Effective boundary conditions for creeping flow along a periodic rough surface

B. CICHOCKI[1], P. SZYMCZAK[1] & F. FEUILLEBOIS[2]

[1] *Warsaw University, Institute of Theoretical Physics,,*
ul. Hoża 69, PL-00-681 Warsaw, Poland
cichocki@fuw.edu.pl

[2] *Laboratoire de Physique et Mécanique des Milieux Hétérogènes, ESPCI*
10, rue Vauquelin, 75005 Paris, France

Abstract The creeping flow along a periodic rough surface is calculated as a series in the slope of the roughness grooves. On a scale much larger than the grooves, this flow is equivalent to that over a smooth plane which is shifted from the top of the riblets. The convergence of the series for the shift distance in term of the slope is accelerated by use of Euler transformation and of the existence of a limit for large slope. The case of a flow along the grooves is presented in detail. The result for the shift is typically valid for a slope up to 2. A flow perpendicular to grooves can be treated in a similar way. Asymptotic behaviour for large slope depends on the profile shape.

Flow past a wall that is rough
Is a problem to do off-the-cuff;
When the surface is toothed,
It's effectively smoothed,
By a mapping that's complex enough.

1. Introduction

Modelling the flow of a viscous fluid along a rough surface is relevant for various applications and for a better understanding of fundamental problems like modelling the boundary condition of a porous material (see e.g. Taylor 1971), reducing the shear stress of a turbulent boundary layer as compared with that on a smooth surface (Bechert & Bartenwerfer 1989, Luchini, Manzo & Pozzi 1991).

The rough surface considered here has periodic corrugations with wavelength λ along one dimension. The corrugation profile is symmetric, but its shape is otherwise not restricted. Normalising distances with $\lambda/(2\pi)$, and using the notation shown in the figure, the conditions for the profile $f(x)$ are: