THE CONTACT BETWEEN ROUGH SURFACES IN PRESENCE OF A FLUID FLOW IN THE INTERFACE: A STRONG COUPLING SCHEME

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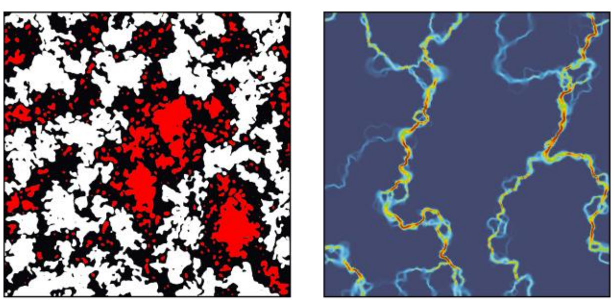
ABSTRACT
We study the problem of a thin-film viscous flow of compressible and incompressible fluids (governed by the Reynolds equation) across the contact interface between elastic solids with rough surfaces brought in contact by the external load. We derive a coupled weak formulation, perform finite-element simulations on a representative volume element (RVE) and consider a self-affine Gaussian roughness [1]. This problem has applications for static seals and lubrication in mixed regime, but also for poromechanics, slip in geological faults and basal sliding of glaciers.

The roughness of the surfaces determines the real contact area and the free volume distribution, and thus the transmissivity of the interface, while the fluid provides additional pressure on the contacting surfaces, see Fig. 1. Two approaches can be used for numerical treatment of the strongly coupled problem: (I) the partitioned approach, in which the solvers for mechanical contact and fluid flow are separated, and (II) the monolithic, meaning that the equations for contact and fluid are rendered into one system and solved simultaneously. We implement both of these approaches in the finite-element method (FEM) framework and compare their results.

It is important to note that under sufficiently high external loads or for sufficiently rich spectral content of the surface, non-simply connected contact patches can be present in the contact interface (see Fig. 1a, in red color), and the entrapment and pressurization of the fluid in the valleys between the contacting asperities must be taken into account.

In addition to the global coupling study, the particular problem of the trapped fluid is considered in detail using a simplified geometry: the frictional contact between an elastic body with a wavy surface and a rigid plane with incompressible or linear and nonlinear compressible fluid present in the valleys, see Fig. 2. This problem has an analytical solution under the assumption of small slope of the profile [2]. We derived a monolithic weak form for contact and fluid volume constraints and solved the problem in the FEM framework. We have shown that, unlike the analytical solution, if the slope of the profile is considered finite, then under the increasing external pressure the fluid will eventually open the contact interface, and the maximal static frictional force first increase and then decrease to zero under monotonically increasing external pressure [3].

We study also the generalization of the considered problem for the fluid flow across the wavy contact interface, using the aforementioned strong coupling framework and compare the numerical results with an approximate analytical solution.



(a) (b)

Fig.1 (a) Morphology of the contact interface: black is the contact area, white is out of contact, red is "trapped". (b) Incompressible fluid flow through the interface: the color represents the flow intensity.

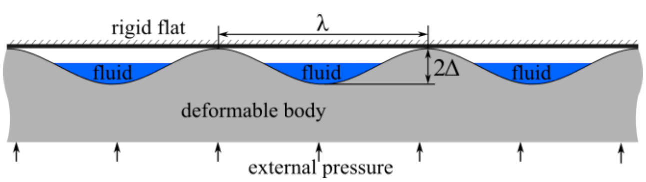


Fig.2 Fluid trapped in the contact interface between an elastic body with a periodic wavy surface and a rigid flat.

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