HOMOGENIZATION OF SOFT INTERFACES IN TIME-DEPENDENT HYDRODYNAMIC LUBRICATION

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ABSTRACT

We study the thin film lubrication problem with highly deformable surfaces which are both rough and moving. In order to understand the physics of the fluid film at the interface, the problem is modeled by means of the Reynolds equation. However, the common assumption of microscopically smooth surfaces is not invoked since real surfaces are inevitably rough or textured by design. Based on the motion and the roughness of the surfaces, the problem is considered in three regimes: stationary, quasi-stationary, and unsteady [1]. Presently, we concentrate on the unsteady case on which there are a limited number of studies. Furthermore, most biological and synthetic interfaces are soft. Hence, we focus on the study of the microscale lubrication problem where the deformation and the surface roughness effects are taken into account.

The difficulty behind the unsteady lubrication problem is the oscillation of the film thickness in both position and time. Hence, the present study aims to extend the multiscale analysis of lubricated interfaces to the unsteady case with deformable random microrough surfaces. In this work, the microscopic problem is considered in a decoupled framework and deformation effects are reflected in this level through a uniform projection of the boundary layer deformation into the cell. The homogenized lubrication response is then extracted from the frozen interface configuration.

For that purpose, the homogenization framework for the time-dependent problem will first be presented. The differences between the periodic commensurate and incommensurate as well as random microrough surfaces are highlighted with numerical investigations. A time-averaging method is proposed in order to deliver the effective macroscopic response and its efficacy is discussed for different types of microrough surfaces. Finally, the deformation is implemented through the Taylor assumption at the microscale and the ability of the proposed method to reflect the deformation effects is discussed.

Overall, the advocated approach constitutes a numerically efficient homogenization-based scale transition theory that unifies all soft hydrodynamic lubrication regimes in a single framework.

REFERENCES

[1] G. Bayada, I. Ciuperca, M. Jai. "Homogenized elliptic equations and variational inequalities with oscillating parameters. Application to the study of thin flow behavior with rough surfaces" *Nonlinear Analysis: Real World Applications*, 7:950-966 (2006).