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Fast workflow to estimate petrophysical properties: From Digital Rock Physics Scale to Laboratory Scale

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Petrophysical rock properties (i.e., porosity, absolute and relative permeabilities) are key information for any reservoir characterization and represent fundamental input parameters for the simulation studies. To access to such information typically core analysis are needed. Although core analysis tests are an accurate way to obtain such properties (Gaafar et al. 2015), there are cases where these tests are not accomplished or not profitable to oil companies. Firstly, laboratory experiments can take a long time to be completed. Secondly, core plugs can be scarce, damaged or unsuitable for the tests. Recently in order to obtain reliable petrophysical properties from core plugs even when they are no longer suitable for laboratory experiments, digital rock physics techniques (DRP) may represent a as a powerful approach to obtain these parameters. DRP has progressed at rapidly and is becoming an indispensable tool for rock physics analysis even if the comparison between DRP results (micrometric scale) and laboratory tests (centimetric scale) needs the implementation of an additional upscaling method. DRP investigates the physical fluid flow properties of porous rock combining modern macroscopic imaging with advanced numerical simulations. The implementation of an upscaling method is required to validate DRP results (micrometric scale) and laboratory tests (centimetric scale). In this context, we propose a novel methodology (Miarelli and Della Torre 2021) allowing the digital characterization of rock properties at the plug scale. In particular, the developed workflow valorizes and combines different technologies (Figure 1): (i) micro-CT scan, (ii) advanced image processing, (iii) machine learning (Menke et al. 2021, Jouini et al. 2021), (iv) Computational Fluid Dynamic (CFD) numerical simulation. The first step of the methodology consists of acquiring micro-CT low-resolution scan of the entire core plug; then, machine learning techniques are applied to decompose the digital plug (derived by image processing on micro-CT scan) in reference element of volume(REV)-type equivalent blocks, determining the optimum number of REV type and their locations. One or several high-resolution 3D fine-scale images are used to derive the petrophysical properties of each REV type from individual fluid flow simulations at the pore scale. The resulting REV-type properties are then scaled up to the core plug scale. Finally, the scaled-up results are compared to the results of core analysis tests. The overall methodology is validated on a heterogeneous carbonate rock.
The structure of the implemented workflow allows to improve every single step to adapt the procedure to every different core plug rock types. In this sense, the developed workflow could be further upgraded in several ways. From the detection side of texture analysis, increasing REV attributes number, including spatial point process (Weil et al.2006), could better cluster analysis results. Optimal value for clusters number can be investigated adopting supervised machine learning technique instead of unsupervised ones. The developed workflow can be expanded to two-phase flow properties, using volume-of-fluid(VOF) approach, in order to evaluate relative permeability and capillary pressure of drainage and imbibition processes (Heyns and Oxtoby 2014;Brackbill et al. 1992;Shams et al. 2018) by an accurate modelling of low capillary or tension surface-dominated flows.

Participation

In-Person

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