Effect of molecular weight on friction of PolyStyrene

Schaake, R.P.; Vellinga, W.P.; Meijer, H.E.H.

Published: 01/01/2002

Document Version
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the author's version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal ?

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Download date: 02. Jan. 2019
Effect of molecular weight on friction of PolyStyrene

R.P. Schaake††, W.P. Vellinga†, H.E.H. Meijer†
Eindhoven University of Technology, Department of Mechanical Engineering
†DTI Deutsche Technische Institute, Eindhoven
††Dutch Polymer Institute, Eindhoven

Introduction
Single asperity friction measurements are an effective method to study the origin and phenomenology of friction and wear. Using well-defined micron-sized contacts one can probe friction and wear mechanisms that are relevant for macroscopic contacts [1]. Our aim is to relate microscopic features of polymers to their friction and wear behaviour. In this poster we present measurements on two grades of monodisperse PolyStyrene (PS). Mechanical properties of PS are well understood [5] which makes it a good model system.

Material and methods
PS samples with a molecular weight of 56 kg/mole and 966 kg/mole, and a polydispersity of 1.05 and 1.15 respectively, were used. Pressed samples of these materials were flattened by embossing with a silica wafer above Tg. The resulting surfaces can be considered smooth for our purpose. For the single asperity friction measurements the Lateral Force Apparatus described in [4] was used. This apparatus has recently been improved and is now capable of spanning 6 decades in velocity. A spherical diamond tip with a radius of 5 μm was mounted on a cantilever with a normal and lateral stiffness of 243 and 104 N/m respectively. "Start-stop" experiments were performed, in which the contact was prepared by bringing it into a reproducible sliding situation. Tip motion was then halted at time t=0 for a certain period, after which the motion was resumed. Lateral force and (vertical) z-displacement are measured continuously from t=0 onwards.

Results
At higher loads both materials showed an increase in friction in a certain sliding velocity range. The effect of molecular weight on the velocities at which this phenomenon occurred was consistent with trends in the work by Tanaka et al. [2] who found a shift of a friction peak to lower velocities with increasing molecular weight.

The right graph of figure 2 shows the diamond tip sinks into the material when standing still. This process is slower for the high MW material (red) than for the low MW material (blue). After 10 seconds the tip had already sunken 3 μm into the low MW material. The high molecular weight material sank only 1 μm in the same amount of time at a higher load. From this it could be concluded the contact area was growing faster in the lower MW material.

Discussion
The low MW PS has a reduced Tg. This reduction is about 5 K, calculated from a fit through values found in literature. The thermal mobility of the low MW chain is therefore higher than for the high MW chain, resulting in easier plastic deformation with decreasing Tg or MW. The easier plastic deformation will lead to a larger contact area.

The rise in friction can also be ascribed to the glass transition. The increase in the loss modulus causes an increase in friction. Nanofriction measurements by Wang et al. [3] show that the friction peak associated with Tg becomes more pronounced with increasing load. They explain the presence of the peak with the presence of a wedge in front of the tip. This could mean that the appearance of the friction peak in our experiments is associated with a transition from a ploughing deformation without, to one with wedge formation. Characterisation of the material used will have to be carried out to better understand the mechanisms leading to the observed phenomena.

References:

Figure 1 Average kinetic friction force as a function of velocity on both the high (right) and low molecular weight material (left).

Figure 2 Friction and horizontal displacement from t=0 till just beyond the friction peak. Δz=0 at t=0. v= 2.5 μm/s. Red line: high MW PS Fn = 2.5 mN. Blue lines: low MW PS, Fn = 2.2 mN.

During the period the motion was stopped, the friction force relaxed. Upon the subsequent resumption of motion, the tip had to climb out of the pit it had just created, causing a peak in friction.