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Multi-resolution X-ray CT research applied on geo-materials

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Many research topics in geology concern the study of internal processes of geo-materials on a pore-scale level in order to estimate their macroscopic behaviour. The microstructure of a porous medium and the physical characteristics of the solids and the fluids that occupy the pore space determine several macroscopic transport properties of the medium. Understanding the relationship between microstructure and transport is therefore of great theoretical and practical interest in many fields of technology.

High resolution X-ray CT is becoming a widely used technique to study geo-materials in 3D at a pore-scale level. To be able to distinguish between the different components of a sample on a pore-scale level, it is important to obtain a high resolution, good contrast and a low noise level. The resolution that can be reached not only depends on the sample size and composition, but also on the specifications of the used X-ray source and X-ray detector and on the geometry of the system. An estimate of the achievable resolution with a certain setup can be derived by dividing the diameter of the sample by the number of pixel columns in the detector. For higher resolutions, the resolution is mainly limited by the focal spot size of the X-ray tube. Other factors like sample movement and deformation by thermal or mechanical effects also have a negative influence on the system's resolution, but they can usually be suppressed by a well-considered positioning of the sample and by monitoring its environment. Image contrast is subject to the amount of X-ray absorption by the sample. It depends both on the energy of the X-rays and on the density and atomic number of the present components. Contrast can be improved by carefully selecting the main X-ray energy level, which depends both on the X-ray source and the used detector. In some cases, it can be enhanced by doping the sample with a contrast agent. Both contrast and noise level depend on the detectability of the transmitted X-rays by the detector. Besides the detector characteristics, they also depend on the chosen scanning parameters. Since detection of X-rays is a statistical process, image quality will improve with increased exposure time.

Several geo-materials were scanned under different acquisition parameters and with different hardware components. The resolution of these scans is crucial when pores or minerals inside geo-materials need to be analysed in 3D. The higher the resolution, the better one can distinguish pores and/or minerals. The results of these experiments will be illustrating the possibilities of flexible X-ray CT systems, like the ones of the Centrum for X-ray CT of the Ghent University (Belgium). Following the previous section, the quality of a scan strongly depends on using the appropriate equipment, the optimal scanner settings and adequate experience.

Using optimized scanning conditions, it is even possible to visualize water in geo-materials. This offers a new promising future for high-resolution X-ray CT research in the domain of fluid flow in porous media. This non-destructive technique is able to simultaneously monitor the petrophysical conditions of the pore network and the fluid migration within, which enables for example optimisation of fluid-flow models. Additionally, visualisation of fluids inside geo-materials can also be used for the study of impregnation depths of conservation products. Some results of fluid migration inside geo-materials will be presented.

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