Asymptotic and Numerical Investigations on Shallow Hydraulic fractures

†,*Z.Q. Wang[1], E. Detournay[2]

[1]School of Engineering and Technology, China University of Geosciences, Beijing100083, PR China
[2]Department of Civil, Environmental, and Geo- Engineering, University of Minnesota, Minneapolis, Minnesota 55455, USA

*Presenting author: zqwang@cugb.edu.cn
†Corresponding author: zqwang@cugb.edu.cn

Abstract

There are many instances where hydraulic fracturing involves growth of a fracture near a free surface. Examples include viscous fluid peeling of an elastic sheet from an adhesive, excavation of hard rocks, and cave inducement in mining. Furthermore, hydraulic fracturing is an important mechanism in a number of near-surface geological processes, such as the formation of saucer-shaped sills.

This paper investigates shallow hydraulic fractures asymptotically and numerically. The models are formulated on the basis of beam theory, fracture mechanics and lubrication theory, which is used to describe the fluid flow in the gap. Beam finite element algorithm is developed to numerically solve this nonlinear lubrication problem.

The tip region of a shallow hydraulic fracture is analyzed systematically; the nonlinear fluid-solid coupling mechanism is discussed. The dependence of the fluid front lag and the physical structure of the solution on fluid viscosity, fracture toughness, elastic modulus, propagation speed of the fracture are explained in details. At last, the steady motion of a viscous bubble beneath an elastic layer and penny-shaped shallow hydraulic fracture are investigated further. Numerical results show good agreement with the asymptotic solutions.

Keywords: Shallow hydraulic fracture, Tip region, Scaling, Beam finite element method