

# A two-scale method for slip flow transmissivity computation of a heterogeneous and anisotropic fracture

Tony Zaouter<sup>a,c</sup>, Didier Lasseux<sup>b</sup>, Marc Prat<sup>a</sup>, Florent Ledrappier<sup>d</sup>, Karl Vulliez<sup>c</sup>, Alain Béziat<sup>c</sup>

<sup>a</sup>*Institut de Mécanique des Fluides de Toulouse, IMFT, Université de Toulouse, CNRS - Toulouse, France.*

<sup>b</sup>*CNRS, I2M, UMR 5295 - Esplanade des Arts et Métiers, 33405 Talence, Cedex, France.*

<sup>c</sup>*CEA, DEN, SEAD, Laboratoire d'Étanchéité, 30207 Bagnols-sur-Cèze, France.*

<sup>d</sup>*Technetics Group France, Laboratoire d'Étanchéité, 26700 Pierrelatte, France.*

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## Abstract

1 The situation of pressure-driven gas flow between confined rough walls (i.e., in a fracture) is com-  
2 mon in many industrial applications, ranging from fluid recovery through fractured rocks to leak rate  
3 determination of static metal-to-metal seals. In such applications, knowledge of the transport properties  
4 of the fractures represent a key issue as it can determine the success or failure of the whole system. A  
5 real rough fracture is usually characterized by a heterogeneous and multi-scale aperture field along with  
6 localized contact spots. A direct modelling of the flow in this connected topography can therefore be a  
7 very challenging task, demanding large computational capabilities.

8 In this work, a two-scale method is developed to study the slightly compressible flow of a gas in the  
9 slip regime within a rough, multi-scale fracture. Starting from the first-order slip-corrected Reynolds, or  
10 lubrication equation at the microscopic scale (the roughness scale), a macroscopic model that operates  
11 at the scale of a local cell can be derived using the method of volume averaging [1, 2]. This macroscopic  
12 model, analogous to a two-dimensional Darcy law, is characterize by an effective transmissivity tensor  
13 that is function of the microstructure and rarefaction through the Knudsen number,  $Kn$ , defined as  
14 the ratio of the mean free path of the gas to a characteristic aperture. The fracture generally being  
15 heterogeneous at large scale (due to the presence of waviness for example), it is subdivided in a set of  
16 tiles in which a transmissivity tensor is locally computed by the method discussed above, embedding the  
17 local underlying structural and gas rarefaction information. Then, the transport property of the entire  
18 fracture is determined by computing the flow in this heterogeneous and fully anisotropic transmissivity  
19 tensor field. This is achieved making use of a boundary element method [3, 4].

20 Numerical examples will be given on synthetic fractures such that of figure 1. The ability of the  
21 two-scale model to reproduce the results of a direct simulation in slip flow conditions, in terms of global  
22 transmissivity, will be presented. The reduction of the overall computational cost achieved by the  
23 two-scale method will be discussed as well.

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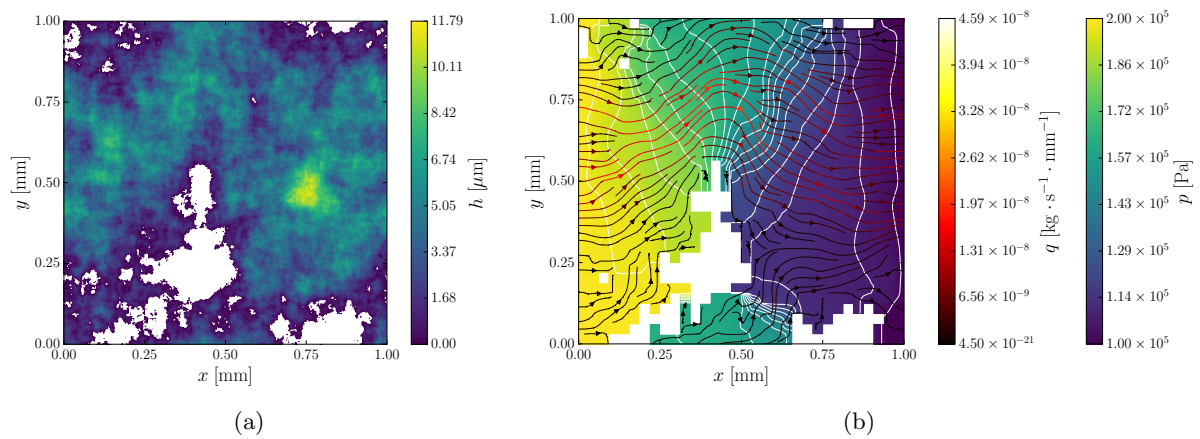


Figure 1: 1a: Aperture field,  $h(x, y)$ , of a fractal surface. White spots denote contact zones of zero aperture. 1b: Internal pressure and flux fields,  $p$  and  $q$ , computed by the two-scale method at  $\text{Kn} \approx 0.04$ , with a subdivision of  $32 \times 32$  tiles. White spots denote non-percolating tiles.