Multiscale Analysis of the Compressible Thin Film Flow between Two Rough Surfaces

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The present work introduces an original multiscale analysis model and its application for the Reynolds equation of a compressible flow in a 2D slider with rough walls. The multiscale analysis is based on an original finite volume method where the conservative character of the equations is preserved. The results obtained for the compressible flow between two closely spaced rough walls depict the importance of small-scale details. The efficiency of the multiscale models enables statistical analysis of the impact of different roughness parameters on the global characteristics of the slider, for example on the lift force.

Keywords (from 3 to 5 max): multiscale analysis, rough surface, compressible thin film

1. Introduction

The multiscale method is applied when the small-scale details cannot be discarded on coarse discretization grid. It enables the transmission of information from the fine grid to the coarse grid in an economic way without solving large size systems of equations. Flows in stochastic media governed by elliptic partial differential equations are typical applications. In the present work, it is developed for the compressible flow in a 2D slider with rough surfaces. Its field of application could be the analysis of dry gas seals operating with µm film thickness.

2. The finite volume multiscale method

The present multiscale approach is based on the finite volume method. It is inspired from [1] where it is used for the pressure equation in porous media. However, the compressible Reynolds equations is different because the rapidly variable film thickness intervenes in both the Poiseuille and the Couette part of the equation. The original method was therefore adapted. Figure 1 depicts the coarse grid and the dual grid; each volume of the dual (coarse) grid is discretized with a fine grid. The pressures in the vertex of the dual grid are used for defining boundary conditions for the fine grid. The mass flux calculated on the fine grid is used to correct the discretized Reynolds equation on the coarse grid. Thus, detailed information from the fine grid are transmitted to the coarse grid via additional source terms. By carefully defining the boundary conditions on cells of the dual coarse grid, the method retains is conservative character. A 2D slider made of two closely spaced, parallel, rough surfaces was considered; the film thickness was generated by using the method given in [2].

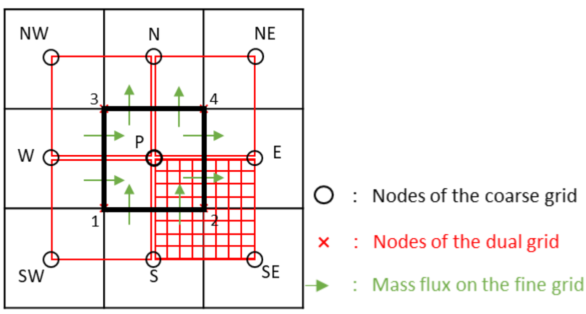

Figure 1: Coarse, dual and fine grid discretization

3. Results

Figure 2 shows an example of the coarse and the fine grid pressures for a square 2D slider of 0.35mm length (h_{mean}= $2.5\mu m$, $Sq=0.6\mu m$, $Ssk=0$, $Sku=3$, $b_x= b_y= 0.2\ mm$). Figure 3 depicts a statistic analysis of the dimensionless lift force generated by this slider for a compressibility parameter Λ=10 and two different skewness. For zero skewness, the mean lift force is close to zero while for negative skewness the mean lift force shows a slight shift to positive values. This suggests that a compressible 2D slider with worn rough surfaces can generate lift.

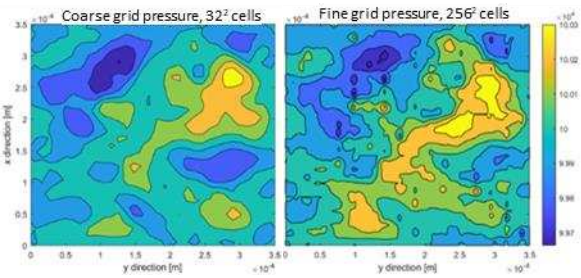

Figure 2: Pressure in a compressible 2D slider

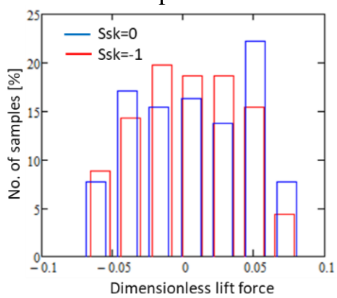

Figure 3: Lift force variation with roughness skewness

4. References

[1] Jenny, P. et al., "Multi-scale finite-volume method for elliptic problems in subsurface flow simulations", J. Comput.Phys., 187, 2003, 47-67.

[2] Pérez-Ràfols, F., Almqvist, A., "Generating randomly rough surfaces with given height probability distribution and power spectrum" Tribology International, 131, 2019, 591-604.