \varepsilon_{Vol}), \tag{5}$$

where ζ is the fluid flow content, the Biot modulus can be defined through the porosity φ and Bulk moduli K_s and K_f: