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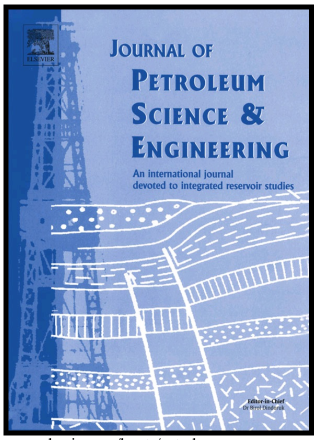

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A Non-Local Model for Fracture Closure on Rough Fracture Faces and Asperities

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Abstract

Natural fractures, hydraulic fractures, and acid etched fractures have some degree of fracture surface roughness. These surface asperities are largely responsible for the hydraulic conductivity of these fractures. This paper presents a model to quantify the fracture closure process that is crucial to predicting the stress dependent conductivity of fracture networks in unconventional reservoirs and estimating the minimum in-situ stress using fracture injection tests. Past studies that have investigated the fracture closure process have assumed the fracture surfaces to be two parallel plates closing in uniformly on rough surfaces and asperities. In reality hydraulically induced fractures are wider in the middle and narrower near the fracture tip. As a result, asperities on the rough fracture surfaces come into contact near the fracture tip well before they do near the middle of the fracture. The evolution of the entire fracture geometry and its impact on stress redistribution and dynamic fracture closure behavior has not yet been investigated.

In this paper, we present a method and general algorithms to model the dynamic closure behavior of a hydraulic fracture while accounting for the initial fracture shape, rough fracture surfaces and deformation of asperities in contact. Analytic solutions from linear elastic fracture mechanics for three fracture models (PKN, KGD and radial fracture geometry) are coupled with a general contact law to show that the fracture closure process is a gradual, non-local process, which occurs at the fracture edges initially and then moves progressively to the center of fracture, as the fluid pressure inside the fracture declines. Our study also reveals that the minimum in-situ stress should not be picked at the occurrence of mechanical closure as conventional practice suggests.

Keywords: hydraulic fracture; fracture closure; surface roughness; asperities; stress determination; surface contact

Nomenclature

a Half fracture height (PKN model) or half fracture length (KGD model), m.
a_m Half fracture height (PKN model) or half fracture length (KGD model) or local fracture radius (Radial model) at the start point of the m^{th} segment along a discretized fracture, m.
A_f Fracture surface area of one face of one wing, $m.^2$
E Young's modulus, Pa
E' Plane strain modulus, Pa
h_f Fracture height, m.
I Integration operator for PKN and KGD model
P_f Fluid pressure inside fracture, Pa
P_{Net} Net pressure/stress, Pa
P_{Netm} Net pressure/stress at the m^{th} segment along a discretized fracture, Pa
r Local fracture radius, m.
r_D Normalized radius
R_f Fracture radius, m.
$R1$ First integration operator for Radial model
$R2$ Second integration operator for Radial model
s Dummy variable
S_f Fracture stiffness, Pa/m.
u Dummy variable
V_f Fracture volume of one wing, $m.^3$
w_0 Contact width, m.