Advances in the Characterisation of Rough Fractures in Hydrocarbon Reservoirs

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Fracture surface roughness has major control over the flow of fluids through fracture systems and effects significant departures from the Cubic Law for predicting fluid flow through fracture apertures. This is particularly the case in crystalline reservoirs where flow mainly occurs through fractures [1]. We present a 5-stage approach for the full characterisation of rough fractures in hydrocarbon reservoirs aided by in-house developed software (Fig. 1). This is central to our drive to replace the parallel-plate model assumed in larger multi-fracture models with a model that fully accounts for rough fractures at a range of scales. The stages are:-

1. Optical profiling of resin replicas of rough fracture surfaces in a suite of rocks (Fig. 2), [2] using OptProf™,
2. Statistical analysis of these surfaces using ParaFrac™ [3],
3. Creation of synthetic models (Fig. 2) tuned to this data by SynFrac™ [3],
4. Experimental investigation of fluid flows [4], (Fig. 3a), and,
5. Computational fluid flow modelling in 2D cross sections of fractures, using the above data as boundary input [4], (Fig 3b).

OptiProf™ incorporates image improvement and noise suppression features as well as calculating the final topography of the fracture surface (Fig. 2). Procedures 2 and 3 take full account of the complex matching properties of the fracture surfaces as a function of wavelength, as well as anisotropy within the properties defining the fracture surfaces and their resulting aperture using the improved model of Isakov *et al.,* [3]. They have been rigorously tested on a large suite of synthetic fractures as well as real rock fractures. These tests have allowed relationships between the standard deviation of surface asperity heights, the fractal dimension and the matching parameters to be related to the resulting aperture of the fractures. In fact, mean aperture increases with an increase in standard deviation of asperity heights, anisotropy, roughness and fractal dimension of fracture surfaces.

This combined image analysis and modelling approach [1-5] is proving successful in enabling the physical constraints upon fluid flow through rough fractures to be well characterised.

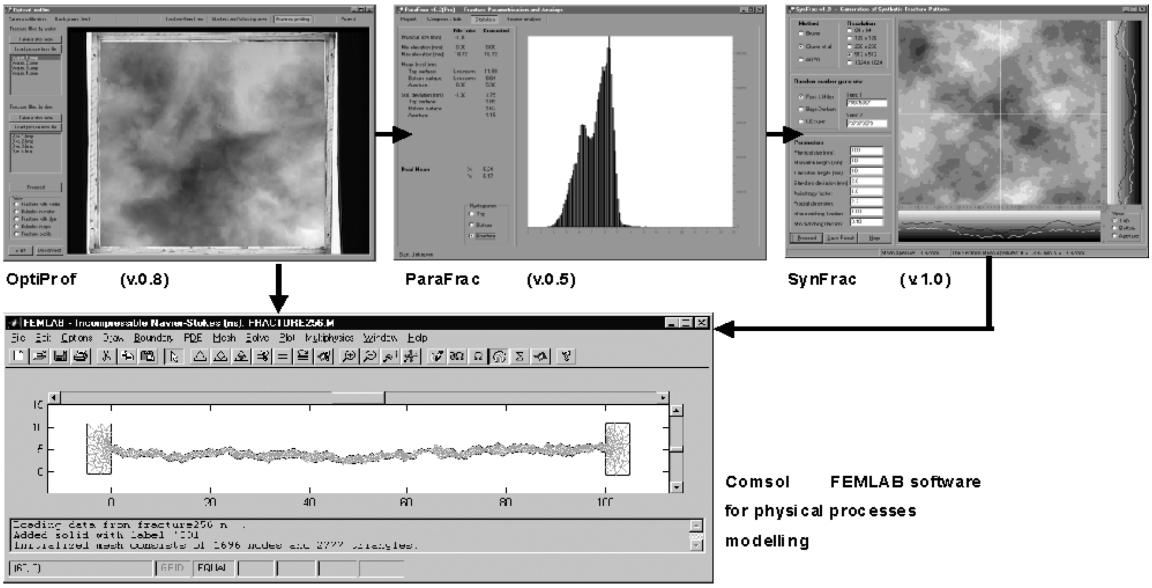

Figure 1. The software framework for the full characterisation of rough fractures

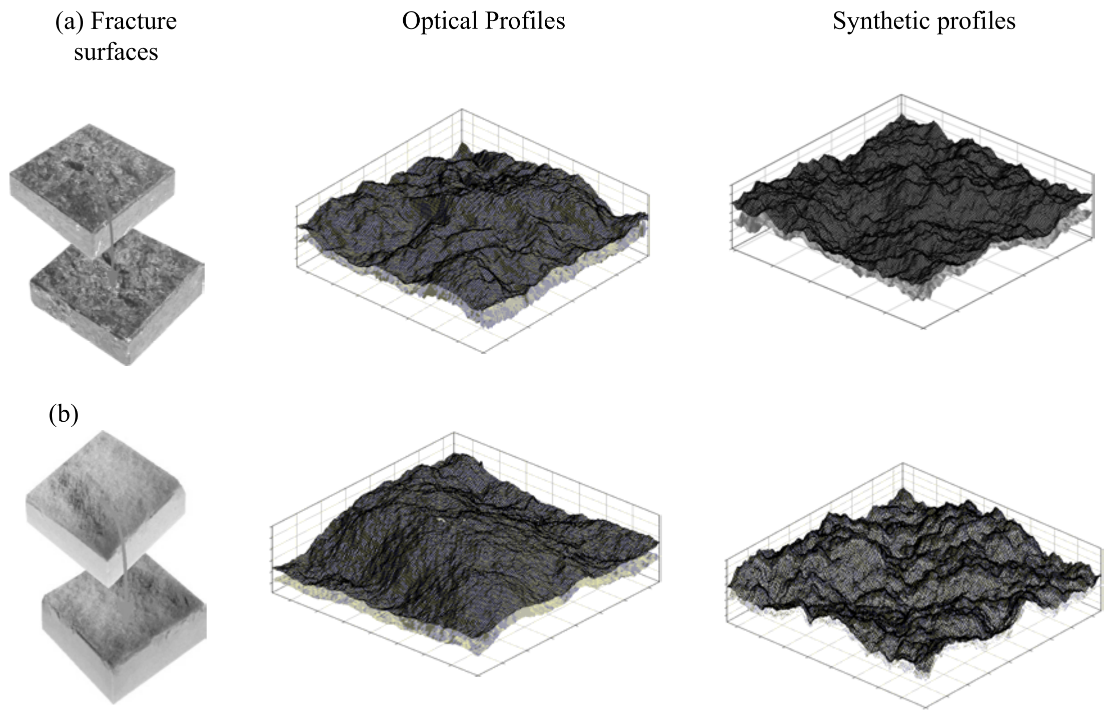

Figure 2. Mode I fractures in (a) syenite, (b) sandstone and their respective optical and synthetic profiles.

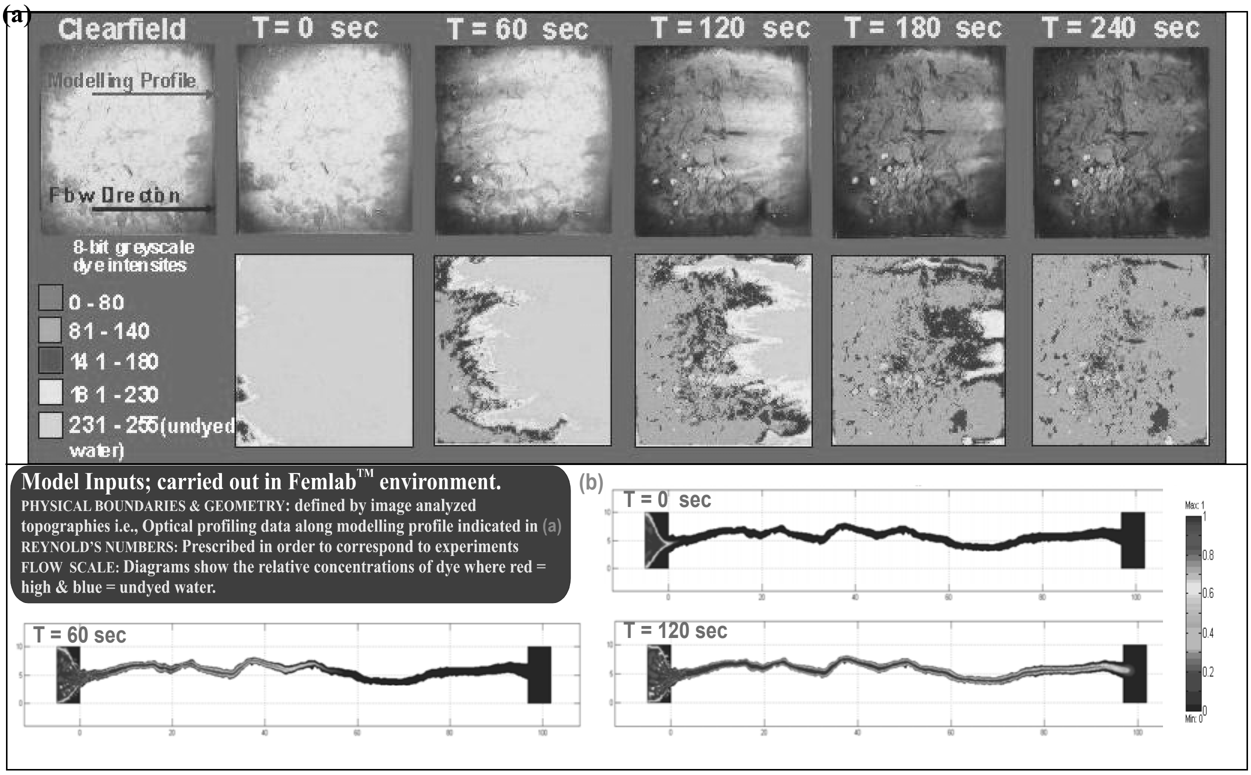

Figure 3. Experimental (**a**) and simulated fluid flow (**b**) for dyed water through a rough fracture in a resin model of syenite, where, Reynolds number = 1.2 (prescribed to fit that of the experiments) and Flow charge = 0.06 cm^3/sec. The fluid front (along the modelling profile indicated in **a)** reaches the output at the same time as the equivalent simulation frame.

References:

[1] Hakimi, E. Larsson, E. 1996. Aperture measurements and flow experiments on a single natural fracture, *International Journal of Rock Mechanics and Mineral Science Abstracts*. **33**, 395-404.

[2] Isakov, E. Ogilvie, S.R. Taylor, C.W. Glover, P.W.J. 2001. Fluid Flow through Rough Fractures in Rocks I. High Resolution Aperture Determinations, *Earth and Planetary Science Letters.* **191**, 267-282.

[3] Isakov, E. Glover, P.W.J. Ogilvie, S.R. 2001. Use of Synthetic Fractures in the Analysis of Natural Fracture Apertures. Proceedings of the 8th European Congress for Stereology and Image Analysis, *Image Analysis and Stereology*, **20** (2) SUPPL. 1, Sept, 366-371.

[4] Ogilvie, S.R. Isakov, E. Glover, P.W.J. Taylor, C.W. 2001. Use of Image Analysis and Finite Element Analysis to Characterise Fluid Flow in Rough Rock Fractures and their Synthetic Analogues. Proceedings of the 8th European Congress for Stereology and Image Analysis, *Image Analysis and Stereology*, **20** (2) SUPPL. 1, Sept, 504-509.