Rubber Friction – Experimental Investigations and Comparison to Theory

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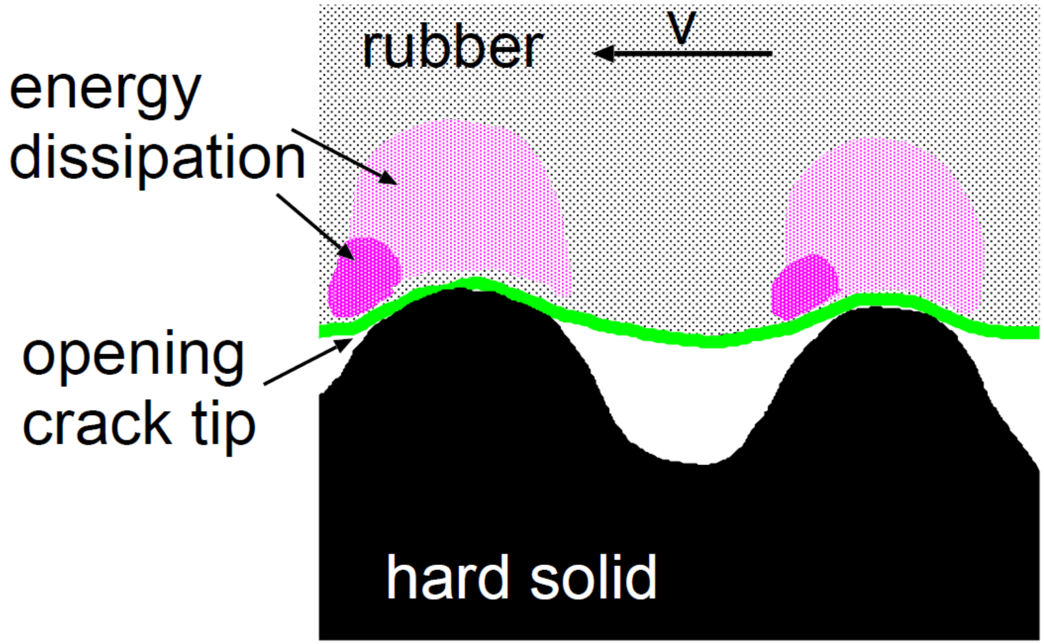
JÜLICH FORSCHUNGSZENTRUM

Rubber Friction

Motivation

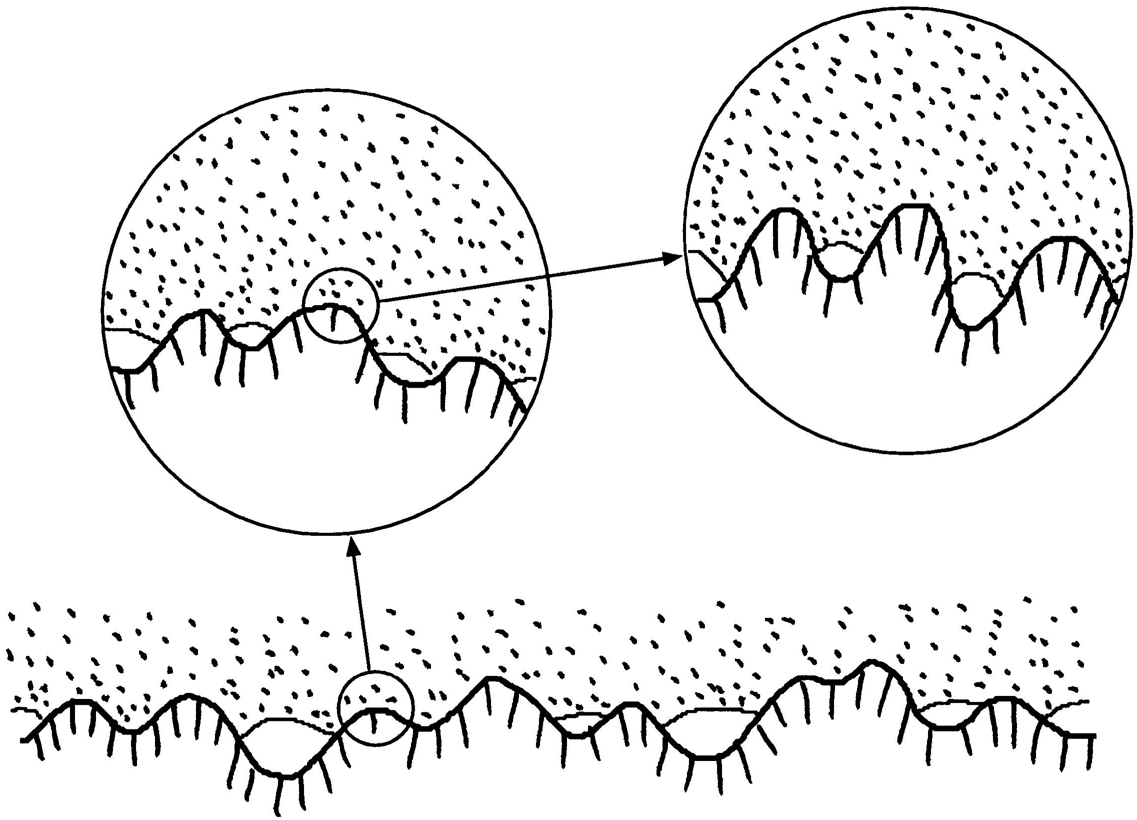
Dissipation Mechanisms



(process a)	viscoelastic deformation in the rubber bulk
(process b)	opening crack tip dissipation
(process c)	shearing of a thin contamination film

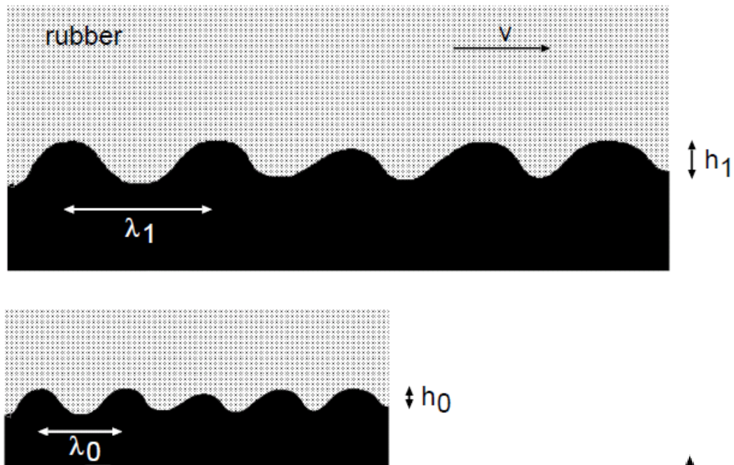
Contact Mechanics

Surface roughness

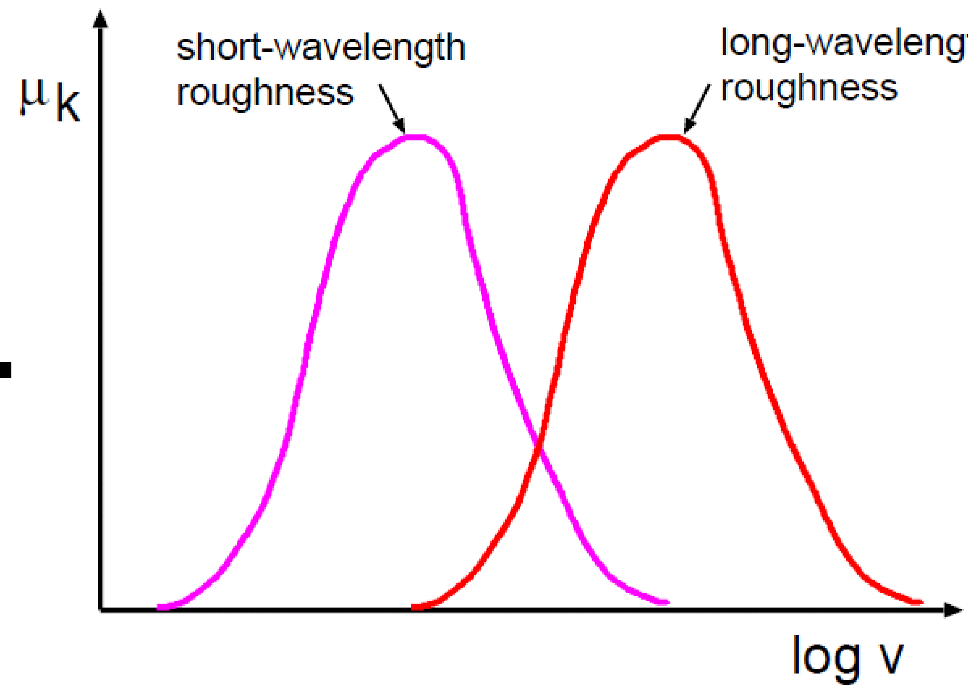


Real surfaces exhibit fractal-like roughness

Relevance of Different Length Scales

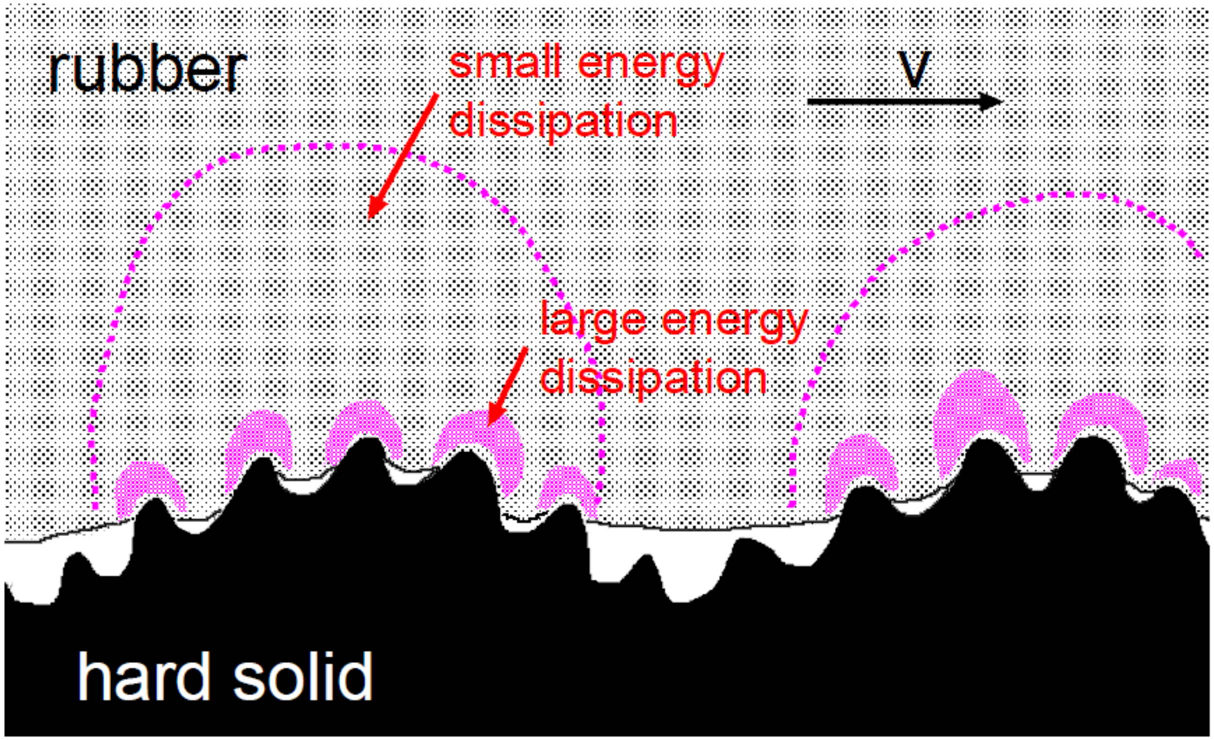


if $$\frac{h_0}{\lambda_0} = \frac{h_1}{\lambda_1}$$



Not exclude a priori
any length scale!!!

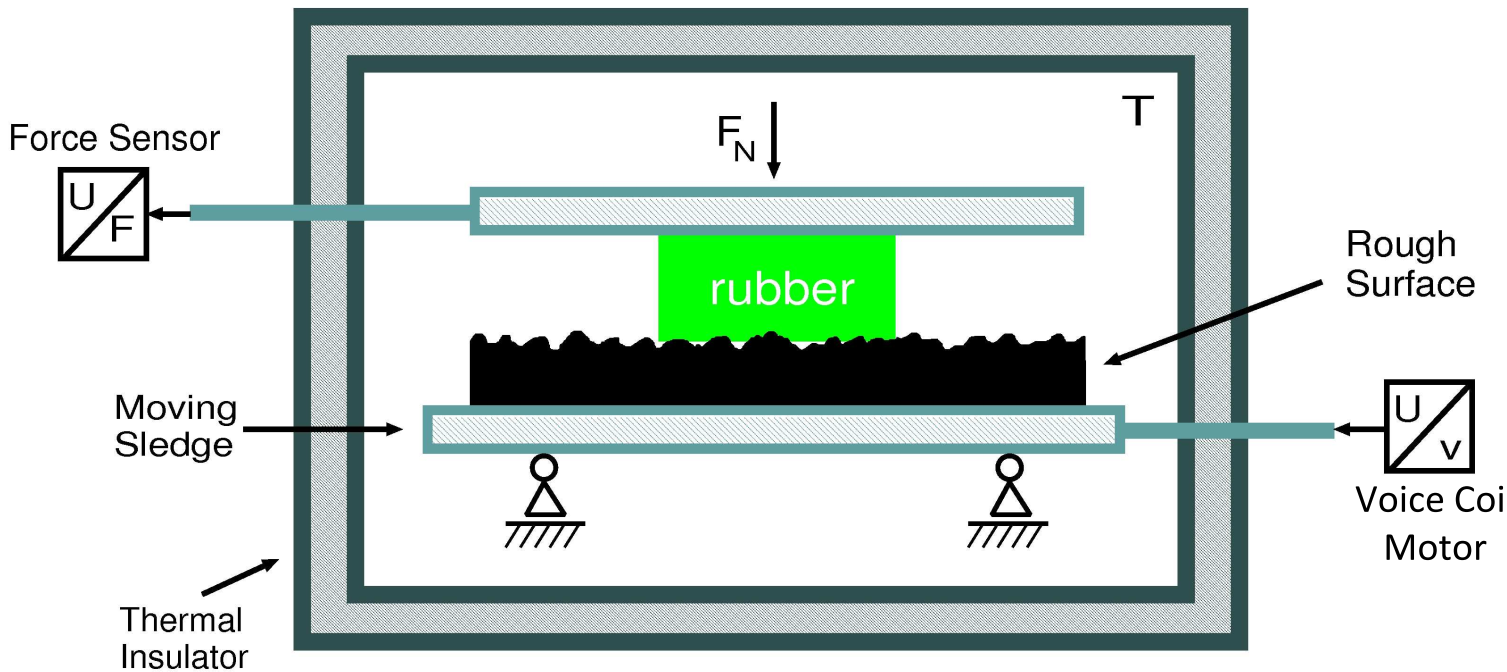
Rubber Friction Theory by Persson



B.N.J. Persson, J. Chem. Phys. **115** (2001) 3840

Rubber Friction on Rough Surfaces

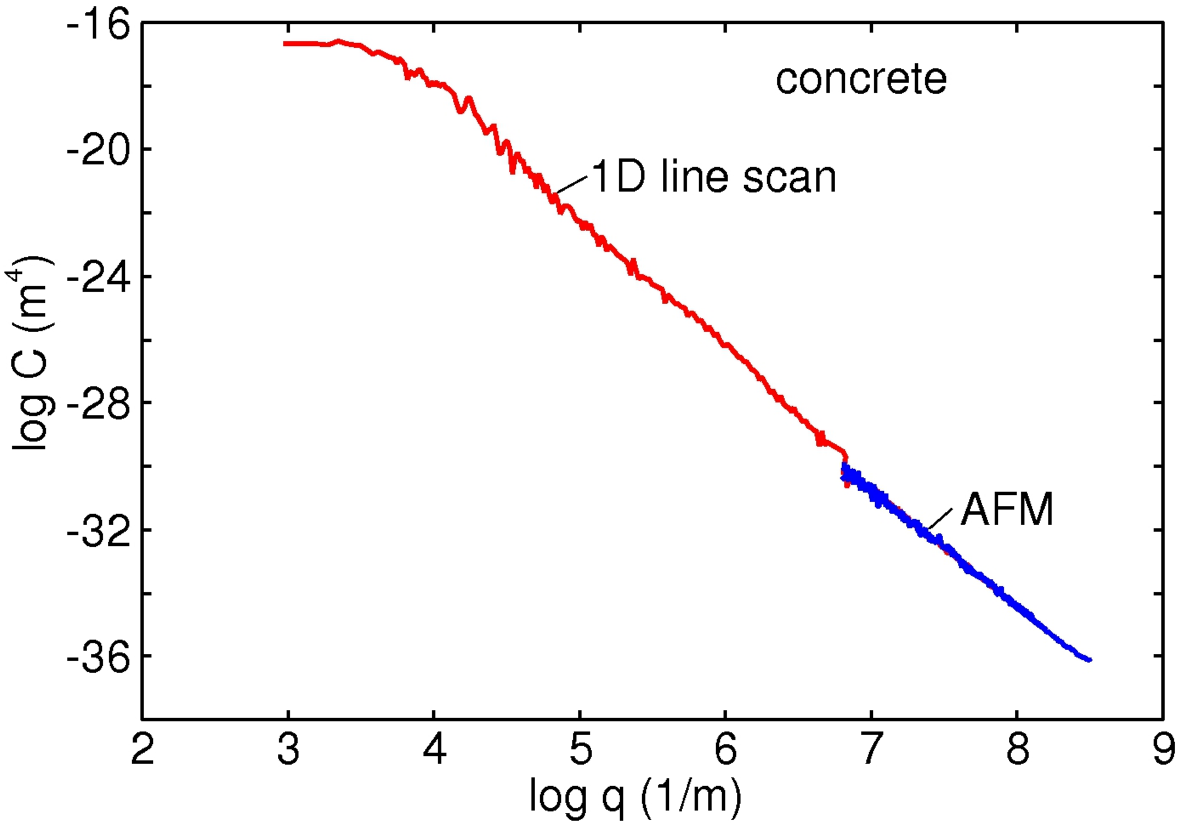
Experimental Set-up



$$\mu = f(v,T)$$

Friction coefficient as a function of the sliding velocity

Surface Roughness Power Spectrum



$$h(q) = \int h(x) e^{iq \cdot x} d^2 x$$

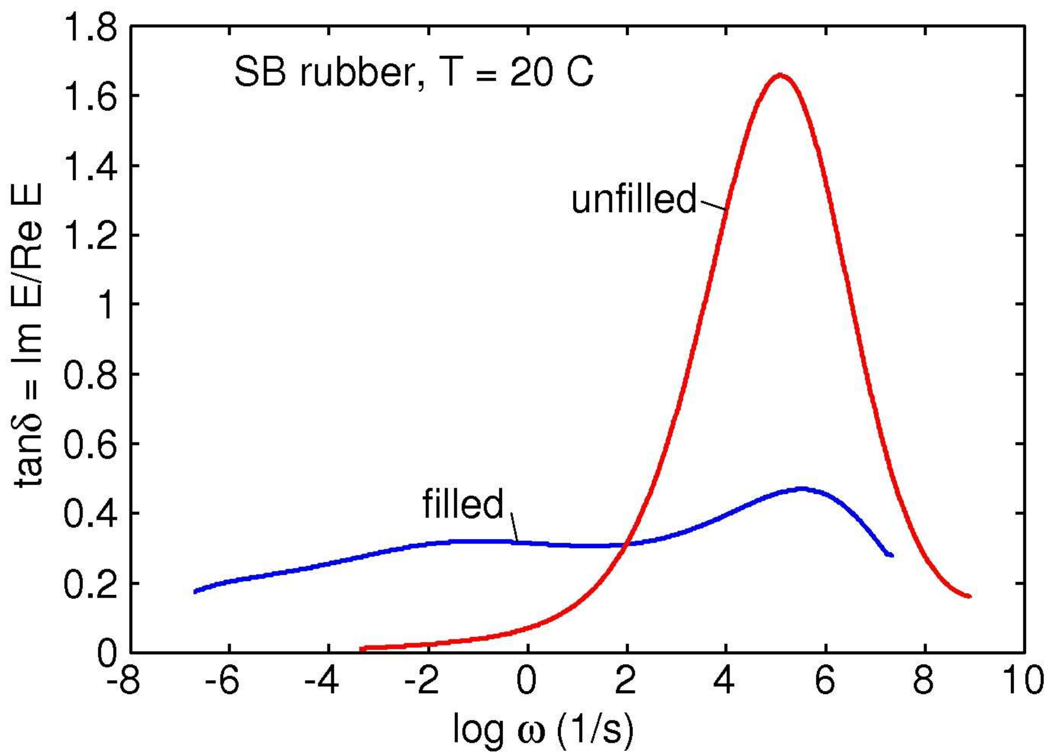
$$C(q) = |h(q)|^2$$

Mitglied in der Helmholtz-Gemeinschaft

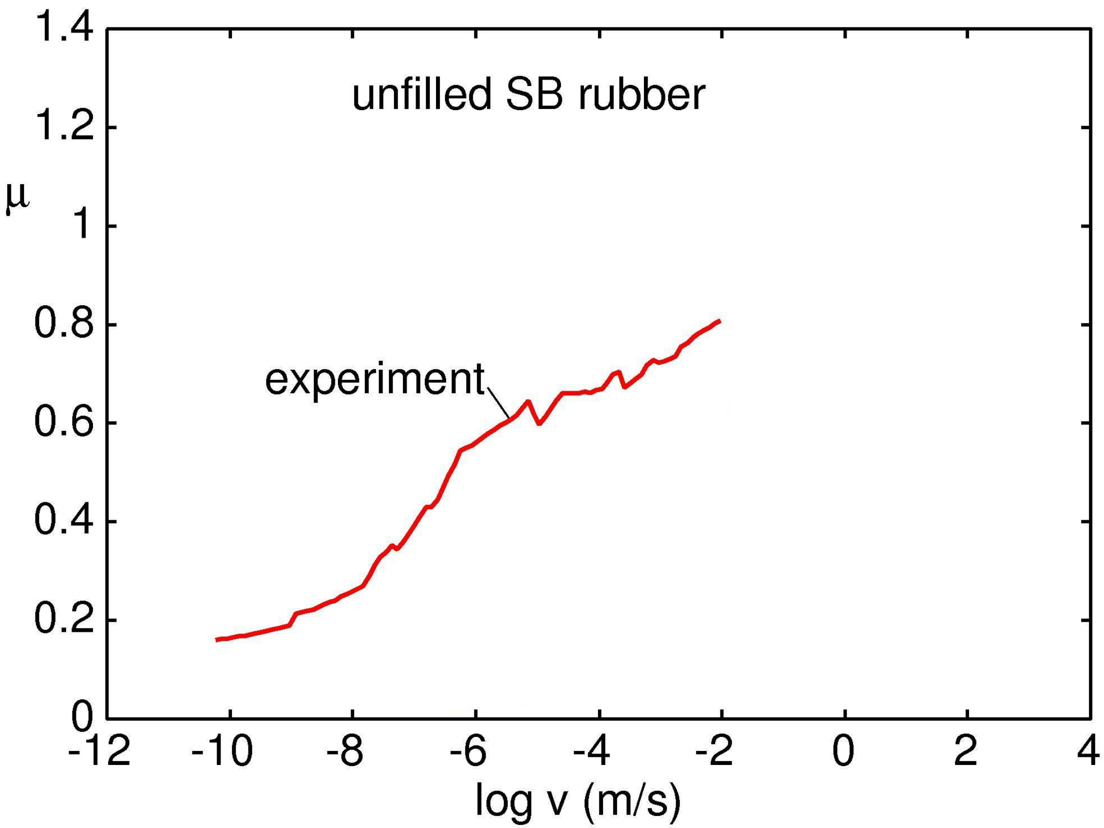
Viscoelastic Modulus

(a) Unfilled styrene butadiene (SB) rubber

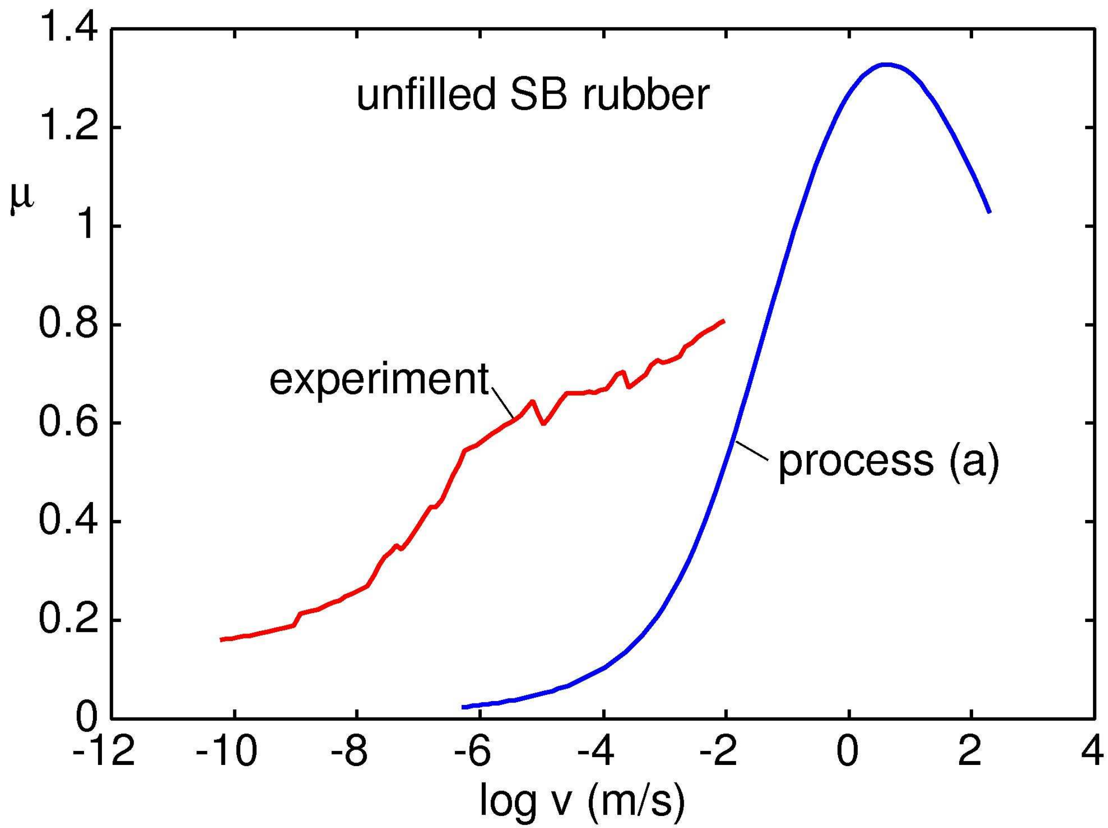
(b) Carbon black filled styrene butadiene (SB) rubber



Results for unfilled SB rubber

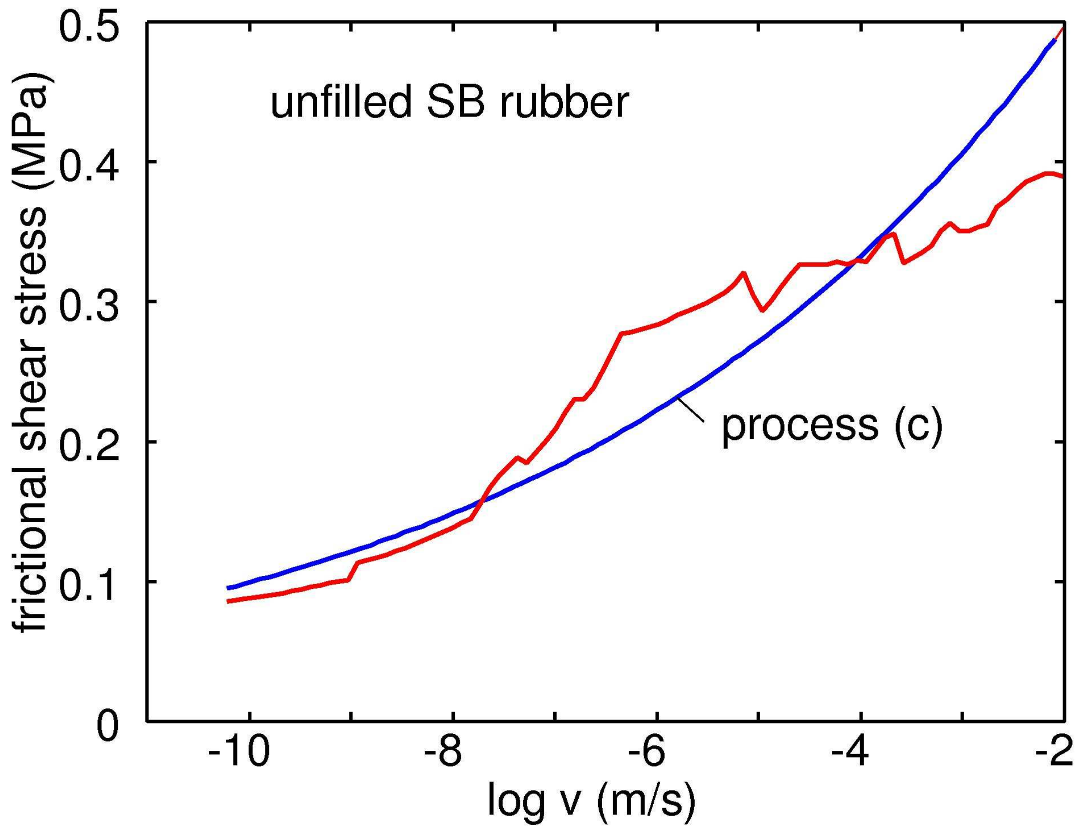


Results for unfilled SB rubber



process (a) asperity induced bulk energy dissipation

Results for unfilled SB rubber



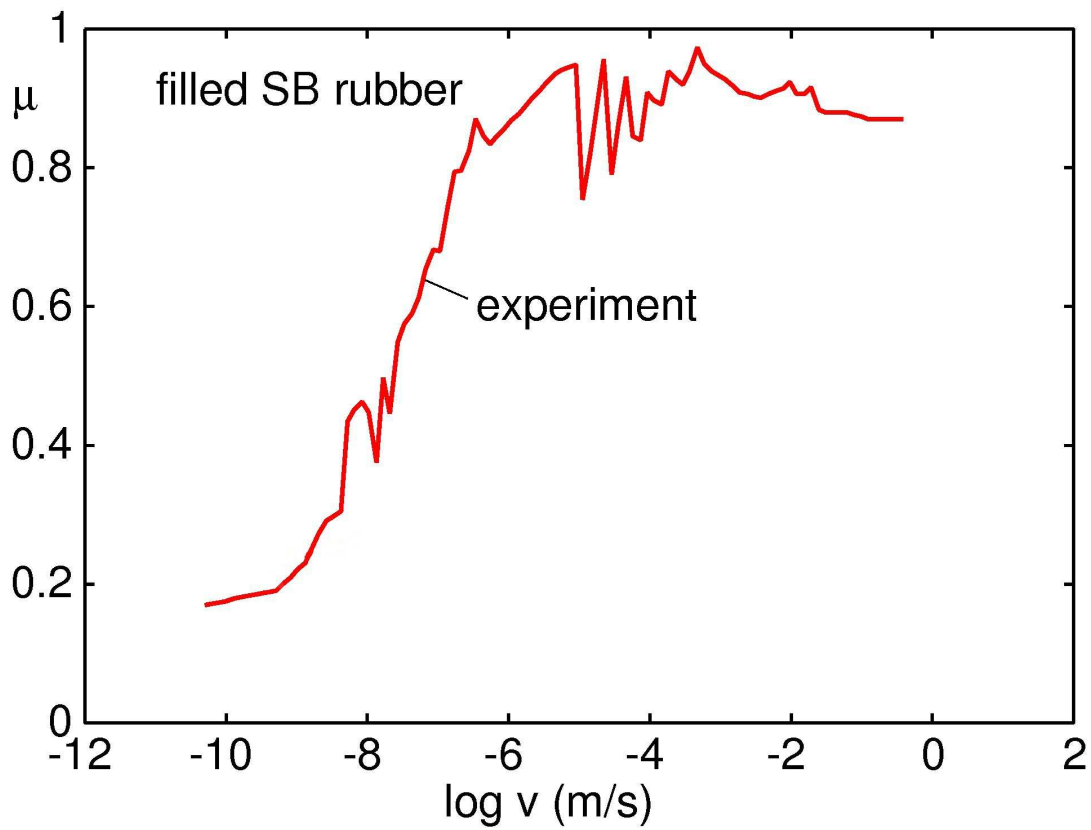
process (c)   shearing of a thin contamination film

$\sigma_f = B\dot{\gamma}^{\alpha}$, with B and α in agreement to direct measurements and MD calculations

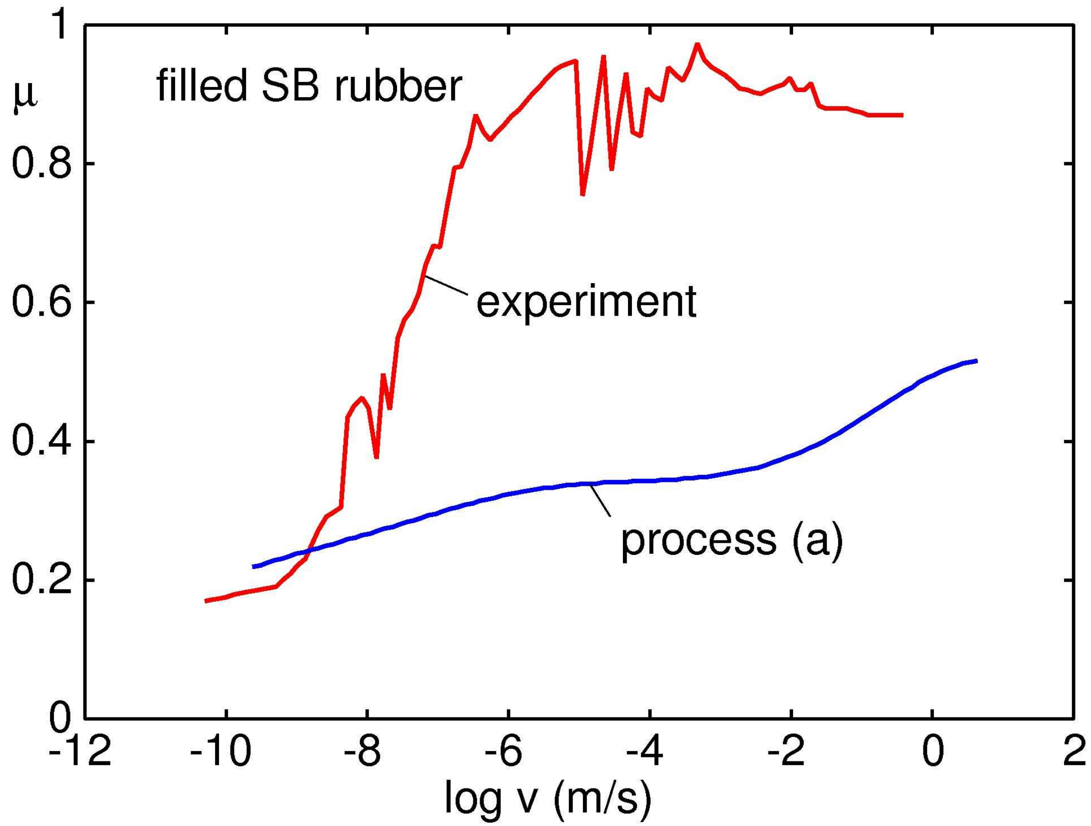
S. Yamada, Tribology Letters **13**, 167 (2002)

I. Sivebaek, V. Samoilov and B.N.J. Persson, to be published

Results for filled SB rubber

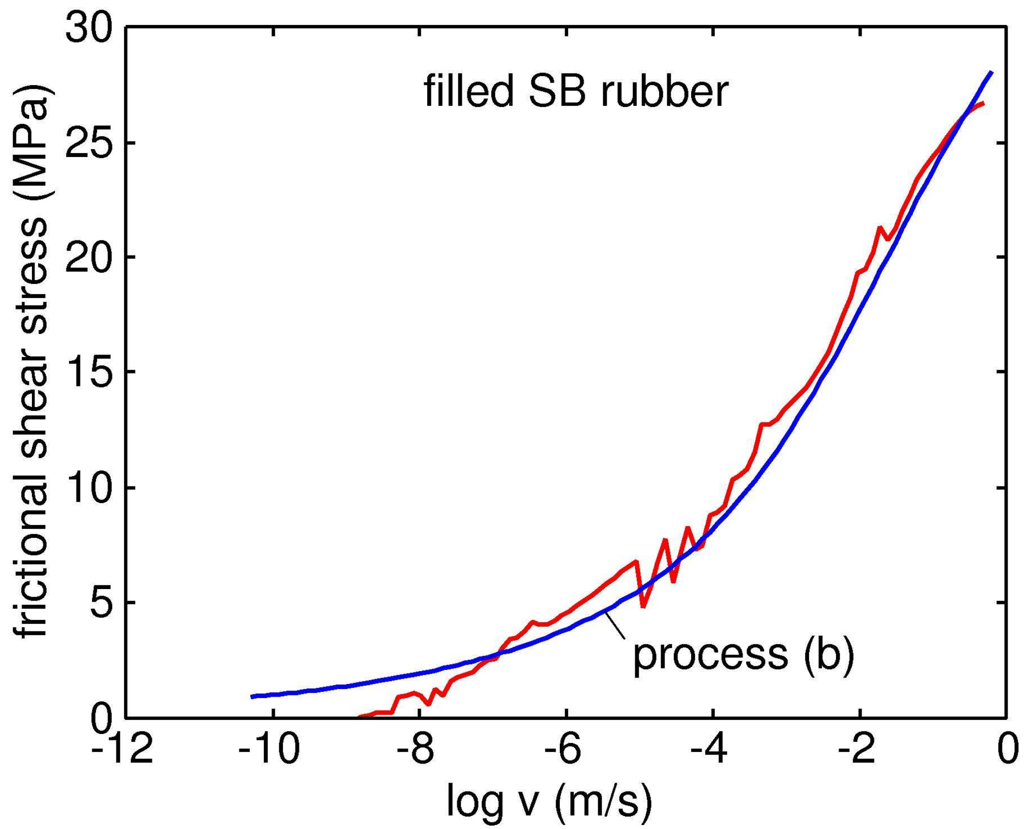


Results for filled SB rubber



process (a)   asperity induced bulk energy dissipation

Results for filled SB rubber

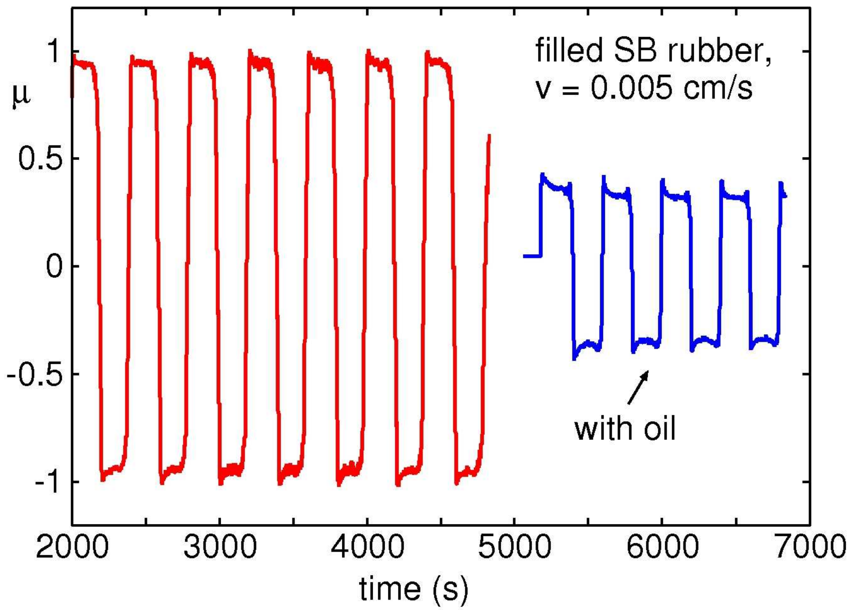


process (b) opening crack tip dissipation

$$\sigma_f = G(v)/l = [G(v)/G_0][G_0/l]$$

B.N.J. Persson et al., J. Phys.: Condens. Matter **17**, R1071 (2005)

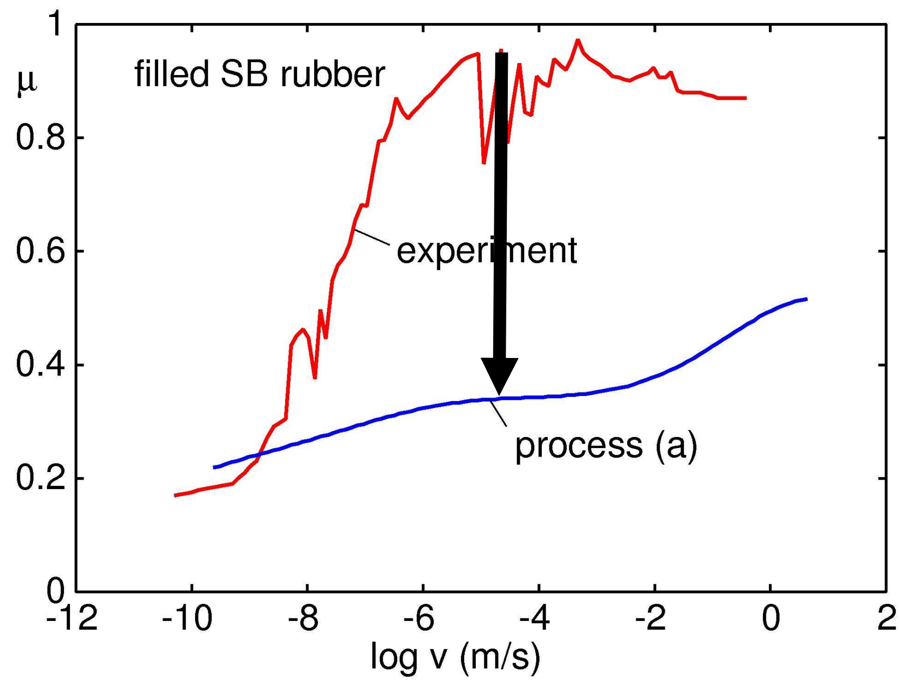
Results for filled SB rubber



Coefficient of friction ≈ 0.95

with a thin silicone oil film (viscosity 1 Pas)

≈ 0.34



A thin lubricant film can remove the crack-opening contribution!

Conclusions

- We have developed a set-up to test friction of rubber on rough surfaces at different sliding velocities
- The results have been compared to the predictions of a theory for rubber friction by Persson
- The measured results of the tested systems are well described by the predictions of the theory

Thank you for your attention!