

## DETERMINISTIC MODEL FOR RUBBER-METAL CONTACT INCLUDING THE INTERACTION BETWEEN ASPERITIES

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### ABSTRACT

Rubber-metal contact involves relatively large deformations and large real contact areas compared to metal-metal contact. Here, a deterministic model is proposed for the contact between rubber and metal surfaces, which takes into account the interaction between neighboring asperities. In this model, a description of the actual micro-contact is used instead of a summit which is a local maximum at the surface. Linear viscoelastic behavior, modeled by a three-element mechanical model, is assumed for the rubber. In the present model, the equations regarding the deformation due to a Hertzian pressure inside and outside the contact area have been modified for the viscoelastic case. The deterministic case is compared with the statistical one. Besides this, the deformation of the bulk material beneath the asperities is taken into account. The results reveal that the bulk deformation has a significant effect at higher nominal pressures.

### 1. INTRODUCTION

Although extensive work has been done on contact between rough surfaces, not much attention has been paid to the interaction between neighboring asperities. This interaction becomes more important when one of the materials in contact has a low elasticity modulus. Zhao et al. [1] proposed an asperity-interaction approach, which is incorporated in an elastic-plastic contact model. Some other models have been found in literature but none of them includes viscoelastic bodies and deterministic approach in terms of different radii and heights of asperities.

### 2. ASPERITIES AND SUMMITS

The surface micro-geometry inside a micro-contact is obtained from the measured height data. The simple geometrical shapes representing the micro-contact height data are so-called asperities. The summits are defined as points with a local surface height higher than their neighboring points.

The distinction between summits and asperities is depicted in Fig. 1.

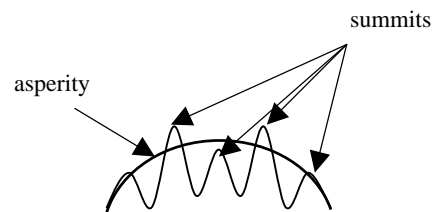


Fig. 1. Micro-geometry: asperity and summits.

### 3. VISCOELASTIC-RIGID CONTACT MODEL

Modeling contact between two rough surfaces relies on the contact of a single asperity couple. The Hertz theory was extended by Lee and Radok [2] to the viscoelastic case using the correspondence principle. Accordingly, the elastic constant is replaced in the elastic solution by the corresponding viscoelastic operator, in terms of creep compliance or relaxation function. The viscoelastic-rigid asperity contact has been described by Johnson in [3]. When the viscoelastic behaviour is modeled by a three element mechanical model (Standard Linear Solid), the distribution of pressure is similar to the Hertzian distribution at each stage of deformation. So, at each time instant (quasi-static case), calculations are performed using time-dependent mechanical properties.

### 3. DETERMINISTIC APPROACH INCLUDING ASPERITY INTERACTIONS

The statistical approach of Greenwood and Williamson [4] has been used by Hui et al. [5] to study the contact between a rigid flat and a rough viscoelastic surface. The constant radius of summits and the absence of interaction between the

neighbors constitute two major limitations of the previous theory. It will be shown in the following that, for rubber-like materials, this interaction is important.

A deterministic approach is proposed which includes the interaction between neighboring asperities. The equations for the normal displacement  $\delta$  due to a Hertzian pressure inside and outside the contact area [3] enables one to determine the influence of asperities on the normal displacement. In a load-controlled case, the modified equations for the viscoelastic material (time-dependent mechanical properties in terms of creep compliance function) are given by:

$$\delta = (1-\nu) \cdot \varphi(t) \cdot \pi \cdot \frac{p_o}{4a} (2a^2 - r^2) \quad r \leq a$$

$$\delta = (1-\nu) \cdot \varphi(t) \cdot \frac{p_o}{2a} \cdot$$

$$\cdot \left[ (2a^2 - r^2) \cdot \sin^{-1}(a/r) + r^2 \cdot (a/r) \cdot (1 - a^2/r^2)^{1/2} \right] \quad r > a$$

where the load has been taken as a Heaviside step function.

Here,  $\nu$  is the Poisson's ratio,  $\varphi(t)$  is the creep compliance function,  $t$  is the time,  $p_o$  is the maximum pressure,  $a$  is the contact radius and  $r$  is the radius. The iterative cycle regarding the interaction between asperities is presented in Fig. 2 and is used inside of the main loop from which the separation between a rough viscoelastic material against a rigid flat and the contact area are obtained.

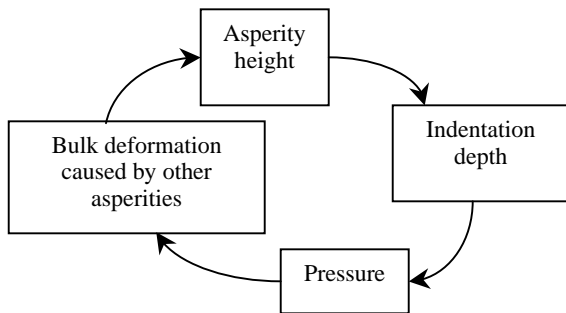


Fig. 2. Iterative cycle.

#### 4. RESULTS AND CONCLUSIONS

The results from a load-controlled case are presented at a certain time instant ( $t = 1$  s), at which the load balance is also done. In order to compare the results of the deterministic model with those obtained from a statistical one, the roughness properties of the rubber sample have been determined. The surface roughness of a polyurethane sample has been measured with an interference microscope and analyzed as in [6].

The separation as a function of nominal pressure is shown in Fig. 3 for both the statistical (summits) and the deterministic (summits and asperities) case with and without asperity interaction. At relatively large nominal pressures it can be observed that the separation is lower when asperities are used instead of summits, while at smaller pressures they are closed. The variation of the fraction of area in contact (total contact area divided by the nominal contact area) with nominal pressure is presented in Fig. 4. The area calculated with the deterministic approach (asperities) including interaction of asperities is larger than the statistical one and this increase becomes more significant for higher pressures. When summits

are used instead of asperities, the fraction of area in contact in the deterministic case is similar to the statistic one.

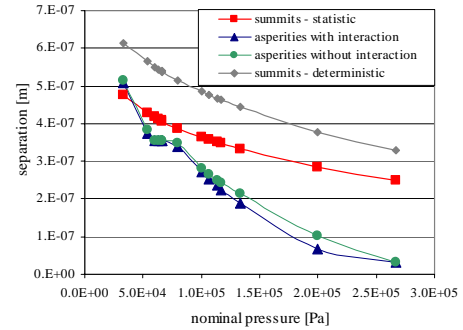


Fig. 3. Separation vs. nominal pressure.

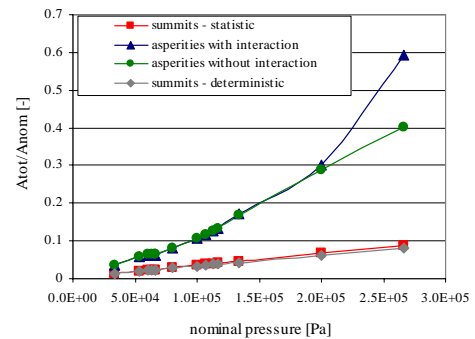


Fig. 4. Fraction of area in contact vs. nominal pressure.

Conclusively, the results reveal that the interaction between neighboring asperities has a large effect at higher nominal pressures. Using asperities instead of summits determines a decrease of separation and an increase of fraction of area in contact.

#### ACKNOWLEDGMENTS

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