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A multi-scale approach for estimation of real contact area and frictional behaviour of rubber sliding on rough surfaces

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INTRODUCTION

Frictional behaviour and contact area of sliding rubber on rough surfaces depend mainly on the material properties and the surface texture. Depending on sliding velocity and normal pressure different values of hysteresis friction (dissipated energy due to deformation of rubber caused by rough surface) and contact area occur due to the material behaviour. This paper presents a multi-scale model for prediction of contact area and frictional behaviour of non-linear-elastic and non-linear-visco-elastic bodies on a rigid rough surface.

MULTI-SCALE MODEL

According to [1] rough surfaces like asphalt are of fractal nature. They are self-similar. The roughness of macro scale occurs with a magnification factor ξ on the micro scale. Due to the self-similarity, it is possible to characterize a surface texture by the height difference correlation (HDC). In this work the surface is described by an approximation of the HDC by using sine waves. The superposition of the sine waves results in comparable HDC as the measured one. Investigations to identify significant and characteristic sine waves of rough surfaces according to the level-method [2] show that the ratio of amplitude to wavelengths gets higher in micro roughness scale. In this approach magnification factors for the wavelength s_λ and amplitudes s_A are introduced. The calculation of friction coefficient and contact area based on [3, 4]. The scales are coupled as follows:

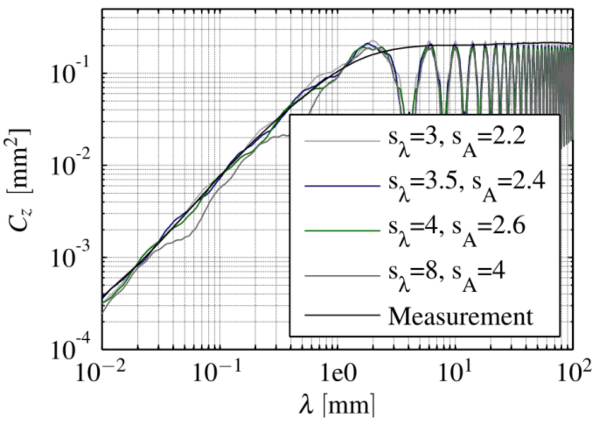

Fig. 1. HDC of measured surface and approximation by supperpostiton of sine waves with different magnifiation factors.

(1) The estimation of contact area and in dynamic case of friction coefficient starts on the first (largest) scale.

(2) The estimated contact pressure will be transmitted to the next lower scale (force balance: *action=reaction*).
(3) The real contact area A_r is calculated according to:

$$A_r = \prod_{i=1}^{i_{\max}} A_i \cdot \eta_i \,.$$

Where A_i is the single scale contact area and η_i sine wave density related to the previous contact area A_{i-1}.

RESULTS AND DISCUSSION

In this study, the multi-scale model is used with different magnification factors s_λ and s_A. For the static case (normal load) the computed results are shown in Fig. 2a. The contact area decreases for all magnification factors for increasing scales of roughness. At similar wavelengths occur similar contact areas.

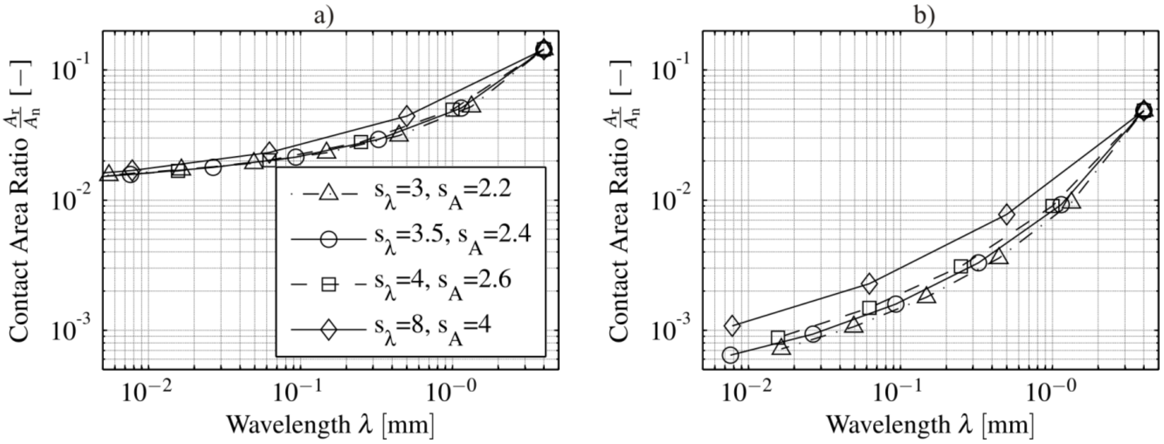

Fig. 2. Contact area ration as function of magnification factorors a) in static case; b) in dynamic case.

In the dynamic case with a sliding velocity the convergence depends mainly on the approximation quality of the surface. The better the approximation quality the better the convergence. Furthermore a material stiffening effect is observed. Due to frequency dependent material behaviour the contact area gets smaller than in static case. Besides the contact area, the friction coefficient of each scale is calculated. Thus, statements of relevant excitation wave lengths are possible.

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