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Measured and simulated contact stiffness of dry, metallic joints

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ABSTRACT

Joints reduce the overall stiffness of a structure. The stiffness depends on the material and on geometrical properties of the surface. Since mean value and variance of heights are not sufficient to describe the surface roughness, often further stochastic parameters are introduced. However, these additional stochastic parameters depend strongly on the measurement resolution and cannot be considered as intrinsic properties of the profile. Therefore, we describe the surface as a fractal over several length scales with parameters which are independent of the measurement resolution.

One way to describe the typical features of a profile is the use of a discrete structure function. For a large class of typical surfaces measured structure functions can be approximated by a three-parameter function [1], employing the RMS-value of the roughness, a transition length x_T between fractal behaviour at high wavenumbers and stationary behaviour at low wavenumbers, and the fractal dimension D in the fractal region, respectively, as intrinsic parameters to describe an isotropic rough surface.

In order to study the influence of the different parameters and to develop constitutive contact laws it is necessary to numerically generate surfaces with specified properties [2]. These generated surfaces are then used in a simulation of the normal contact based on elastic halfspace theory. The method is based on a variational approach using the minimization of the total complementary potential energy of two elastic bodies in frictionless contact. Introduction of a discretization using Boussinesq's solution and subsequent minimization leads finally to a linear system, which is solved by a Gauss-Seidel iteration for the unknown pressures p. The additional restrictions $p_k \geq 0$ and $p_k \leq H$ have to be observed, since no tension is allowed at the interface and to model elasto-plastic contact by iteratively correcting the height values, where H is a suitable hardness value.

A variational approach is also used for the simulation of the tangential contact. In this case, the active contact patches and pressures p_k have to be calculated from a previous normal contact calculation. By solving the linear system of equations the restrictions $q_k \leq \mu p_k$ for a local Coulomb contact law or $q_k \leq t_{\max}$ for a local Tresca contact law have to be observed.

The presented halfspace model of the fractal surface is tested against experimental data which are obtained from contact tests. Several surfaces were generated by spark erosion (Figure 1) and sandblasting. These surfaces are isotropic such that the intrinsic parameters can be identified easily. The normal and

tangential contact tests are conducted separately in two different setups. In both setups the deflection of the loaded specimens consists of two parts: The deflection of the solid material which is elastic and the deformation of the surface asperities of the joint interface which is elasto-plastic at initial load. Therefore it is necessary to determine the bulk deformation by a test on a single equivalent solid specimen or by a FE-model. The difference in deflection is the deformation of the asperities. The deformation is measured by two extensometers, which are clipped on opposite sides of the specimens to assess bending in a normal contact test or bending and rotation during sliding in a tangential contact test.

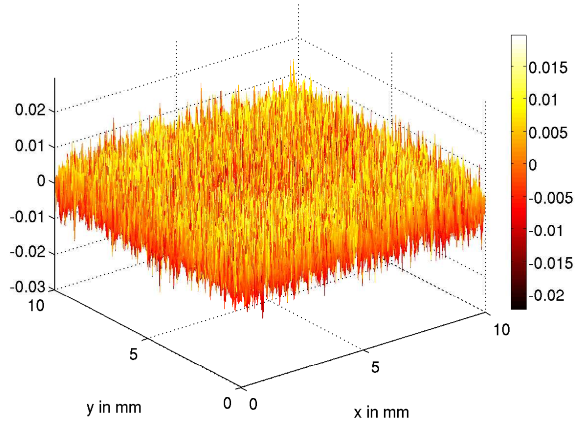

Figure 1: Topography of a spark eroded aluminium specimen

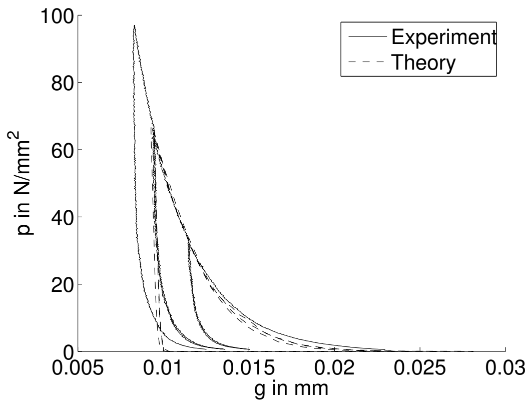

Figure 2: Eroded aluminium surface under normal load

In order to assess the normal contact stiffness the pressure vs. gap curves of generated fractal surfaces calculated by the halfspace model are compared with the results of the experiment. Figure 2 shows that the simulation predicts almost complete plastic deformation for initial contact. Accordingly, the simulated unloading curves show only a small elastic spring-back at the end of the unloading process. By contrast the experiment shows a larger elastic spring-back during unloading.

A reason for this difference is that it is impossible to produce real surfaces without geometrical irregularities. As a result the surface is skew and waved with larger wavelength than the surface roughness. We have shown in [3] that geometrical irregularities increase the elastic deformation of a loaded joint.

Because of the restriction $p_k \leq H$ in the halfspace model the height values are corrected in order to obtain the pressure for the real area of contact. An enlargement of the contact area caused by the plastically deformed material which is flowing to the valleys of the rough surface and work-hardening is not considered. These effects increase additionally the elastic deformation of jointed specimens.

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