ТЕЗИСЫ ДОКЛАДОВ

МЕЖДУНАРОДНАЯ КОНФЕРЕНЦИЯ

«Физическая мезомеханика. Материалы с многоуровневой иерархически организованной структурой и интеллектуальные производственные технологии»,

посвященная 90-летию со дня рождения
основателя и первого директора ИФПМ СО РАН
академика Виктора Евгеньевича Панина

в рамках
Международного междисциплинарного симпозиума
«Иерархические материалы: разработка и приложения для новых технологий и надежных конструкций»

5–9 октября 2020 года
Томск, Россия

Томск
Издательство ТГУ
2020

DOI: 10.17223/9785946219242/4

FIRST YIELD IN THE MAUGIS-ADHESIVE CONTACT OF ELASTIC SPHERES

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Contacts are highly stressed components of structures. By examining the state of stress inside the contacting bodies, it is possible to determine the contact load to locally initiate plastic yield. In Hertzian contact, for example, this problem has been solved long ago.

The influence of adhesion on plastic yield is high due to the stress concentration at the edge of adhesive contacts, which can be thought of as an "external crack". Yet, the interplay of adhesion and plasticity is still poorly understood, despite the fact that it is especially important for the mechanics of microcontacts – or, in another word, asperities – which constitute various tribological surface parameters and phenomena of the meso- and macro-scale, including e.g. friction and wear.

Due to the constitutive non-linearity elasto-plastic contact simulations are numerically costly. The focus therefore will be on the problem of first yield in adhesive contacts. In the JKR limit of adhesive interaction, the stresses at the contact edge are singular. Hence, at an arbitrarily small load there would be plastic deformation in a finite environment of the contact boundary. In the opposite DMT limit of adhesion the contact pressure distribution is the same as in the non-adhesive case with a reduced normal force; first yield thus occurs on the axis of symmetry at a lower load than in the non-adhesive contact.

Both limiting cases are insufficient to investigate the problem; in fact, the stress concentration at the contact boundary is finite, so a reasonable framework for solving the problem must take into account the Tabor parameter for characterizing the range of adhesion. In the talk the solution of the adhesive normal contact problem with arbitrary range of adhesion according to Maugis, based on the Dugdale model for the adhesive interaction, will be used. To determine the point of first yield, the stresses within the elastic half-space induced by the applied pressure distribution found by Maugis need to be computed. These can be obtained by superposition of the stresses caused by a concentrated normal load (originally found by Boussinesq) i.e. integration over the whole pressure distribution. To predict the onset of plastic yield within the elastic half-space, the von Mises yield criterion is used. Hence, all results are obviously only applicable for materials, whose mechanisms to release inelastic stresses are captured by this yield criterion. For example, this is probably not the case for the wide class of adhesive contacts formed by very soft (and often viscoelastic) biomaterials. Also note that it has been shown in Finite-Element simulations that, especially for large indentation depths, there are differences in elasto-plastic contacts between indentation (i.e. contact between a rigid sphere and a deformable flat) and flattening problems (where instead the sphere is deformable). This aspect has not been captured in the analysis.

It is found that yield can be first initiated either on the axis of symmetry inside the softer sphere (for small values of the Tabor parameter, i.e. long range adhesion) or at the contact boundary (for large values of the Tabor parameter). In both cases adhesion severely reduces the external load necessary to initiate plastic yield. For yielding on the axis of symmetry the Tabor parameter has almost no influence on the critical load and the simple analytical solution for the DMT-limit can be used. Nevertheless, in this case, the point of first yield moves towards the surface for stronger adhesion and the hydrostatic component of the stress state is reduced.

The results obtained are quantitatively similar to previously published findings based on the double Hertz model of adhesion [1]. This suggests that the precise form of the adhesive potential has only a small influence on the onset of plastic yield.

1. Y.C. Wu, G.G. Adams. Plastic Yield Conditions for Adhesive Contacts Between a Rigid Sphere and an Elastic Half-Space, Journal of Tribology 2008, 131(1), 011403.