CSCanada
Advances in Petroleum Exploration and Development
Vol. 6, No. 2, 2013, pp. 38-40
DOI:10.3968/j.aped.1925543820130602.1786

ISSN 1925-542X [Print]
ISSN 1925-5438 [Online]
www.cscanada.net
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The Study of Rock Body Damage Constitutive Model on Refracturing

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Supported by Youth Science Foundation of Northeast Petroleum University (The research of chaos characteristics on evolution of three-dimensional multifractal fracture network of shale under hydraulic fracturing), The Scientific research fund of Heilongjiang Provincial department of education (Study on chaotic characteristics of reservoir fracturing three-dimensional fracture network evolution of coaled gas), PetroChina Innovation Foundation (2011D-5006-0212), Youth Foundation of Heilongjiang Province (QC2010096), The National Natural Science Foundation of China (51104032), PetroChina Innovation Foundation(2013D-5006-0209) and Academic Backbone of Heilongjiang Province University Youth Support Program (1253G011).

Received 9 November 2013; accepted 13 December 2013

Abstract
In order to characterize the mechanical behavior of rock body damage evaluation and forming multiple fractures, in this paper in multiple fracturing , we have established rock body damage evaluation constitutive model, and given the point that the rock can bear secondary damage in multiple fracturing. Established the secondary damage evaluation model, and obtained the method for calculating the parameter of the crack in multiple fracturing. We have verified the model by a oil well in Jilin oilfield, the result has well anastomosis with the actual engineering.

Key words: Multiple fracturing; Damage evaluation; Secondary damage

Wang, T. T., Wang, C., Zhang, J. B., Zhao, W. C., & Cai, M. (2013). The Study of Rock Body Damage Constitutive Model on Refracturing. *Advances in Petroleum Exploration and Development*, *6*(2), 38-40. Available from: URL: http://www.cscanada.net/index.php/aped/article/view/j.aped.1925543820130602.1786
DOI: http://dx.doi.org/10.3968/j.aped.1925543820130602.1786

INTRODUCTION
Refracture reorientation and crack formation are the key and bottleneck problem in the study of hydraulic fracture. In order to simulate and describe the initiation, propagation and geometric shape of crack actually, we must use damage and fracturing mechanics theory. Kachanov and Krajcinovic[1] proposed the initiation, propagation and converge of the micro crack can form macro crack. In this process, it cannot cause obvious plastic deformation brittle damage mechanism and nucleation, growing up and converge of the micro void, but it has obvious plastic deformation toughness damage mechanism. Guo[2] simulated and analyzed the damage and cracking process of rock under the effect of hydraulic fracture using Kachan and PKN models, and he concluded that it has a damage weaken area at the crack tip. Yang[3-5] applied the mesomechanics theory to material damage problem in the view of the nonhomogeneity of the medium. He proposed that the pore and crack is a network system which is combined by meso element. And he established the meso structural model that described the micro and meso deficiency structural morphology of the rock. Yuan[6] have studied the rock problem using damage mechanics, and described the meaning and character of the rock damage from micro and macro aspect. Liu[7] had analyzed the hydraulic fracture crack initiation and propagation mechanism based on fractal theory, damage mechanics and nonlinear dynamics combining the actual fracturing field. Liu[8] had established hydraulic fracture damage mechanics model based on Gurson damage model, analyzed the damage effect of hydraulic fracturing on porous media by simple numerical simulation.

Moreover, some scholars had studied some rock damage model. In this paper, we have used the variation of pore volume as the parameter to describe the rock damage, and defined new tensor damage variable, and established hydraulic fracturing rock medium damage deterioration constitutive model. And the porosity and permeability evolution model is established based on damage theory. The numerical simulation results showed that the new method is better than the old one.

1. THE CRACK EVALUATION OF MULTIPLE FRACTURING

In the process of multiple fracturing, the rock body with crack is under the condition of tension-shear stress, the plane crack extended and the relationship between extension force G and stress intensity factor can be described as follow.

$$U_d = 2\int_0^a G d\Omega = 2\frac{1-\tilde{\mu}^2}{\tilde{E}}\int_0^a \left(K_\mathrm{I}^2 + K_\mathrm{II}^2\right)da \qquad (1)$$

By Integrating (1), we can get (2).

$$U_d = \frac{1-\tilde{\mu}^2}{\tilde{E}}\left(K_\mathrm{I}^2 + K_\mathrm{II}^2\right) \qquad (2)$$

Assuming that in the process of multiple fracturing, it have n cracks in the rock propagating, and the rock body stain energy for the total cracks can be described as follow.

$$U_d = \sum_{\mathrm{m}=1}^{n}\frac{1-\tilde{\mu}^2}{\tilde{E}}\left(K_\mathrm{I}^{(\mathrm{m})2} + K_\mathrm{II}^{(\mathrm{m})2}\right) \qquad (3)$$

$$\begin{cases} (\mathrm{K_I}) = \dfrac{\lambda^*\sqrt{\pi a}}{2}\left[(1\text{-}\cos 2J)(\sigma_{xtotal}) + (1+\cos 2J_i)(\sigma_{ytotal})\right] \\ (\mathrm{K_{II}}) = \dfrac{\lambda^*\sqrt{\pi a}}{2}\left[(\sigma_{xtotal})\sin 2J\text{-}(\sigma_{ytotal})\sin 2J\right] \end{cases}$$

The second order stress tensor of the stress state σ_{ij} in the rock is.

$$\sigma_{ij} = \begin{bmatrix} \sigma_{xtotal} & \tau_{xytotal} \\ \tau_{yxtotal} & \sigma_{ytotal} \end{bmatrix} \qquad (4)$$

Derivate the stress, and describe it in the form of tensor:

$$\frac{\partial u_d}{\partial \sigma_{ij}} = \frac{1-\tilde{\mu}^2}{\tilde{E}}\sum_{j=1}^{n}\left(\frac{\partial (K_\mathrm{I})^{(\mathrm{m})}}{\partial \sigma_{ij}} + \frac{\partial (K_\mathrm{II})^{(\mathrm{m})}}{\partial \sigma_{ij}}\right) \qquad (5)$$

We can get (6) according to the damage theory.

$$\frac{\partial u_d}{\partial \sigma_{ij}} = C^{0\text{-}d} \times \sigma_{ij} \qquad (6)$$

The damage flexibility tensor can be described as follow.

$$C^{0-\mathrm{d}} = C^0 + C^\mathrm{d} \qquad (7)$$

Where, C^0 is flexibility tensor of the materials without damage; C^d is flexibility tensor of the materials with damage.

$$\left(C^0 + C^\mathrm{d}\right)\cdot\begin{bmatrix} \sigma_{xtotal} & \tau_{xytotal} \\ \tau_{yxtotal} & \sigma_{ytotal} \end{bmatrix} = \frac{1-\tilde{\mu}^2}{\tilde{E}}\cdot\frac{(\lambda^*)^2 \pi a}{2}\sum_{\mathrm{m}=1}^{\mathrm{n}}$$

$$\left\{ A\cdot\frac{\partial A}{\partial \begin{bmatrix} \sigma_{xtotal} & \tau_{xytotal} \\ \tau_{yxtotal} & \sigma_{ytotal} \end{bmatrix}} + B\cdot\frac{\partial B}{\partial \begin{bmatrix} \sigma_{xtotal} & \tau_{xytotal} \\ \tau_{yxtotal} & \sigma_{ytotal} \end{bmatrix}} \right\} \qquad (8)$$

$$\begin{cases} A = \left[(1-\cos 2\vartheta_\mathrm{m})(\sigma_{xtotal})^{(\mathrm{m})} + (1+\cos 2\vartheta_\mathrm{i})(\sigma_{ytotal})^{(\mathrm{m})}\right] \\ B = \left[(\sigma_{xtotal})^{(\mathrm{m})}\sin 2\vartheta_\mathrm{m} - (\sigma_{ytotal})^{(\mathrm{m})}\sin 2\vartheta_\mathrm{m}\right] \end{cases}$$

2. CASE STUDY

Maximum horizontal principal stress s_H is 32.0 MPa; Minimum horizontal principal stress s_h is 25.1 MPa; Bottom hole flowing pressure PW is 3.0 MPa; Injection pressure PO is 10.0 MPa; Young's modulus E is 28000 MPa; Critical damage strength s_c is 30.0 MPa; Wellbore radius r_w is 0.12 m; External boundary radius R_0 is 50.0 m; Fluid compressibility factor a is 0.8; Poisson's ratio n is 0.22; Matrix porosity Φ_p is 0.25; Fracture porosity Φ_f is 0.25; Internal friction angle f is 0.35 R_{ad}; Softening Modulus Ẽ is 800 MPa.

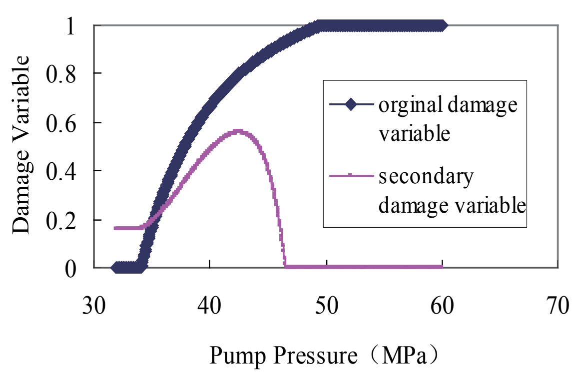

Figure 1
The Curve of Damage Variable with Pressure

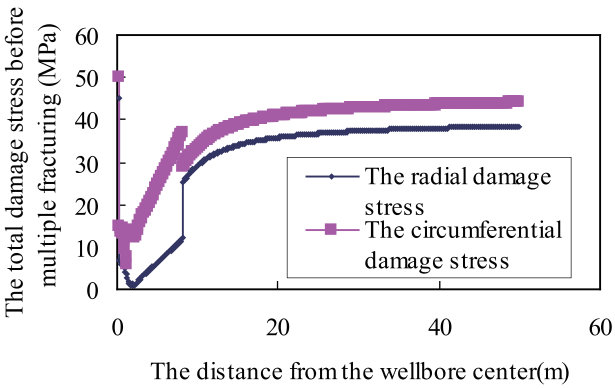

Figure 2
The Curve of Stress in Whole Region

CONCLUSIONS

(1) In the process of multiple fracturing, the rock in the damage region emerge secondary damage deterioration, and the filtration of fracturing fluid in the macro principal crack that have generated in the primary fracturing cannot be ignored.

(2) Establish the model for calculating multiple fracturing micro crack damage evaluation dynamic and static stress intensity factor, and building up crack formation and rock nonlinear damage deterioration stress distribution model in multiple fracturing

(3) Simulate rock body stress distribution state in the process of multiple fracturing using finite element method, the result is in good agreement with the theoretical results. The new method has certain innovative and rationality.

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