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Contact mécanique

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A study on the thightness of contact between rough surfaces

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It is now widely accepted that the contact between two surfaces is in fact a one to one contact between many asperities, depending on the roughness of the contact pair. This represents a strong deviation from the perfect contact assumed in engineering approaches, the real contact area being usually significantly smaller than the apparent contact area. In addition, such an approach also implies the presence of a free space between surfaces in contact. Thus, the purpose of our study consists in the development of numerical tools to analyse the mechanical contact between rough surfaces and the tightness of such a contact.

First, the normal contact between an elasto-plastic rough surface and a rigid plane is studied by means of a finite element approach. However, this approach, which requires a very fine mesh to capture the evolution of the local geometry during the loading, leads to long parallel computations. That is why a reduced model was developed. This model decomposes a rough surface into a field of axisymmetric and sinusoidal asperities. Phenomenological laws were determined by means of contact simulations between an asperity and a rigid plan, to describe both the behaviour of the asperities and the interactions between them. The reduced model turns out to be a robust and powerful tool which provides a very good agreement with finite element analysis and significant CPU time savings.

Second, the fluid flow in the resulting free volume between rough surfaces is also analysed by finite element methods. The laminar fluid flow simulation allows to recuperate the rate of flow in the volume. Thus, it is possible to determine the permeability of the contact interface for given load. The aim of this study is to compare the numerical results with experimental measurements of surface transmissivity and validate the computational model.

At the scale of our contact problem (micrometers), the assumption of a homogeneous material is not physically acceptable. The typical grain size is then comparable to the size of the asperities. The local response is then dependent on the granular stress-strain behaviour. This is why the third and last step will focus on the integration of a crystal plasticity model in our analysis in order to quantify its influence on the resulting aperture field between rough surfaces.

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Dynamics of Local Slip at Frictional Interfaces

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The transition from sticking to sliding of frictional interfaces is a phenomenon of importance for many physical systems in nature as well as in engineering. This transition is marked by the occurrence of local slip events which appear either before or during global sliding. The propagation of such slip events presents variations in many aspects, such as the length of propagation, the position of nucleation, and the propagation speed (also called rupture speed). The origin of these local slip events lies mainly in the presence of a non-uniform stress distribution and non-uniform frictional strengths at the interface. Both observations lead to interfacial stresses that reach the frictional strength at a localized region from which a local slip event starts to propagate. Understanding of the dynamics of local slip events is sought in order to improve the frictional strength of interfaces in engineering as well as to get better insights into the relation between earthquakes and their foreshocks.

Local slip events have been studied experimentally in geometrically simple setups. The experiments have revealed many interesting properties such as local slip events that increase the propagation length with each new slip event until the propagation distance reaches the total length of the interface and global sliding is observed. Other observations include different rupture speeds and variations in the global apparent friction coefficient. Even though, these experiments result in interesting observations, they are challenging due to difficulties of accessing information at the interface. Such experiments are therefore often limited to materials which are translucent and stress measurements are often distant to the interface. Therefore, numerical simulations are needed in order to give additional insights to the observed phenomena.

After summarizing the experimental research on the propagation of local slip events, this presentation will be focused on the numerical approach to study the dynamics of local slip events at frictional interfaces. Different numerical methods that are used to simulate interface ruptures are presented with the corresponding results giving additional tools to analyze the propagation of slip events. Challenges with respect to the applied friction law at the interface and its implications on the stability of the numerical solution are addressed.

Elastic contact between representative rough surfaces

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The subject of this presentation is elastic contact between rough surfaces. In particular, we study the evolution of the real contact-area under normal load. This topic is of a great importance in mechanics and physics of contact interactions as the real contact-area determines the contact resistivity, friction and the transfer of energy (heat and electric charge) through the contact interface. Understanding the contact-area evolution has profound implications in various fundamental (e.g., origin of friction) and engineering studies (e.g., electro-mechanical contact, tire-road interaction).

In this talk we introduce the key notion of surface representativity. Representativity is strongly connected with the normality of the surface heights distribution, which is a known feature of realistic surfaces. We carried out more than 3000 simulations using a computationally-costly complete mechanical model (spectral boundary element method) both for representative and non-representative surfaces. While the former obey a mechanical behavior in close range to that observed for large random realistic surfaces, the later fail to reproduce the correct behavior due to faulty periodicity or edge effects. The simulation results demonstrate that for representative surfaces the evolution of the real contact area is universal and does not depend on the Hurst roughness exponent (characteristic of the self-affine roughness). In contrast to all up to date numerical findings, this conclusion and the associated data are in a good agreement with a well-established analytical theory of rough contact [Bush-Gibson-Thomas theory, 1975]. But in comparison to this theory, our numerical model takes into consideration long range elastic interactions between asperities and the complex spreading of local contact zones. It thus enables to predict accurately the contact area evolution far beyond infinitesimal contact fractions (which is a limit of asperity-based theories). We also obtain a qualitatively new evolution of the real contact area with load. This novel result is owing to accurate statistics (> 3000 simulations) and to the fact that in previous numerical studies the representativity of surface samples was overlooked, which skewed numerical results. Finally, we derive a new contact evolution law, which describes perfectly the nonlinear universal evolution of the real contact area with load.