**Geometry and roughness experimental characterisation of sandstone fractures and its influence on the description of permeability**

The production of potable water, geothermal energy, hydrocarbons - assisted by waterflooding or not, and the prevention of radionuclides propagation around radioactive waste storage sites are examples of engineering applications where a detailed understanding of fluid flow within fractured rocks media can be paramount. Indeed, natural fractures are often jagged, irregular and rough. Still now, there is no single universal law to describe fluid flow in rocks. Particularly, sandstone fractures present features specific to their geologic clastic nature. In addition, while being predominant reservoir rock types, sedimentary rocks, are typically difficult to handle and as a result, experimental data is not always available to run flow models.

This explains the pertinence of an experimental characterisation of natural fracture geometry and flow behaviour, in sandstone. In particular, the Jurassic Luxemburg sandstone was selected for this study because it is representative of regional water-bearing and hydrocarbon-bearing reservoirs in Belgium, Luxemburg and Germany.

A comprehensive and original experimental process was designed to describe fractures geometry and roughness in Luxemburg sandstone from decimetric scale down to the grain size. Both well-known and new methods were deployed to describe the fracture geometry. Looking at roughness, a novel visual classification system was developed to qualitatively describe sedimentary rock surface and texture of the fracture wall. It was put in comparison with global visual observations, then common quantifying methods that focus in, at smaller and smaller scale: the Joint Roughness Coefficient, statistical and fractal methods. Applied to about a hundred samples, all methods appeared consistent with each other. It was found that Luxemburg sandstone fracture wall roughness was average and consistent with existing results for sandstone.
Describing the physical opening E seen between the two fracture walls, called the mechanical aperture, a comparison was made between two methods of measurements. First, the aperture was measured by a laser beam travelling across the base of a fractured sample (the "entrance" of the fracture) and secondly, measurements were taken within the fracture at several points using X-Ray tomography imaging. X-Ray images showed that inside the fractures, there were wide internal channels where the local aperture was much greater than at the entrance of the fracture. It was seen that the aperture E could double in average when these open channels were taken into account in a global computation. So, for a sandstone, clastic and somewhat brittle, it was showed how fundamental it is to calculate the mechanical aperture from as many measured points as possible including measurements taken at several locations within the fracture.

Flow analysis was done for fifteen fractured samples to assess fracture permeability and support a discussion on the influence of fracture morphological features on its determination.
The ability for flow particles to travel through the fractures was quantified by the ratio $f = E/e_h$ where $e_h$ is the hydraulic aperture, a calculated effective aperture that reflects the inner morphology of a real, fracture – irregular and rough. Using at first apertures E taken from laser measurements, the ratio $f$ was unexpectedly found to be $<1$. Using the E values based on X-Ray tomography however, $f$ fell within expected values for sandstone ($>1$). This contradiction was explained by the presence of the local channels that greatly facilitate flow inside the fracture (increasing $e_h$).
Moreover, it was showed that relative mismatch of the two fracture walls also greatly affects flow permeability in the sandstone. It was seen that it was increasing the channelling effect with a moderate to very high severity, up to a 50% increase of $e_h$ for a relative shift of 3mm.
The existence of local contact points between the opposing walls within the fracture together with channels in other areas was also quantified by use of an original new method. It is based on X-Ray data analysis: the Specific Surface $\Sigma$, a ratio of the fracture's surface envelope to the fracture volume. This descriptor was found to be in accordance with permeability results.

In conclusion, a comprehensive and original process based on known experimental and new methods was designed to describe the various morphological contributors to fracture geometry, then, investigate their effect on fluid flow.

The systematic implementation of the experimental process over a large, representative number of samples showed that the description of fracture geometry and roughness is complex and does not allow for a direct, broad classification of rocks.
In a general way, roughness is a significant aspect. It can be expressed by several methods which appeared consistent in the case of the Luxemburg sandstone, even if they describe the surfaces at a different scale. While roughness affected flow permeability within the fractures, the experimental measurement of flow channels in a clastic rock such as the Luxemburg sandstone has been fundamental, because they most contributed to the qualification of flow ($e_h$ and *f*). For a comprehensive description of these channels, it was shown that two elements were paramount: the means used to characterise the mechanical aperture and the relative shear shift between opposite fracture walls.