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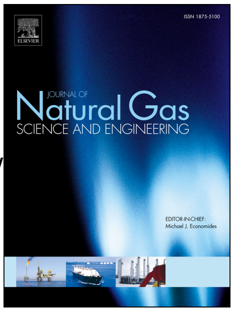

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Stress Field Behavior Induced by Hydraulic Fracture in Shale Reservoirs: A Practical View on Cluster Spacing

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ABSTRACT

Hydraulic fracturing is a complicated hydro-mechanical process, which is used to stimulate reservoir volume, where a pressurized fluid drives fracture propagation in a solid, or porous medium. This process changes the initial state of stress in the reservoir as the applied hydraulic pressure develops discontinuity throughout the media. As the fracture network propagates, it achieves a greater surface contact area with the producing formation and the wellbore, allowing for a greater rate of oil and gas migration in ultra-low permeability reservoirs (e.g. shale reservoirs). This process greatly enhances production, but may lead to instability within surrounding discontinuities or changes to the local stress distribution, which may cause unfavorable events such as hydraulic fracture cluster merging.

Hydraulic fracture design is not recommended when only complicated numerical simulation and modeling techniques are used without verification through accompanying field data. Often times, comparing with field data, complicated mathematical simulation models are altered to better correlate the simulation results to real-time or post-treatment field data. This raises uncertainty in whether the physics of the hydraulic fracturing are being captured correctly or not using commercial numerical simulators. Many times this leads to a trial and error based approach for fracture treatment operations, which are backed by physical results, such as microseismic, or production data. Unfortunately, in initial field or well completion design scenarios, there is significant uncertainty associated with stimulation treatment designs. Observations of treated wells are required to corroborate the simulated data using scientific evidence.

The Theory of Critical Distance (TCD) was developed as a quick analysis method to determining material failure; most often to notched type cases of non-propagating crack fatigue (Taylor, 2007). This theory demonstrates the ability to predict failure based upon the stress concentrations surrounding the notch (Yin, 2014; Louks, 2014). In a similar fashion this methodology is derived and applied to a dynamic pressurized fluid front within a fracture in order to predict stress concentrations surrounding the fracture (Lajtai, 1971; Ito, 1991). The premise of modifying TCD theory is nothing new as this has been done for various cases, however it has yet to be used in this type of application concerning dynamic loading and hydraulic driven fracture propagation.

The application of a modified TCD theory displays the possibility of using a simple technique to predict hydraulic fracture cluster spacing by precisely defining the dynamics of the failure envelope around the fracture tip and surrounding fracture geometry and also to optimize injection pressure required for propagation but eliminate interference between clusters. In this paper Von Mises stress has been calculated and used to analyze the multi-fracture interactions. This behavior can be idealized such that the maximum Von Mises stress emanates from the fracture tip creating a critical angle with the fracture plane or fracture tip. The angle and magnitude of stress can be used to justify the stability of the reservoir or to interpret stress reorientations that are seen surrounding propagating fractures. These reorientations can affect the geometry and relative stress distributions surrounding adjacent fracture propagation by either easing or impeding the ability of the fracture to propagate.

As a result of this study, the modified TCD theory provides a tool for the determination of these stress interactions in order to make quick decisions in the field to modify stimulation treatment plans during injection, which would typically require complicated modeling and simulation results.