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Effect of pre-stretch on the scratch resistance of isotactic polypropylene

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Pre-stretching of thermoplastics induces a reinforcement of the mechanical properties towards the draw axis. This will also modify the scratch resistance of the material. Indeed, the material becomes more scratch-resistant when the scratch takes place along the pre-stretching direction. In these conditions, the lateral track pad appears before the frontal push pad whereas the opposite behavior is observed for a scratch at 90° of the pre-stretch direction. The oriented iPP surface is less damaged than the isotropic one for same normal load and velocity. It should be noted that for an orientation of 45°, only a half of the groove shows damages.

Keywords: scratch resistance, semi-crystalline polymers, anisotropy, orientation

1. Introduction

In industrial applications, polymeric surfaces often undergo damages or are used for moving mechanical parts where friction and wear properties are important. Furthermore, due to process, the polymeric parts cannot always be considered as isotropic but display a preferential direction. Thus, it has been shown by molecular dynamics for semi-crystalline polymers, that orientation of macromolecular chains could decrease the coefficient of friction towards the elongation direction. The aim of this work is to investigate the influence of macromolecular orientation after uniaxial drawing on the scratch resistance of isotactic polypropylene tapes (iPP) by both experimental and numerical approaches.

2. Methods

Scratch experiments were performed on both un-oriented and uniaxially oriented iPP tapes during which in-situ images containing geometrical information of the contact aea are taken. Numerical modeling of the scratch experiment was performed by finite elements simulations using the MSC Marc software. An elasto-viscoplastic constitutive model of a transversely isotropic PP[1] was used to rationalize the impact of the anisotropic mechanical properties on the scratch behavior.

3. Results

Experimental results show that oriented samples are more tough than the isotropic one. One may observe the delay of plasticity for the oriented iPP leading to smaller plastic pads for identical sliding conditions (normal load, velocity) and a lower apparent friction as compared with the isotropic sample.

Focusing on the contact shape, it is elliptical for the oriented iPP contrary to the isotropic case where the contact is circular. It is thus possible to determine both contact tilt and ellipticity for the oriented samples. The contact tilt is defined as the angle between the sliding direction and the minor axis of the ellipse. Results are presented in Figure 1.

The minor axis of the elliptical contact is always oriented towards the draw axis whatever the sliding direction as shown in Figure 2. This can be explained by the increase of the mechanical properties according to the draw axis.

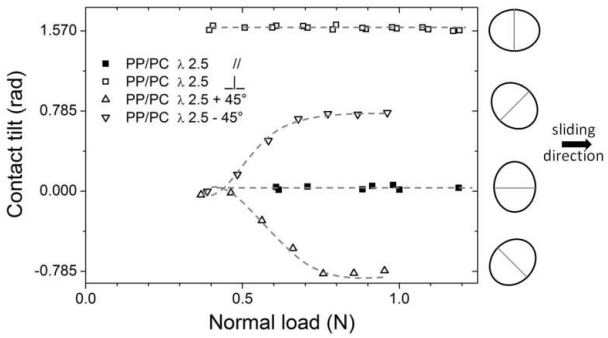

Figure 1: Evolution of the contact tilt of the elliptical contact as a function of normal load and sliding direction.

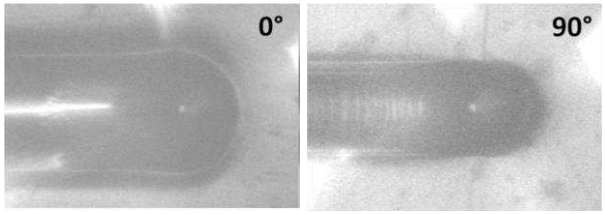

Figure 2: Pictures of scratches on oriented iPP depending on the sliding direction (0°= parallel to the draw axis) .

4. Discussion

Scratch experiments reveal that both contact shape and orientation depend on the stretching direction versus the sliding direction. Comparison between scratches performed on un-oriented and uniaxially drawn iPP has shown that stretching improves scratch resistance by allowing less brittle scratches towards the draw axis.

5. References

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6. Acknowledgements

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