Considerations in developing rock physics NMR software

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ABSTRACT: In order to understand the reservoir and its petrophysical properties, laboratory measurements are performed on rock samples (whole core, plugs or cuttings). It is a well-known fact that the traditional core analysis is very costly, time-consuming and in some cases, sample destructive. Digital Rock Physics (DRP) is gradually emerging as a powerful tool to complement traditional rock analysis. DRP implies imaging and digitizing rock samples, mainly using X-ray micro computed tomography (micro-CT), and then numerically simulating various physical processes in a 3D or 2D digital object. Macroscopic rock properties, such as porosity, permeability, elastic moduli, nuclear magnetic resonance (NMR) relaxation times, capillary pressure curves, electrical parameters (m and n), can be assessed in a faster and non-destructive manner. Nowadays most of these simulations can be performed on common workstations. In this work, we want to share our experiences in developing our own DRP software, providing details on how to handle computational limitations for this type of numerical simulations. To pursue this, we focus on simulating the NMR relaxation response on 2D and 3D samples.

The typical NMR signal of a reservoir rock is a noisy and multi-exponential decaying signal induced by the 1H nuclei present on reservoir fluids molecules. The signal decay rate is associated with the magnetic energy dissipation, or relaxation, caused by the fluid molecules interaction with the pore walls. Fluid molecules residing in smaller pores relax faster because the higher probability of interacting with pore walls. The NMR response can be simulated from a digital rock using the random walk (RW) technique that reproduces the diffusive motion of fluid molecules inside the rock pore. The RW algorithm tracks the random trajectory of an elected pore voxel, the so-called walker, through the voxelized pore network. The number of encounters with the pore wall is recorded for each walker and their magnetic energy dissipation computed accordingly. The resulting multi-exponential decay can be approximated by a linear combination of pure exponentials. The individual exponentials weight, define the relaxation time distribution whose shape, in ideal conditions, mirror the pore size distribution. The computation of the relaxation time distribution is very sensitive to noise and the traditional way to overcome this is applying a regularized non-negative least squares optimization (NNLS). However, the choice of the optimum regularization involves the computation of many exponential fittings, one for each regularization level. Depending on the digital rock characteristics, image size and resolution, the NMR simulated data can become very large, and some level of data compression is necessary.

We created a user-friendly software that helps overcome these difficulties. The possibility to have control on each particle movement and path choices, also allow to have a better understanding of the NMR phenomena, and to adjust the model parameters to experimental data. We introduce the use of a collision histogram, which provides a mechanism to solve the inverse associated problem of a NMR measure

ANP-Compromisso com pesquisa e desenvolvimento.

Key-words: Digital rock physics, Nuclear magnetic resonance (NMR), Inverse problems.