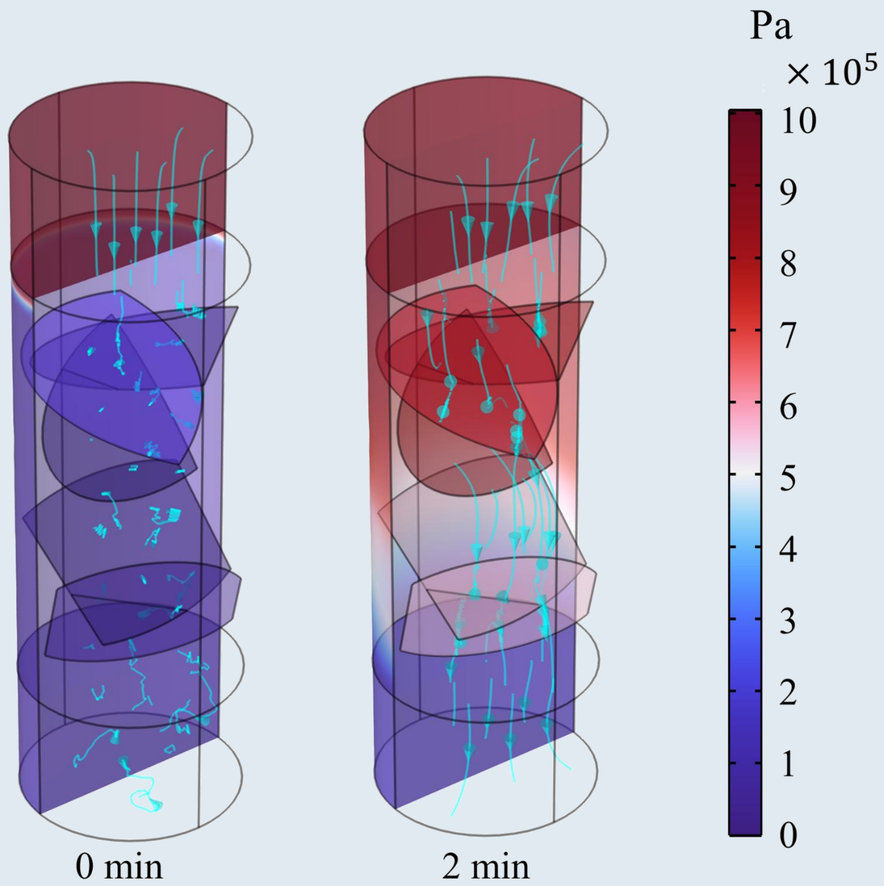
Geometric-Topological Constraint Modeling of Random Fracture Networks

Computational modeling can be used to construct random fracture networks for characterizing fractured reservoirs and predicting their flow response characteristics. The fracture model is generated under geometric-topological statistical constraints, while an uncertainty quantification analysis is employed to evaluate the contribution of each parameter to the fracture network connectivity.

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Introduction

The seepage behavior of fractured rock masses is governed by fracture geometry and topological connectivity, which together determine preferential flow paths. Due to inherent heterogeneity, complex hydraulic conductivity distributions arise, leading to flow patterns that are difficult to predict.

Early studies mainly adopted purely geometric or purely topological approaches, neglecting their synergistic coupling and failing to identify dominant controlling factors. This limits predictive capability and leaves the distinct contributions of geometric and topological parameters largely unquantified.

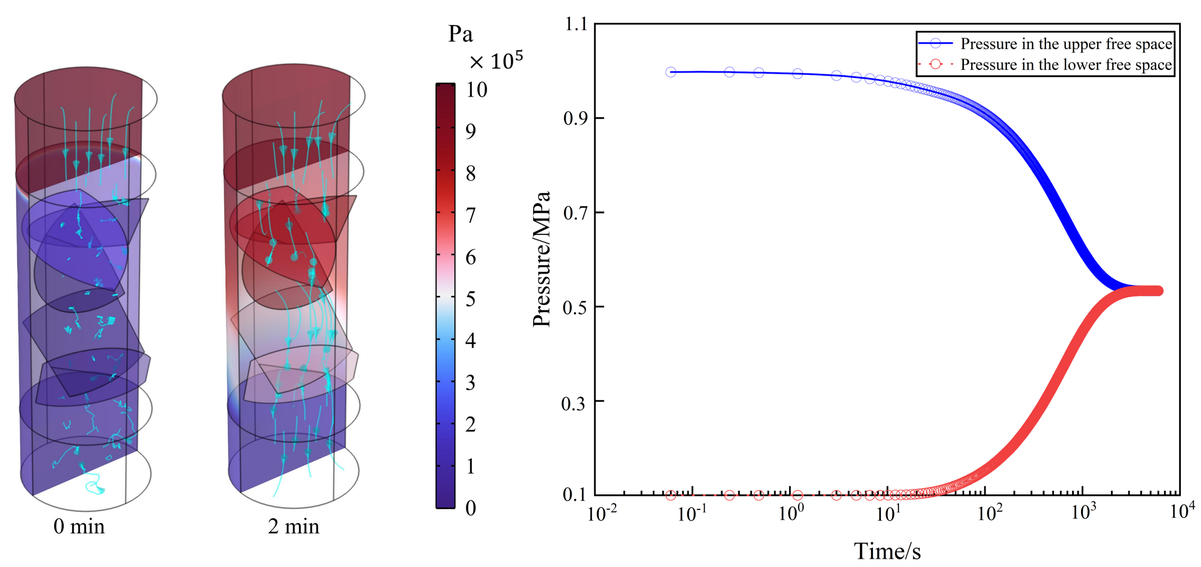


Figure 1. Seepage analysis of random fracture networks

Methodology

Geometric descriptors fracture orientation, length, aperture, and spatial density are first generated in MATLAB to construct stochastic fracture realizations, while topological constraints (node connectivity and percolation pathways) are embedded to honor network integrity. This couples morphology with connectivity, ensuring that generated networks preserve both statistical geometric fidelity and the backbone of conductive pathways.

Results

By integrating geometric and topological constraints, the model better predicts fracture network connectivity and seepage behavior. Uncertainty quantification further identifies the dominant controlling factors, highlighting the critical role of topological parameters in governing system-scale flow responses.

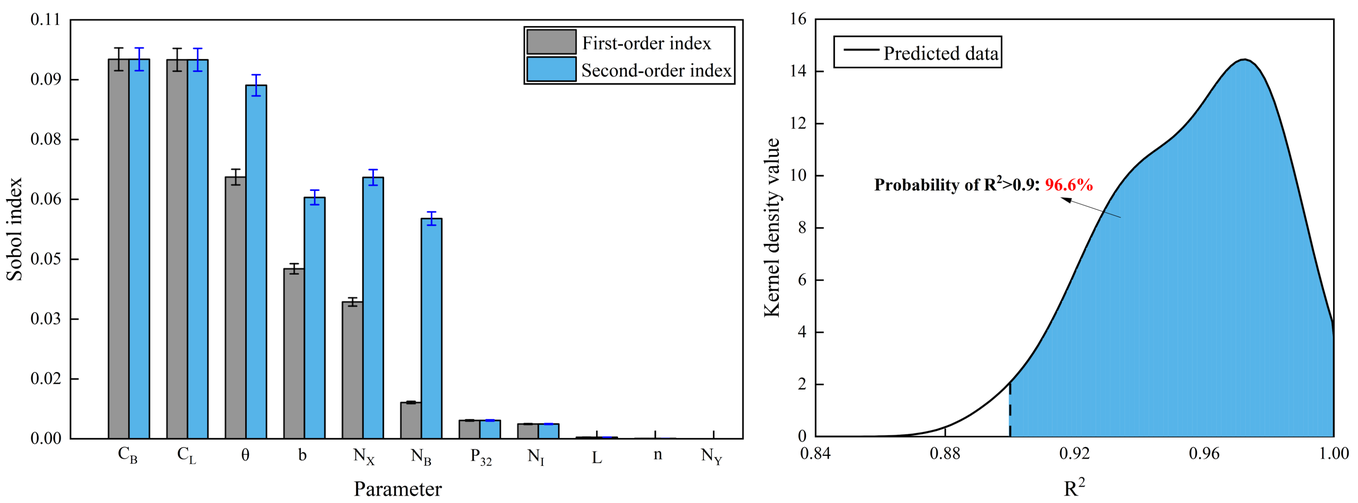


Figure 2. Results of uncertainty quantification analysis

Reference

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