High-fidelity Surface Roughness Characterization: Role Of Super-resolution Technique

Y. Li, King Abdullah University of Science & Technology; X. He, H. Kwak, Saudi Aramco PE&D; H. Hoteit, King Abdullah University of Science & Technology

Abstract

Objectives/Scope: Surface roughness is an infamous troublemaker that sneakily shortens NMR T2 relaxation time, thereby leading to misinterpretation of petrophysical properties. Existing numerical methods enable the extraction of irregular pore shapes from micro-CT images yet fail to capture the "actual" roughness. This work combines a deep-learning-based super-resolution technique with a sophisticated shape descriptor to enhance surface roughness characterization.

Methods, Procedures, Process: This work aims to upgrade conventional surface roughness characterization methods by leveraging the super-resolution technique. The proposed workflow includes four steps. First, a super-resolution generative adversarial network (SRGAN) is trained to generate high-resolution (4x) digital rock model. Then, the interconnected pore space is decomposed into a plurality of disconnected pore structures using a hybrid pore separation algorithm. We use the spherical harmonics to create an orthogonal basis for surface reconstruction. A reference surface, excluding all fine-scale textures, is created for roughness characterization. Eventually, a heterogeneous roughness map is obtained over each coarse pore structure by averaging the surface roughness of the super-resolved images.

Results, Observations, Conclusions: The performance of the SRGAN is first validated by comparing both morphological and hydraulic properties of super-resolved images with high-resolution images. Numerical results show that the SRGAN enables to reproduce surface textures invisible from micro-CT images. Compared to the dimensionless surface roughness parameter calculated from low-resolution micro-CT images, super-resolved images always produce a higher roughness parameter. It is worth noting that pore separation plays a critical role in roughness characterization. The proposed workflow utilizes the SNOW algorithm to effectively reduce the over-segmentation issue. However, the resultant pore structures may still be complicated and cannot be easily solved by the spherical harmonic method. Thus, the pore separation step continues by breaking up the skeleton of disconnected pores if necessary. With high-resolution pore structures, the heterogeneity of surface roughness can be modeled. This helps to reproduce the surface roughness effect accurately and meanwhile reduces the simulation cost.

Novel/Additive Information: We combined super-resolution generative adversarial network and spherical harmonic method to innovate conventional surface roughness characterization methods. The proposed method captures the surface roughness that is missing from low-resolution micro-CT images and makes modeling the heterogeneity of surface roughness technologically feasible. This enables a way to numerically model the spatial effect of surface roughness on pore-scale NMR T2 relaxation.