POLYTECH.MONS

Influence of roughness on fluid flow through rock fractures

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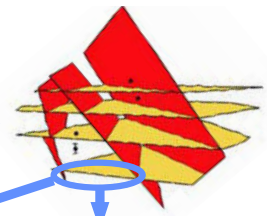
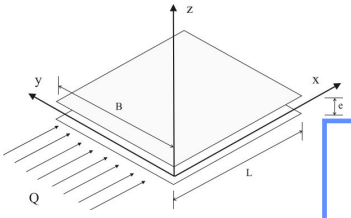
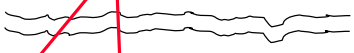
1. Modelisation of fluid flow through fractured rocks



Idealized smooth fracture — **Rough fracture** (no contact points)





f > 1

$$\lambda = \frac{96}{\mathrm{Re}} f \quad \text{or} \quad Q = \frac{1}{f} \frac{\rho g}{12\mu} \frac{B}{L} (e)^3 \Delta h$$

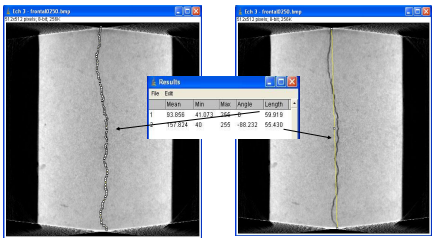
(Modified Poiseuille/cubic law)

λ : pressure losses coefficient, Re : Reynolds number, Q : flowrate (m³/s), e : aperture (m), L : fracture length, B : fracture width, Δh/L : hydraulic gradient, ρ and μ : fluid properties.

ABSTRACT

Experimental results obtained on artificial rock fractures (opening : from 0.3 to 1.2 mm, roughness quantified by profilometry) show that the flow deviates rather clearly from the Poiseuille plane flow (or "cubic law", valid for smooth fractures) because of additional losses by frictions due to the micro-swirls induced by roughness, and because of the tortuosity which lengthens the flow path in the laminar case. Moreover, the observed deviations are also due to the onset of partial or total turbulence for smaller Reynolds numbers as higher relative roughness (relationship between a roughness parameter and the hydraulic diameter of the crack). Semi-empirical models predicting pressure loss according to the roughness, to the opening of the cracks and to the flow rate are thus proposed on the basis of a statistical analysis of the experimental results.

2. Experimental study



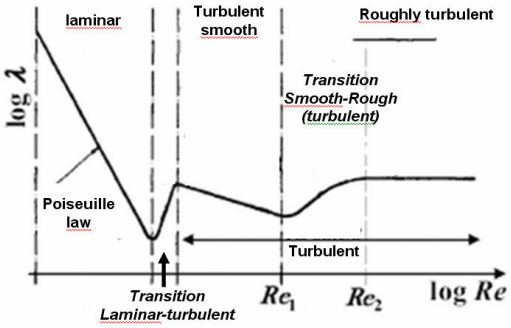
Measurement of aperture and tortuosity
(RX tomography)

Profilometries of fracture surfaces (quantification of roughness)

(laser profilometries)

- ***Absolute roughness*, *standard deviation*** on peaks heights
- ***Descriptive parameter*** : the Joint Roughness Coefficient (**JRC**)
- ***Fractal dimension***

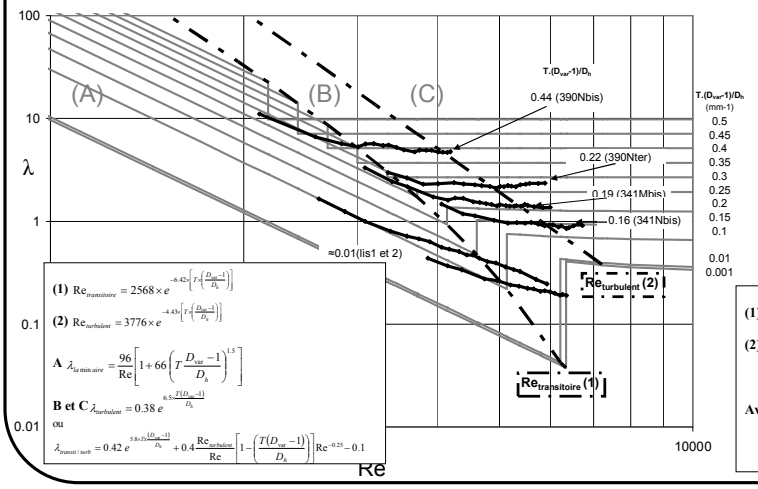
(calculated by « ruler » method, variogram analysis and power spectrum analysis)

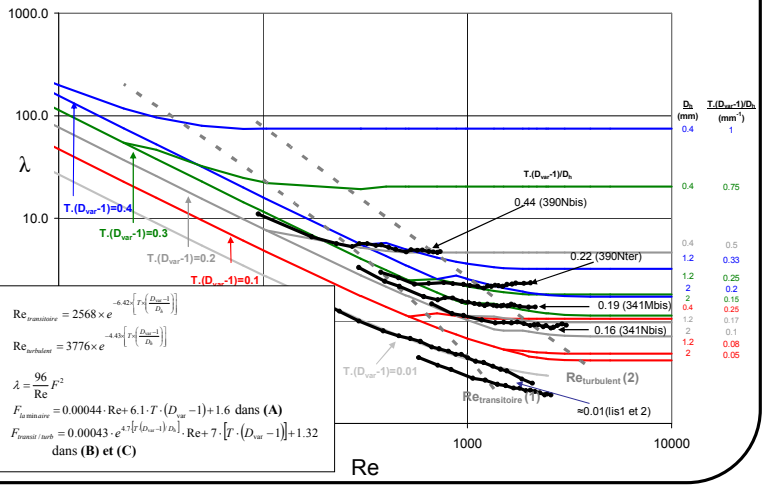


Flow tests in fractured rocks

3. Statistical analysis (linear correlations) → models to predict pressure losses

coefficient of pressure losses λ= f (Re, hydraulic diameter D_h (=2e), fractal dimension D_{var}, tortuosity T)





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