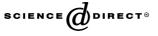


Available online at www.sciencedirect.com



Engineering Fracture Mechanics 72 (2005) 2468–2486

Engineering Fracture Mechanics

www.elsevier.com/locate/engfracmech

## Asymptotic solution for a penny-shaped near-surface hydraulic fracture $\stackrel{\text{tr}}{\sim}$

Andrew P. Bunger<sup>a</sup>, Emmanuel Detournay<sup>b,\*</sup>

<sup>a</sup> CSIRO Petroleum, Private Bag 10, Clayton South 3169, Australia <sup>b</sup> University of Minnesota, Department of Civil Engineering, 500 Pillsbury Drive SE, Minneapolis, MN 55455, USA

> Received 12 July 2004; received in revised form 26 January 2005; accepted 6 March 2005 Available online 31 May 2005

## Abstract

This paper considers the large time asymptotic behavior of a near-surface hydraulic fracture, that is, when the radius (R) is much larger than the depth (H). The fracture is analyzed as an elastically clamped circular plate and stress intensity factors are determined by matching the outer plate problem to the inner problem of a near-surface semi-infinite crack. In the zero-viscosity limit, we derive two terms of a large R/H asymptotic solution. Comparison shows that the accuracy of some published numerical results deteriorates for R/H > 5. This is corrected using smaller element size to ensure that the crack-tip element is entirely in the region that is well-approximated by a square-root tip asymptote. © 2005 Elsevier Ltd. All rights reserved.

Keywords: Hydraulic fracture; Blister crack; Fracture mechanics; Matched asymptotics; Free-surface effects

## 1. Introduction

Hydraulic fracturing in near-surface environments, used in quarrying operations over a century ago [1,2], has been a subject of increasing interest in recent years. Driving this interest are applications of hydraulic fracture for mine caving [3], environmental remediation [4], and for modelling certain geophysical processes [2,5,6]. In addition to experimental contributions [4,7], these applications have motivated recent work aimed at modelling near-surface hydraulic fractures [4,8].

Foundational to much of the recent work in hydraulic fracture modelling is the concept of regimes of propagation [9]. For example, if loss of fluid from the fracture into the solid matrix (fluid leak-off) is

<sup>\*</sup> Submitted to Engineering Fracture Mechanics.

<sup>&</sup>lt;sup>\*</sup> Corresponding author. Tel.: +1 612 625 3043; fax: +1 612 626 7750. *E-mail address:* detou001@umn.edu (E. Detournay).

<sup>0013-7944/\$ -</sup> see front matter @ 2005 Elsevier Ltd. All rights reserved. doi:10.1016/j.engfracmech.2005.03.005

- Nomenclature В a coefficient related to  $\eta$  and v  $C_2$ local compliance, point load D plate flexural rigidity E, E'Young's, plane strain modulus  $F, \mathcal{F}, \mathcal{F}_k, \mathcal{F}_{\bar{k}}$  solution, scaled solution  $G_{in}(G_{out})$  energy release rate of inner (outer) problem fracture depth (plate thickness) Η  $K_{\rm I}, K_{\rm II}$  mode I and II stress intensity factors (SIF's)  $K_{\rm Ic}(K')$  critical mode I SIF, alternate  $(K' = 4(2/\pi)^{1/2}K_{\rm Ic})$  $K_M, K_N, K_T$  stress intensity factor coefficients L,  $L_k$ ,  $L_{\bar{k}}$  characteristic length (see Table 1) M, N, T moment, normal and shear force applied to inner problem  $M_r$ moment Р point force at fracture center р internal pressure loading Q fluid injection rate fluid flux q shear force  $Q_r$ R fracture radius radial coordinate r  $t, \overline{t}$ time, characteristic time fracture opening w a constant related to v α β a constant related to v δ a constant associated with the energy release rate  $\epsilon, \epsilon_k, \epsilon_{\bar{k}}$  scaling parameter (see Table 1) scaling parameter, uniform pressure  $\epsilon_1$ scaling parameter, point load  $\epsilon_2$ 
  - $\eta$  dimensionless clamping coefficient
  - $\gamma, \gamma_k, \gamma_{\bar{k}}$  scaled radius (see Table 1)
  - $\kappa$  elastic clamping coefficient
  - $\mu(\mu')$  fluid viscosity, alternate ( $\mu' = 12\mu$ )
  - v Poisson's ratio
  - $\Omega, \Omega_k, \Omega_{\bar{k}}$  scaled opening (see Table 1)
  - $\Omega_1$  scaled opening, uniform pressure
  - $\Omega_2$  scaled opening, point load
  - $W, W_k, W_{\bar{k}}$  characteristic opening (see Table 1)
  - $\Pi, \Pi_k, \Pi_{\bar{k}}$  scaled pressure (see Table 1)
  - $\rho$  scaled radial coordinate
  - $\sigma$  far-field normal stress parallel to free-surface
  - $\tau, \tau_{\bar{k}}$  dimensionless time
  - $\mathscr{S}, \mathscr{S}_k, \mathscr{S}_{\bar{k}}$  scaling rule (see Table 1)
  - $\mathscr{G}_i$  dimensionless group
- $\varphi, \mathcal{M}_k, \mathcal{M}_{\bar{k}}$  dimensionless viscosity (see Table 1)
- $\mathscr{R}$  radius to depth ratio, R/H

Download English Version:

## https://daneshyari.com/en/article/768468

Download Persian Version:

https://daneshyari.com/article/768468

Daneshyari.com