

ARMA 2026 Student Design Competition:

Hydraulic Fracture Interaction with Natural Fracture

1. Problem Background

1.1 Hydraulic Fracturing

Hydraulic fracturing is a rock reservoir stimulation method in which fluid is injected at high pressure to create fractures in low-permeability rock and improve fluid flow. Fractures are initiated when the fluid pressure exceeds the least compressive in-situ stress and the rock's tensile strength. They tend to grow in the plane perpendicular to the least compressive stress. This technique is widely used in unconventional oil and gas reservoirs and enhanced geothermal reservoirs to create conductive pathways where the rock matrix permeability is too low for economic production.

1.2 Natural Fractures

Natural fractures (NF) are pre-existing discontinuities (e.g., veins, joints, bedding planes) in rocks formed by geological processes in response to lithostatic loading, tectonic and thermal stresses, and evolving pore-fluid pressures. The characteristics of natural fractures vary widely across formations. For example, in the Barnett shale, calcite-sealed fractures appear to be dominant and may serve as weak planes; whereas in Woodford shale, quartz-cemented fractures have been reported and may be mechanically stronger than the host rock. When a hydraulic fracture intersects a natural fracture, the interaction outcomes (e.g., Fig. 1) are governed by many factors, such as the intersection angle, in-situ stress magnitudes and anisotropy, and the frictional/strength properties of the natural-fracture surface.

This competition will explore how those factors influence hydraulic fracture propagation within a prescribed parameter space.

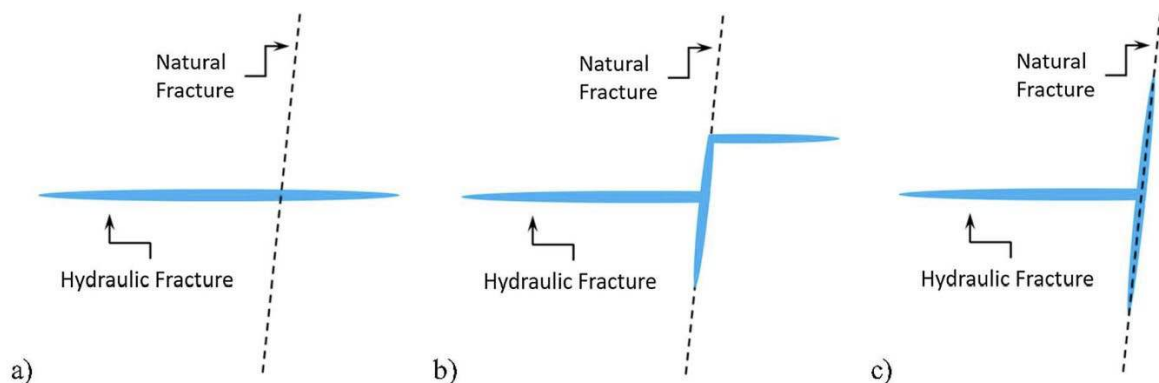


Fig. 1. Interaction examples for a HF intersecting a NF in 2D: (a) crossing; (b) offsetting; (c) branching (Fu et al., 2019).

1.3 Numerical Modeling Tool

XSite is a 3D DEM-based numerical simulator for hydraulic-fracture analysis (Itasca, 2025). It has been applied to unconventional oil and gas reservoirs, enhanced geothermal systems, rock-mass preconditioning for mining, and CO₂ sequestration. For this competition, we highlight three core XSite capabilities:

- Reservoir-scale hydraulic fracturing simulation.
- Fully coupled modeling of hydraulic fracture propagation without a pre-defined path.
- Three-dimensional interactions between hydraulic fractures and natural fractures.

XSite licenses are being provided by ITASCA to all competition participants, but students are free to use any other software or approach they deem appropriate and have access to.

2. Problem Setup

Participants will simulate a horizontal well drilled at a specified depth through a horizontal reservoir of constant thickness. Stress barriers contain the hydraulic fracture in the vertical direction within the reservoir. In the base case, the horizontal section of the well is oriented along the direction of minimum horizontal stress. The hydraulic-fracture treatment is initiated through perforations in the lateral section. A single natural fracture intersects the reservoir at a specified location, as illustrated in Fig. 2. The hydraulic fracture grows perpendicular to the minimum horizontal stress and propagates horizontally toward the natural fracture, which is simplified as a rectangular plane with prescribed properties and orientation. The parametric study will explore how variations in rock properties, stress state, natural-fracture properties, and orientation angles influence whether the hydraulic fracture crosses the natural fracture, offsets, or re-oriens along it, and will evaluate the relative importance of these factors on interaction behavior within the given parameter space.

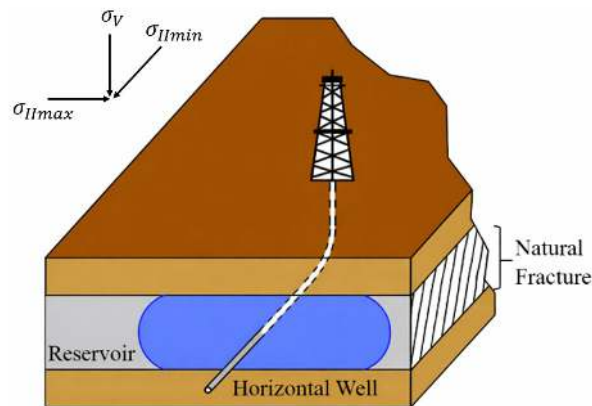


Fig. 2. Demonstration of a hydraulic fracture intersecting a natural fracture in 3D (Fu et al., 2019).

References:

ITASCA Consulting Group, Inc. (2025) *XSite — Hydraulic Fracture Simulation of 3D Fracture Networks, Ver. 4.0*. Minneapolis: Itasca.

Fu, W., Savitski, A. A., Damjanac, B., & Bunger, A. P. (2019). Three-dimensional lattice simulation of hydraulic fracture interaction with natural fractures. *Computers and Geotechnics*, 107, 214-234.