dfnWorks: Discrete Fracture Network Modeling Suite

Virtual Public Meeting
NWTRB Fall 2021 Meeting
3 & 4 November 2021

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Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218CNA000001). LA-UR 8-21-30603
Computational Models for Flow and Transport in Fractured Media

Channel Network

Fractured Rock

Continuum Methods

Discrete Fracture Network

Discrete Fracture Matrix
Discrete Fracture Networks (DFN)
Modern 3D-DFN Modeling

- Fractures are disks or rectangles
- Hydraulic properties can vary between fractures
- Site characterizations inform descriptions of various fracture families
- Flow and transport is resolved within and throughout the connected fracture network
DFNWORKS: MODULAR BY DESIGN

dfnGen

dfnFlow

dfnTrans

dfnGraph
DFNWORKS: DfnGen – Network Generation

Features used in Geologic Disposal Safety Assessment (GDSA)

- Stochastically generated fractures
- Variable Density By Layers
- Multiple Fracture families
- Deterministic features
  - Faults
  - Repositories
- Detailed geologic output report

Synthetic Repository System ~ 7000 Fractures
**Meshing**

- Spatially variable mesh resolution
- Conforming Delaunay triangulation
- Allows for in-fracture aperture variability
- Dual Mesh – Voronoi cells – used by two point flux finite volume codes (PFLOTRAN)
- Octree-resolution - Upscaled Discrete Fracture Matrix model (UDFM)
Mapping a DFN to a Equivalent Continuum Porous Media (ECPM)

DFNWORKS: MODULAR BY DESIGN

- dfnGen
- dfnFlow
- dfnTrans
- dfnGraph
DFNWORKS: DFNFLOW

- Seamless integration with PFLOTRAN
- Allows for access to all PFLOTRAN capabilities
  - Reactive transport
  - Radionuclide decay
  - Tracer Transport
  - Multiphase flow
  - Wasteform process models
- Backend analysis of PFLOTRAN runs
- Additional solvers include FEHM and AMANZI
DFNWORKS: MODULAR BY DESIGN

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Particle Tracking

- Internal velocity field pathline tracking
- Matrix Diffusion
- Low-fidelity pipe-network
- Flow Topology Graph Analysis toolkit
- Future Integration with Migration Analysis of Radionuclides in the Far Field (MARFA)

In the GDSA reference case simulations we are relying on upscaling and ADE.

With development of simulations for the DECOVALEX task we are working toward using DFN with particle tracking.
dfnGraph – Graph based network analysis toolkit

**Graphical Analysis**

- Used in GDSA Sensitivity Analysis

- Multiple-graph representations of the DFN

- Rapid analysis of network properties using networkX
  - Path identification
  - Backbone identification
  - Local and global topological attributes

- Rapid low-fidelity pipe-network flow and transport simulations

• Currently in Use
  – Network Generation
    • Stochastically generated fractures
    • Multiple families
    • Layers
    • Deterministic features (Faults/Repositories)
      • Detailed geologic output report
  – Graph-based DFN analysis
  – Transport in DFNs to benchmark ECPM transport

• On Deck
  – Network Generation
    • Depth/stress dependent aperture/permeability
  – DFN - Particle tracking / ADE in DECOVALEX Task F benchmarks
dfnWorks in GDSA workflow

- **ECPM**
- **dfnGen**

![Diagram of workflow with nodes and connections](image-url)
Additional Applications

- Repository Science
- Carbon Sequestration
- Unconventional Hydrocarbon Extraction
- Enhanced Geothermal Energy Extraction
- Fundamental Research Science

Internal fracture aperture variability

Matrix Diffusion

Stress Dependent Apertures
dfnWorks: 3D Discrete Fracture Network Modeling Suite

Additional Details

- Open Source (github.com)
- Robust Online Documentation
- dfnWorkShop Training
- dfnworks.lanl.gov
- Contact: dfnworks@lanl.gov
Thank you for your time