METHOD OF TREATING BOTTOM-HOLE FORMATION ZONE

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CROSS-REFERENCE TO RELATED APPLICATIONS

0001. This application claims the benefit of priority to Russian Patent Application No. 2006122049 filed Jun. 22, 2006, which is herein incorporated by reference.

FIELD OF THE INVENTION

0002. This invention relates to the art of oil and gas well production and can be used to treat a bottom-hole formation zone to increase in well productivity and rocks permeability.

BACKGROUND OF THE INVENTION

0003. At present, various methods of treating a bottom-hole formation zone are directed to the increase in oil recovery coefficient. These are reactive treatments of the producing formations involving the injection of different processing media based on organic and non-organic matters to a well, pulse methods combined with mechanical, thermal and chemical effect, and hydraulic fracturing of the formation, being a better-known well stimulation of hydrocarbons through increase in permeability of the bottom-hole zone of the producing formation due to fissuring.

0004. The methods of treating a bottom-hole zone involving pressure pulses are based on elastic wave/pressure wave excitation in rock formation. The pressure wave effect was proposed more than 40 years ago as an alternative procedure resulting in higher efficiency of the standard methods. This method has not found a wide application yet despite some beneficial results in practice (e.g., flow rate increase and/or oil recovery coefficient). The central problem is the lack of reliable field data and theoretical reasoning too. Particularly, it is impossible to predict or stimulate what will be the effect (positive or negative) of pressure pulses on production. Nevertheless, some equipment has been developed, among them surface vibrators and downhole tool (pressure pulse excitation tool, sparkers, magnetostriective and piezoceramic sources), which results in wide range of frequency pulses.

0005. A most close analog to a method applied is a method of treating a bottom-hole zone involving the trip of a pulse generator in a well followed by the formation pulse treatment specified in patent RU 2105874, 1998.

SUMMARY OF THE INVENTION

0006. The present invention provides a method of treating a bottom-hole zone that provides a high fissuring rate by breaking formation fluid-bearing permeable rocks around a wellbore. This method increases the rock permeability through the generation of formation microfractures or the regeneration of earlier fissures; and combined with the hydraulic fracturing provided that fractures propagate and reach the surface of the hydraulic fracturing fissures the pressure pulses form rock lumps that do away with the fissure surface and become proppants themselves.

0007. In the present invention a provision is made for the method of treating a bottom-hole zone involving the trip of a pulse generator in a well followed by the formation pulse treatment to generate the negative pressure pulses of amplitude higher than tensile formation strength.

0008. In case of hydraulic formation fracturing, pressure pulses are fed as a breaking fissure grows. Moreover, prior to pulse action the pressure is built in a bottom-hole well zone higher than pore pressure in a far-field zone for the formation; or in case of hydraulic fracturing the pressure is built in the created fracture higher than principle maximum stress in the far-field zone for the formation.

DETAILED DESCRIPTION OF THE INVENTION

0009. The invention is carried out as follows. A pulse generator should be tripped in a well and negative pressure pulses be generated around oil-bearing formation of amplitude higher than the tensile formation strength. A short and power pulse of magnitude of several MPa can initiate fissuring near a wellbore and in a created fracture (in case of hydraulic fracturing). Each next negative pressure pulse should make formation fissures grow. In case of hydraulic formation fracturing, pressure pulses can be fed as a breaking fissure grows. To create ruptures prior to pulse action the pressure is built in a bottom-hole well zone higher than pore pressure in a far-field zone for the formation; or in case of hydraulic fracturing the pressure is built in the created fracture higher than the principle maximum stress in the far-field zone for the formation. As an example let us consider an axisymmetric well of radius R being drilled straight, and the hydraulic fracturing (straight and vertical) of L long is in a permeable rock formation. The well cavity and the hydraulic fracturing are filled with fluid at a certain pressure $P_w$. For a well $P_w > P_o$, for hydraulic fracturing $P_w > \sigma_t^{(0)}$, where, $P_o$ is the pore pressure in the far-field zone (e.g. 5 MPa), and $\sigma_t^{(0)}$ is the principle maximum stress in the far-field zone (e.g. 8 MPa) (it is taken that the tensile stress is positive). The pressure $P_w$ has been applied for the set time to build up excessive pressure in the formation (i.e. fluid diffusion process). Elastic motion in the fluid-bearing pore medium is described by the following equations for a medium displacement vector $u$ and a relative fluid displacement vector $w$:

\begin{align}
\rho \ddot{u} + \rho \dot{w} = \nabla \left( K + \frac{1}{3} G + \sigma^3 M \right) \nabla u + \sigma M \nabla \nabla u, & \\
\rho \ddot{w} + \nabla \cdot \left( \rho \nabla \dot{u} \right) + \frac{\rho}{\mu} \dot{w} = - \nabla \left( \sigma M u + M \nabla \nabla u \right). & \quad (1b)
\end{align}

0010. Where, $\rho$ is the total mass density of the saturated rock, $p$ is the pore fluid mass density, $G$ is the shear modulus, $K$ is the bulk modulus under drainage, $M$ is the Biot\!\!\!\!$M$ modulus, $\alpha$ is the elastic pore medium coefficient, $\beta$ is the porosity, $T_\phi$ is the rock pore tortuosity coefficient, $\mu$ is the fluid viscosity, $k$ is the rock permeability, and a point is the time derivative. Stress components and the pore pressure are in the form of the first space derivative $\nabla u$ and $\nabla w$:

\begin{align}
\sigma_{ij} = 2G \varepsilon_{ij} + \frac{1}{2} \left( \sigma - \frac{2}{3} G \right) \varepsilon_{kk}, & \\
\sigma_{ij} = \nabla \varepsilon_{ij} = \nabla \nabla u + \nabla \nabla w. & \quad (2a)
\end{align}
\[ p = -aM\epsilon + M\zeta. \quad (2b) \]

Where,

\[ \epsilon_{ij} = \frac{1}{2}(\partial u_i/\partial x_j + \partial u_j/\partial x_i), \]

\[ \epsilon = \sum \epsilon_{ij}, \]

\[ \zeta = -\sum \partial w_i/\partial x_i. \]

[0011] At the interface between the well fluid and the porous reservoir the following conditions are satisfied:

\[ \sigma_{mm} = P, \quad \sigma_{m0} = 0, \quad P = P. \quad (3) \]

[0012] Where, the left-hand side of the equations has normal stress, shear stress and pore pressure, respectively, and \( P = P_{w} + P(t) \) is the total pressure of the well fluid. Solving a problem (1) of the boundary conditions (3) for the wellbore and hydraulic fracturing gives the space stress and pore pressure distribution. The use of the below known criteria of the tensile failures and the failures according to a Mohr-Coulomb law is the possibility of estimating the tensile rock failure and the failure by shear fractures:

\[ g_{TC} = \frac{\sigma_{1}}{T_{D}} = \sigma_{1} + p > T_{D}, \quad (4a) \]

\[ g_{MC} = \frac{\sigma_{1}^{2} + \frac{\sigma_{3}}{2}}{3} - \sigma_{3} = \sigma_{t}. \quad (4b) \]

[0013] Where, \( g_{TC} \) and \( g_{MC} \) are the function of fissure flow for ruptures and shear fractures, respectively, being analyzed to predict rock fracturing; \( T_{D} \) and \( \sigma_{t} \) are the tensile strength and the crushing strength of the rock, respectively.

[0014] Dynamic pulses \( P(t) \) applied are of negative amplitude, for example, \( P(t) = -P_{\text{pulse}} \exp(-t^{2}/T_{\text{pulse}}^{2}) \), where, \( P_{\text{pulse}} \) is the amplitude, and \( T_{\text{pulse}} \) is the pulse period.

[0015] Should the tensile formation strength \( T_{1} \) is 1 MPa, the amplitude \( P_{\text{pulse}} \) is rather powerful, e.g. 5 MPa, and the pulse duration for rock permeability \( k \) equal to \( 10^{-3} \) is rather short, e.g. 0.01 s; ruptures and shear fractures occurring around wellbore and created fractures. A fissure propagation direction can be predicted by the nature of the fissures themselves, i.e. ruptures or shear fractures. With pressure reduced, a maximum tensile component is radial relative to a wellbore wall and normal relative to a fissure direction at the surface of the fracturing. Therefore, ruptures propagate in parallel to the wellbore boundary or a created fracture. Shear fractures, if any, are inclined at an angle \( \theta_{F} = \pi/4 - \Phi/2 \) to the direction of principle minimum stress, where, \( \Phi \) is the rock friction angle.

What is claimed is:

1. A method of treating a bottom-hole formation zone involving a pulse generator to be tripped in a well followed by formation pulse treatment distinguishing by the fact that negative pressure pulses should be generated of amplitude higher than tensile formation strength.

2. A method according to claim 1 distinguishing the fact that prior to pulse action the pressure is built in a bottom-hole well zone higher than the pore pressure in a far-field zone for the formation.

3. A method according to claim 1 distinguishing the fact that in case of hydraulic formation fracturing, pressure pulses should be fed as a breaking fissure grows.

4. A method according to claim 2 distinguishing the fact that prior to pulse action in the created fracture zone the pressure should be built higher than the principle maximum stress in a far-field zone for the formation.