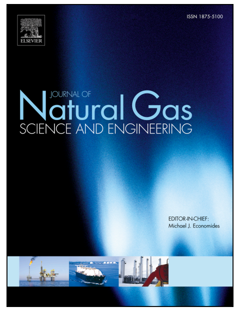

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Quantitative Phase Field Modeling of Hydraulic Fracture Branching in Heterogeneous Formation under Anisotropic In-Situ Stress

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Abstract

Unconventional reservoir hydraulic fracturing is often characterized with diverting and branching. A fundamental understanding of the fracture branching mechanism remains elusive due to the complicated fusion of geo stress, formation heterogeneity and pre-existed complex natural fracture topologies. Existing sharp fracture models such as, finite-element method (FEM) and its modified versions, often suffer in complex fracture topologies owing to the computationally expensive remeshing when fracture diverts and/or branches. In this paper, phase-field modelling (PFM) is proposed to quantitatively investigate the hydraulic fracture branching condition in heterogeneous formation under anisotropic *in-situ* stress. The PFM is featured with the diffusive interface, enabling it to automatically capture the fracture branching and diverting without the need of tracking the fracture interface. The model is first verified in predicting the fracture width, stress distribution and fracture propagation via benchmark examples, followed by the comprehensive investigation on hydraulic fracture branching in a heterogeneous formation where a rock strip is laid across the shale main formation with anisotropic *in-situ* stress. Parametric study shows no branching occurs when the hydraulic fracture propagates towards soft strip (e.g. soft shale), while fracture branches when it propagates towards stiff strip (e.g. hard shale or sandstone) as long as the Young's modulus ratio ($E_R=E_{strip}/E_{main}$) exceeds a critical value. Such a critical value increases as the principal *in-situ* stress difference (S_d) goes up. Finally, the hydraulic fracture branching is quantified in terms of the deviation distance and reentry angle, both of which are found to rise as the E_R increases , and as S_d decreases, which indicates relatively low S_d and high E_R are in favor of increasing the fracture complexity and drainage area. These results could provide valuable insights in predicating and creating complex reservoir hydraulic fracturing patterns.

Key words: Numerical Simulation; Phase Field; Hydraulic Fracturing; Branching; Heterogeneous; Anisotropic.

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