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# Two Phase Relative Permeability Prediction of Rock Fractures Using Optimized Deep Learning

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**Abstract**

1. **OBJECTIVE/SCOPE**

Relative permeability are essential parameters for the modeling of fluid flow in conventional and unconventional reservoirs. Traditional static- and flow-based methods used to estimate the fracture relative permeability suffer from low accuracy and high computation cost, respectively. Experimental measurements are even more time-consuming. This work presents a data-driven, physics-included model based on machine learning as an alternative to traditional methods.

2. **METHODS, PROCEDURES, PROCESS**

The objective of this study is to develop a data-driven, physics-featuring model for estimating fracture relative permeability, with the consideration of geometric fracture properties (e.g., mean aperture, wettability distribution, minimum aperture, roughness, tortuosity, contact angle, etc.) and other flow parameters (e.g., Reynolds number, Klinkenberg constant). The workflow includes four main steps, as shown in Figure 1. Step 1: We first identify the uncertain parameters which affect the shale fracture relative permeability using global sensitivity analysis and then generate ns training samples using LHS based on the identified uncertain parameters. Step 2: High-resolution simulations with parallel computing for the Navier-Stokes equations (NSEs) are run for each of the ns training samples. Step 3: A data-driven model is then built to model the nonlinear mapping between the input and output parameters based on results collected from Step 2. Herein, four popular and powerful machine-learning techniques, including Multivariate Adaptive Regression Splines (MARS), Support Vector Regression (SVR), Random Forests (RF), and Artificial Neural Network (ANN), are implemented to select the most suitable algorithm. Step 4: We finally conduct blind validation on the proposed model with high-fidelity simulations and further test it with experimental measurements.

3. **RESULTS, OBSERVATIONS, CONCLUSIONS**

We demonstrate the developed surrogate model with hundreds of fracture cases with a broad range of roughness, tortuosity, wettability distribution, minimum aperture, and contact angle. We further extend its applicability by incorporating the inertial and gas slippage effects, which are quantified by Reynolds number and Klinkenberg constant, respectively. We then compare its performance in terms of accuracy and efficiency to the reference solutions (i.e., NSEs simulations and experimental measurements) and seven other traditional models from the literature. Results show that the developed data-driven model shows the best accuracy among the selected models. Specifically speaking, the proposed model offers more computational efficiency than the flow-based models by two-orders of magnitude and provides more accurate results than the analytical-based models yet with the same level of efficiency.

4. **NOVEL/ADDITIVE INFORMATION**

We propose a comprehensive workflow for developing a data-driven, physics-included model using deep learning to estimate the fracture relative permeability. To our knowledge, this technique is introduced for the first time. The proposed model offers an efficient and accurate alternative to the traditional upscaling methods that can be readily implemented in reservoir characterization and modeling workflows.

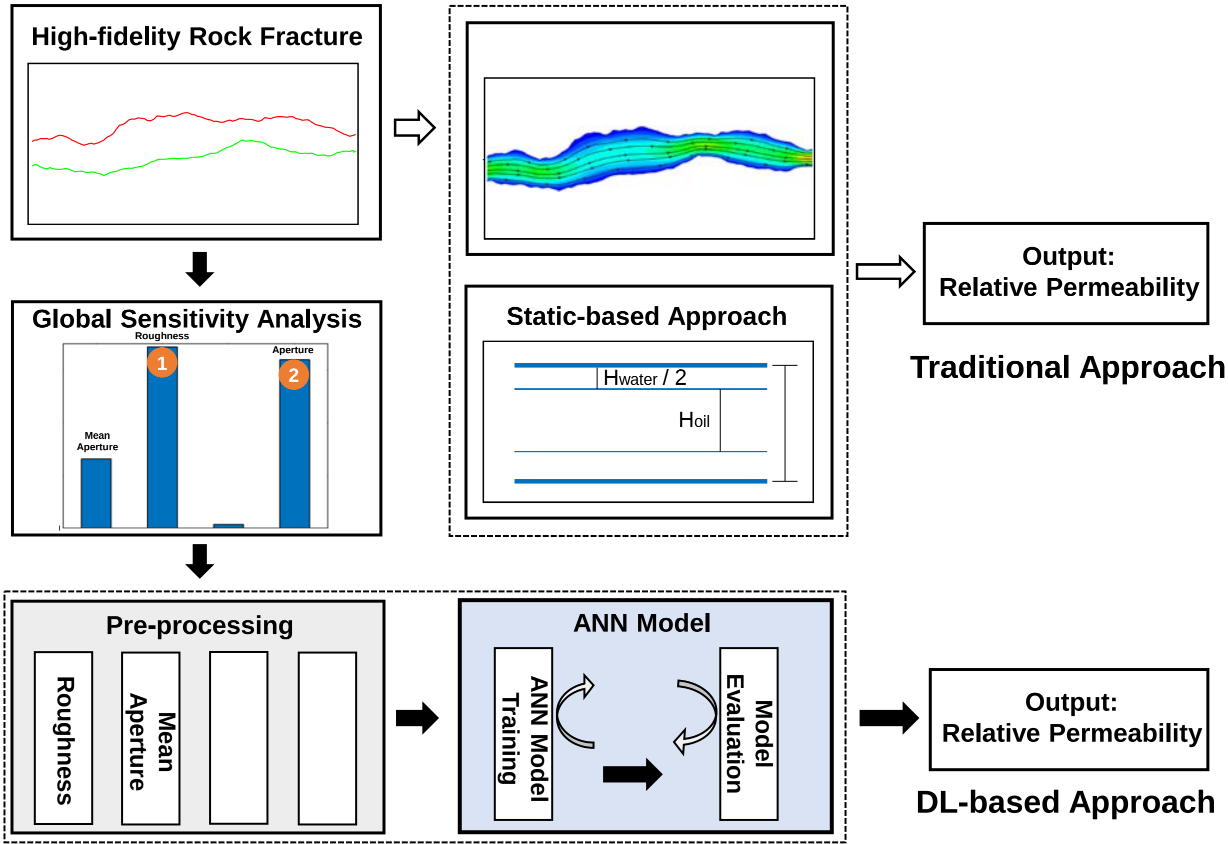


**Figure 1.** Workflow shows the development of the proposed data-driven model.