Criteria for Hydraulic Fracture Intersection Behavior with Structural Planes in Toughness- and Viscosity-Dominated Regimes Postprint

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Abstract

Structural surfaces (such as joints, natural fractures, and faults) that are widely developed in unconventional reservoirs significantly control the propagation morphology of hydraulic fractures. To fully stimulate the reservoir and enhance ultimate recovery, it is necessary to accurately predict the morphology of the hydraulic fracture network and clarify the mechanical response characteristics of structural surfaces when hydraulic fractures intersect with them. Based on the theory of linear elastic fracture mechanics, this paper proposes a new criterion for predicting the intersection behavior between hydraulic fractures and structural surfaces under non-orthogonal conditions. This criterion comprehensively considers the coupling effects of fluid flow, stress shadow, poroelastic response, and the influence of plastic yielding at the fracture tip. Through comparative verification with published theories, laboratory experiments, and numerical simulation results, the results demonstrate that the new criterion exhibits good reliability under both toughness-dominated and viscosity-dominated fracture propagation modes. Sensitivity analyses are conducted on key parameters in rock mechanics and fracturing operations under different dominant modes. The results indicate that structural surface parameters are the primary controlling factors for intersection behavior in both dominant modes. In toughness-dominated mode, short extended fracture length, high friction coefficient, and high cohesion are favorable for hydraulic fractures to cross structural surfaces; in viscosity-dominated mode, high injection rate, low-viscosity fracturing fluid, short extended fracture length, high friction coefficient, high cohesion, and high fracture toughness are favorable for hydraulic fractures to cross structural surfaces. Furthermore, the study reveals the significant influence of intersection angle on intersection behavior: when the intersection angle exceeds the critical transition angle, high stress difference promotes hydraulic fractures to cross structural surfaces; conversely, high stress difference inhibits intersection behavior, and hydraulic fractures are either blocked by structural surfaces or propa-

gate along them. The research findings provide important theoretical basis for the optimal design of hydraulic fracturing in unconventional reservoirs and facilitate rapid characterization of propagation features in complex hydraulic fracture networks.

Full Text

Preamble

Criterion for Hydraulic Fracture-Discontinuity Intersection Behavior in Toughness- and Viscosity-Dominated Regimes

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Abstract

In unconventional reservoirs, extensively developed discontinuities (such as joints, natural fractures, and faults) significantly control the propagation morphology of hydraulic fractures. To effectively stimulate reservoirs and enhance ultimate recovery, it is necessary to accurately predict the morphology of hydraulic fracture networks and clarify the mechanical response characteristics of discontinuities when intersected by hydraulic fractures. Based on linear elastic fracture mechanics theory, this paper proposes a new criterion for predicting hydraulic fracture-discontinuity intersection behavior under non-orthogonal conditions. This criterion comprehensively considers the coupled effects of fluid flow, stress shadow, poroelastic response, and plastic yielding at the fracture tip. Through comparison and verification with published theories, laboratory experiments, and numerical simulations, the results demonstrate that the new criterion exhibits good reliability in both toughness-dominated and viscosity-dominated fracture propagation regimes.

Sensitivity analyses were conducted for key parameters in rock mechanics and fracturing operations under different dominant regimes. The results indicate that discontinuity parameters are the primary controlling factors for intersection behavior in both regimes. In the toughness-dominated regime, short fracture extension length, high friction coefficient, and high cohesion are favorable for hydraulic fractures crossing discontinuities. In the viscosity-dominated regime, high injection rate, low-viscosity fracturing fluid, short fracture extension length, high friction coefficient, high cohesion, and high fracture toughness are favorable for hydraulic fractures crossing discontinuities. Furthermore, the study reveals the significant influence of intersection angle on intersection behavior: when the intersection angle exceeds the critical transition angle, high stress difference promotes hydraulic fracture crossing of discontinuities; conversely, high stress difference inhibits intersection behavior, causing hydraulic fractures to be blocked by discontinuities or propagate along them. The findings of this study provide important theoretical basis for optimizing hydraulic fracturing design in unconventional reservoirs and facilitate rapid characterization of complex hydraulic fracture network propagation features.

Keywords: hydraulic fracturing; fracture mechanics; intersection criterion; toughness-dominated regime; viscosity-dominated regime

Note: Figure translations are in progress. See original paper for figures.