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ORIGINAL PAPER

A Novel Method for Rock Permeability Determination Based on the Pressure Pulse Decay Method and Inverse Numerical Simulations

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Abstract

Rock permeability is a critical parameter for assessing rock's ability to facilitate fluid flow. The pressure pulse decay method, characterized by its short testing duration and high accuracy, is widely employed for permeability testing of low-permeable rocks. This method acquires pressure differential data by conducting experiments on regular-shaped samples. Due to the theoretical solution's requirements (cross-sectional area and length), this method cannot be applied to rocks that are challenging to shape into regular samples, such as soft rock and soft coal. In this paper, a novel permeability determination method based on the numerical simulation of inverse problem is proposed. This method involves constructing a mathematical model that accurately describes the entire process of determining permeability using the pressure pulse decay method. The sample's pressure difference data over time is used as a penalty function, and the sample permeability is calculated by inverse problem numerical simulation. Specifically, a computation strategy is introduced to determine the initial range for permeability, aiming to avoid locally optimal issues in the inverse problem numerical simulation. Utilizing the new model, forward and inverse problem numerical simulations were conducted. The pressure difference decay data obtained from these calculations closely match the laboratory-measured data for regular samples, with correlation coefficient (R^2) reaching 0.992 and 0.990, respectively. The permeability calculated by inverse simulation is determined to be 0.28 mD, showing minimal deviation from the theoretically derived permeability. This demonstrates the accuracy of the proposed model in describing the experimental process of the pressure pulse decay method and the precision of the obtaining permeability parameters. Furthermore, when applied to numerical experiments with irregular-shaped samples, the inverse simulation yields pressure difference data that closely matches the experimental data. The established new method effectively addresses limitations posed by the shape of samples, providing a novel approach for measuring rock permeability. The convenience of numerical experiments also offers a new and efficient means to investigate the competitive effects of permeability influencing factors. This provides promising applications in unconventional gas development, depleted reservoir carbon dioxide storage, and geological hydrogen storage, among other fields.

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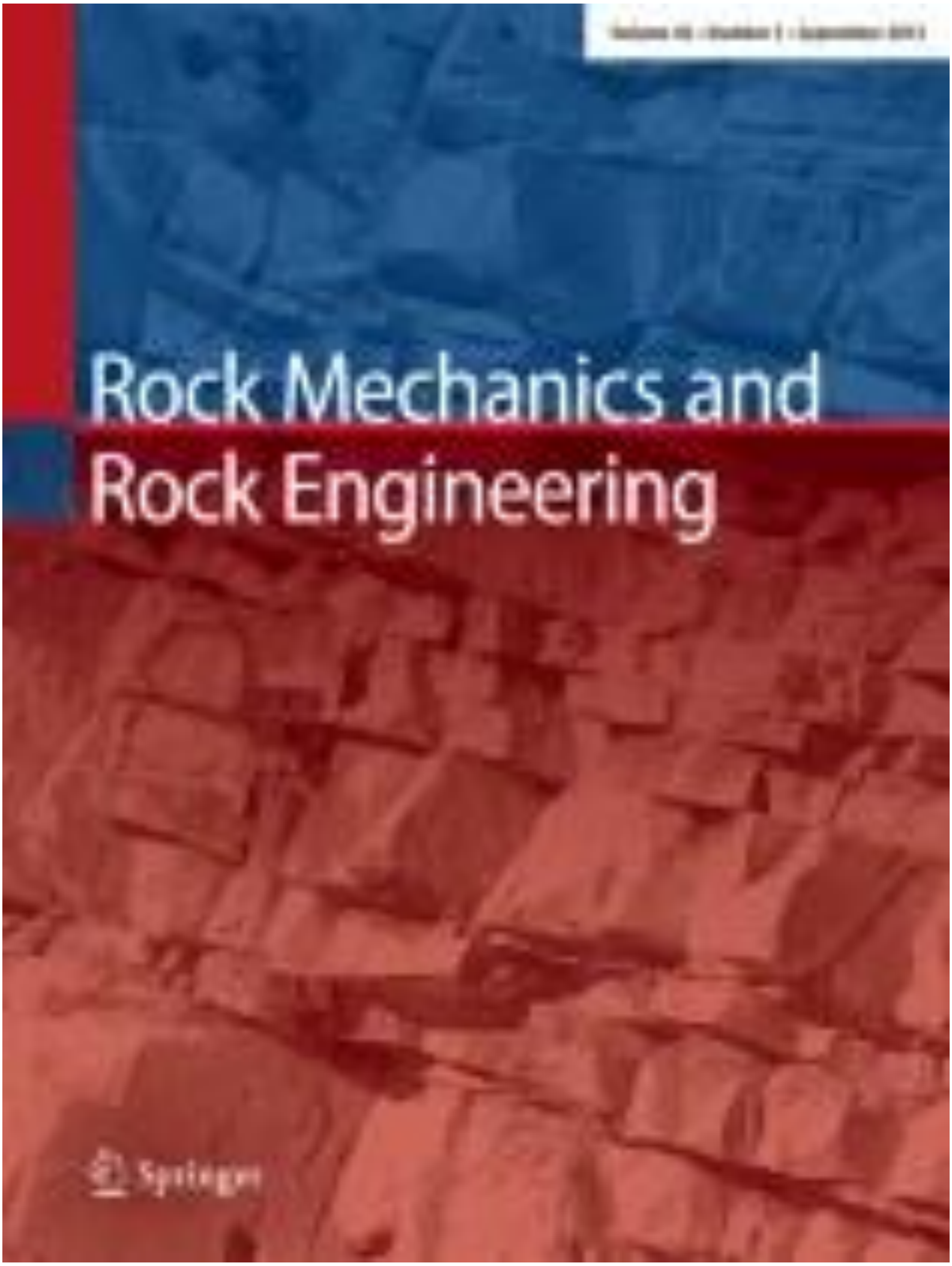
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