Temporal Mixing Behavior of a Conservative Solute through Self-affine Fractures: Investigation and prediction

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Introduction

Mixing is the fundamental process for solute transport in geological formations. Detailed characterizations and temporal scaling properties of the mixing behavior of a conservative solute in self-affine fractures are critical for predicting the fate of solutes. In this work, the influence of the Hurst exponent and Peclet number (*Pe*) on the temporal mixing behavior of a conservative solute through the self-affine fractures with and without the shear displacement (i.e. the constant-aperture fracture (see Figure 1 (a)) and the variable-aperture fracture (see Figure 1 (b))) were investigated. We quantified the mixing by the scalar dissipation rate (SDR) in self-affine fractures. Our investigation shows that the variable-aperture distribution leads to local fluctuation of the temporal evolution of the SDR, whereas the temporal evolution of the SDR in the constant-aperture fractures is smoothly decreasing as a power-law function of time (see Figure 2). The *Pe* plays a dominant role in the temporal evolution of mixing in both variable-aperture and constant-aperture fractures. The exponent of the best-fitting SDR scaling decreases significantly as the *Pe* increases, indicating that the relatively large *Pe* enhances the mixing process. In the constant-aperture fracture, the influence of Hurst exponent on the temporal evolution of the SDR becomes negligible when the *Pe* is relatively small. The longitudinal SDR can be related to the global SDR in the constant-aperture fracture when the *Pe* is relatively small. As the *Pe* increases the longitudinal SDR overpredicts the global SDR. In the variable-aperture fractures, predicting the global SDR from the longitudinal SDR is inappropriate due to the non-monotonic decrease of the longitudinal concentration second moment, which results in a physically meaningless SDR (i.e. the negative SDR).

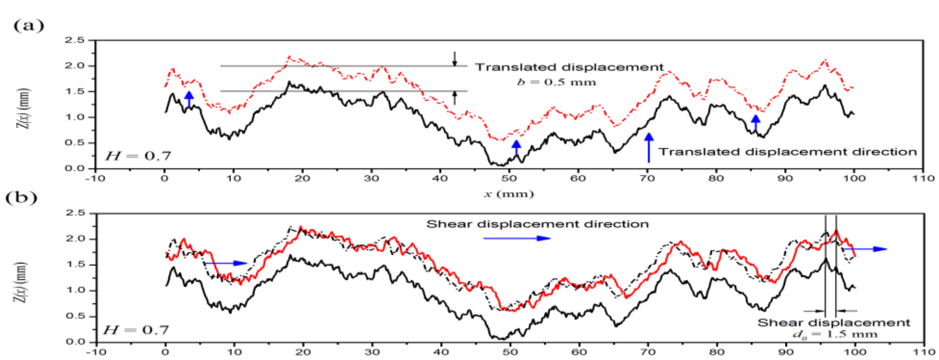

Figure 1: Reconstruction of aperture field in the self-affine rough fracture with H=0.7.(a) Reconstruction of constant-aperture rough fracture. (b) Reconstruction of variable-aperture rough fracture.

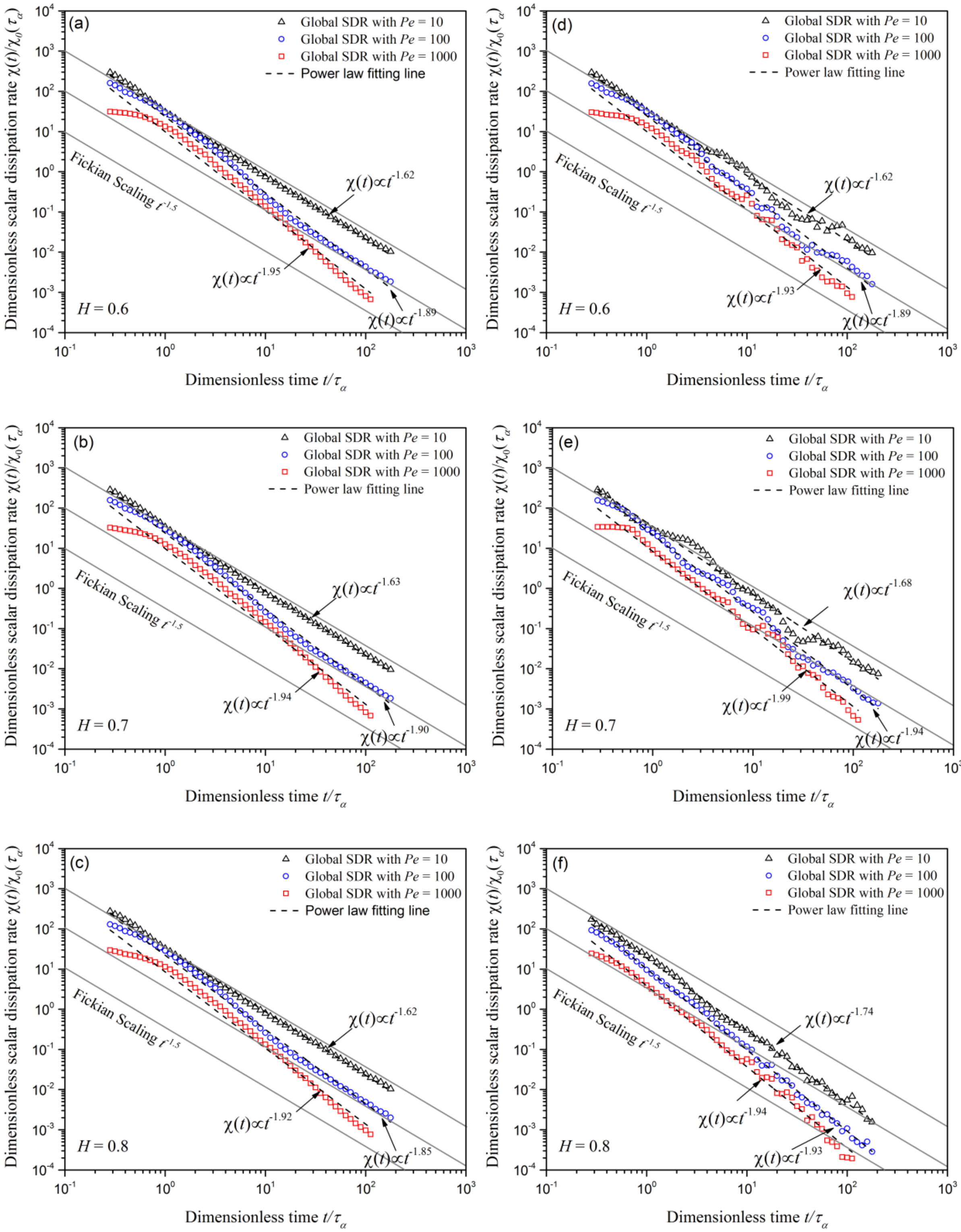

Figure 2: Scalar dissipation rate estimated in the constant-aperture fracture and variable-aperture fracture with H=0.6, 0.7, and 0.8 for Pe=10, 100, and 1000, respectively.