Frictional Contact of Elastomer Materials on Rough Rigid Surfaces

Peter Wriggers* **& Jana Nettingsmeier***

*Institut für Baumechanik und Numerische Mechanik
Leibniz Universität Hannover
Appelstraße 9a
30167 Hannover
wriggers@ibnm.uni-hannover.de

ABSTRACT

Frictional contact has to be considered in the analysis of technical problems like metal forming or driving of cars. In the latter case the tire is in contact with a rough road surface which leads to a complex frictional behaviour between the rubber and the surface. It is known from experiments that the frictional coefficient is not constant and depends upon various parameters like sliding velocity, surface roughness, applied normal forces and temperature.

The description of rubber friction is generally based on the modelling of two main effects [1],[2]. Hysteretic induced friction is based on energy dissipation in the viscoelastic material which undergoes permanent cycling loading due to the changing deformation of tire treads relative to the height of the surface asperities. It can be shown that depending on the viscous material properties, the resulting frictional resistance changes with the sliding velocity. The friction coefficient advances to zero for both, very high and very low sliding velocities, but reaches a maximum for middle speed, where the material damping is maximal. The second effect - adhesion - arises from attractive forces at molecular level between the contact partners. Its biggest influence has been observed in case of small sliding velocities.

The aim of this work is the derivation of a friction law based on micromechanical modelling of the treads and the road surface. Due to the fact that different length scales influence the rubber friction, see e.g. [1], a multiscale analysis of the problem is necessary. Thus the road track surface is modeled at different length scales. Starting on one microscale homogenization yields a certain friction law, which depends upon the sliding velocity and adhesion which is modelled after [3] and contains time-dependent behaviour. The obtained friction law is then projected onto the next length scale and used there as local friction law, see Fig. 1. This process is carried out until the true macroscopic length scale is obtained. Within this procedure the fractal road surface is approximated by a superposition of several harmonic functions.

Since the target of this research is to obtain quantitavie values for the fricitional constitutive behaviour a three-dimensional analysis has to be used. The rubber tread is modelled using finite elements where a four-node contact element [4] is introduced. Its GAUSS points are projected to the closest point on

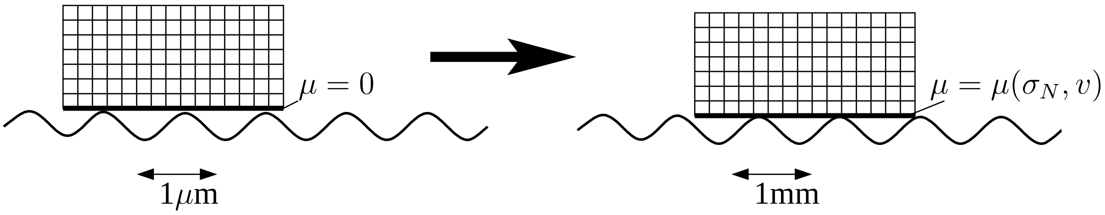

Figure 1: Scale transition

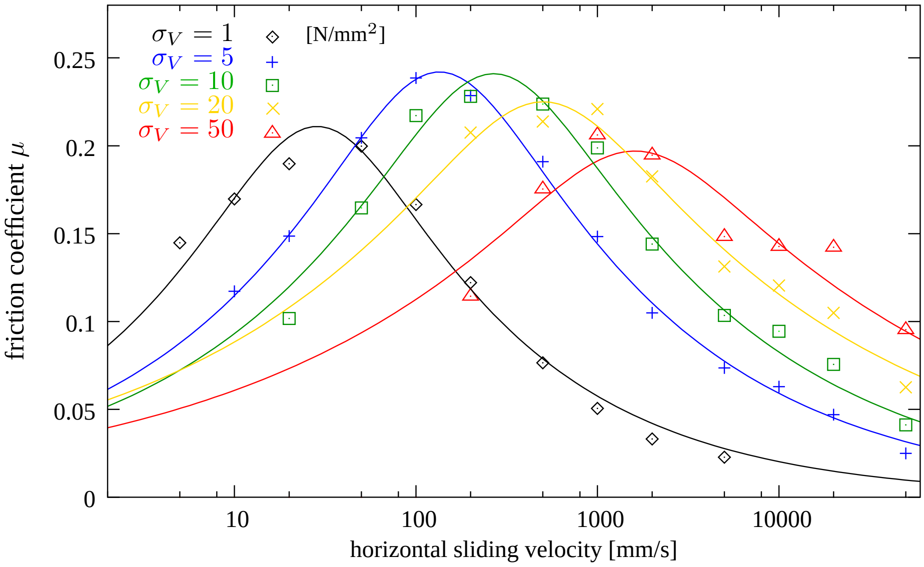

Figure 2: Friction coefficient on microscale

the rigid surface, which is given as an analytical function $z = f(x, y)$ which matches over the different length scales the fractal behaviour of the real road surface. The simulations are performed on various scales, whereas the constitutive properties of the smaller scale are mapped to the larger one. The friction coefficient will be changed according to the local conditions (normal stress, sliding velocity, etc.) which are present within each contact element.

The standard contact formulation is enhanced by the possibility of transmitting adhesional tensile stresses. One of the results obtained is the friction coefficient at the microscale scales, see Fig. 2. It can be observed that it depends upon the sliding velocity as well as on the normal pressure.

References

[1] M. Klüppel, G. Heinrich *Rubber Friction on Self-affine Road Tracks*. Rubber Chemistry and Technology 73: 578-606, 2000.

[2] B. Persson *Theory of Rubber Friction and Contact Mechanics*. Journal of Chemical Physics, 115,8, 2001.

[3] M. Raous, L. Cangémi, M. Cocu, *A consistent model coupling adhesion, friction and unilateral contact*. Computer Methods in Applied Mechanics and Engineering 177: 383-399, 1999.

[4] P. Wriggers, *Computational Contact Mechanics*. 2^{nd} edition, Springer, 2006.