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 \( \xi \) 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 \( s_\lambda \) and amplitudes \( s_A \) are introduced. The calculation of friction coefficient and contact area based on [3, 4]. The scales are coupled as follows:

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

Fig. 1. HDC of measured surface and approximation by superposition of sine waves with different magnification factors.
(2) The estimated contact pressure will be transmitted to the next lower scale (force balance: \textit{action=reaction}).

(3) The real contact area $A_r$ is calculated according to:

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

Where $A_i$ is the single scale contact area and $\eta_i$ 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 $s_{\lambda}$ 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.

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.

REFERENCES


