Understanding micro-friction in polymers

technische universiteit eindhoven

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L.C.A. van Breemen, L.E. Govaert and H.E.H. Meijer

Introduction

Friction of polymers is a very common phenomenon in daily life and is responsible for huge energy losses. Processes governing friction are occurring in the thin surface layers of two moving bodies which are in contact. This leaves us with the following question: "Which intrinsic properties of a polymer contribute to friction and how, by knowing these properties, can we tailor polymers to minimize friction?"

Approach

Decouple the friction force (F_f) into a deformation (F_d) and adhesion (F_a) related component according to Bowden and Tabor's law of friction [1].

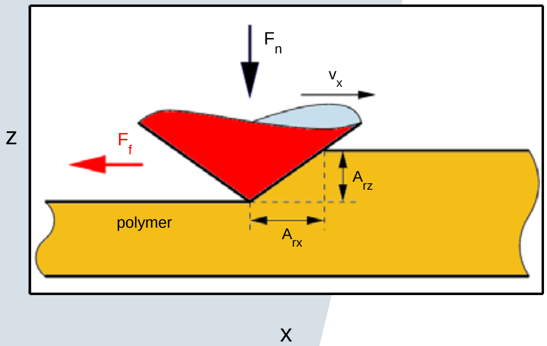

Figure 1 : *Graphical representation of a single-asperity friction experiment.*

$$F_f = F_a + F_d = \tau_{eff} A_{rz} + \sigma_{bulk} A_{rx}$$

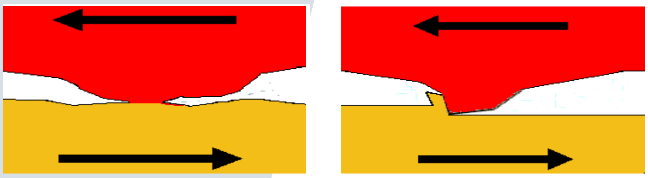

Figure 2 : *Decoupling of the friction force into an adhesive and deformation component.*

Current status

Numerical

To adequately predict the response of a polymer we need to accurately describe its intrinsic deformation (figure 3).

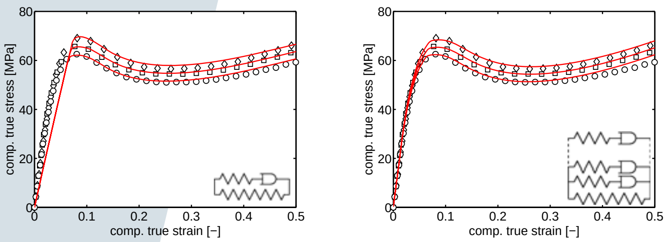

Figure 3 ***Left***: *Single-mode model.* ***Right***: *Multi-mode model.*

To accomplish this, we extend our single-mode model to a multi-mode model [2], according to

$$\boldsymbol{\sigma} = \boldsymbol{\sigma}^h_{s,x} + \boldsymbol{\sigma}^d_{s,x} + \boldsymbol{\sigma}_r \qquad \text{where}$$

$$\boldsymbol{\sigma}_{s,x} = \kappa_x (J-1)\boldsymbol{I} + G_x \tilde{\boldsymbol{B}}^d_{e,x} \quad \text{and} \quad \boldsymbol{\sigma}_r = G_r \tilde{\boldsymbol{B}}^d.$$

Experimental

The focus will be on the initial step of a scratch experiment, which is indentation. This needs to be understood before we can continue to a more complex loading mechanism such as scratching.

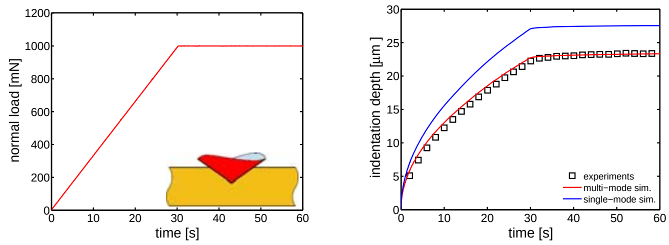

Figure 4 ***Left***: *Prescribed force versus time.* ***Right***: *indentation depth versus time.*

Outlook

The ultimate goal is to compare FEM-simulations with scratch experiments and isolate the deformation contribution to the friction force.

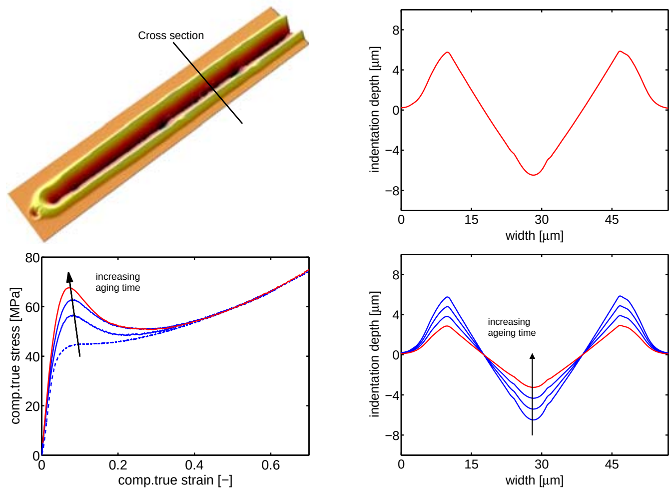

Figure 5 ***Upper left***: *3D profile of scratch.* ***Upper right***: *Cross section of scratch.* ***Lower left***: *Effect of ageing on intrinsic deformation.* ***Lower right***: *Expected effect of ageing on indentation depth.*

References:

[1] Bowden, F.P. and Tabor, D. : *The friction and lubrication of solids.*

[2] Klompen, E.T.J.: *Mechanical properties of solid polymers.*

/department of mechanical engineering

PO Box 513, 5600 MB Eindhoven, the Netherlands