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Numerical investigations of the scratch behavior on a pre-oriented polycarbonate surface

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The scratch behavior on a pre-oriented polycarbonate (PC) surface was investigated under the numerical point of view, using Finite Element Analysis (FEA) with the commercial software Marc Mentat®, since it provides very nice capabilities for remeshing applications during the simulation. This is particularly useful, when the rheology is anisotropic and the friction at the surface relatively important.

Keywords: scratch experiment, polycarbonate, pre-oriented, FE simulations

1. Introduction

Polycarbonate, or many other transparent polymers, are massively used as glasses and windows for their magnificent optical properties, their lightness and their relatively high mechanical resistance. For some specific applications, it might be useful to impose a pre-orientation to customize / improve the bulk mechanical or the scratch resistance in some specific directions. In this work, the PC was selected for the ease of control the structural/molecular orientation at room temperature with a simple tensile machine. As a consequence, the contact response of the polymer is completely re-arranged by this introduced anisotropy and thanks to the *in-situ* display of the true contact area during scratching time [2], it is easy to record the anisotropic behavior of the scratching, see Fig. 1. In addition, one still cannot affirm that this anisotropy is only due to the anisotropic bulk rheology, by an eventual anisotropy in the friction model or by a combination of both.

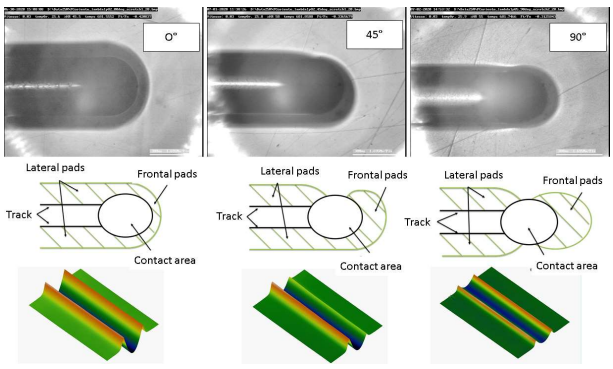

Figure 1: contact geometries during a scratch experiment on a pre-oriented PC surface. For a sliding direction at 45° from the pre-orientation direction, the contact geometry becomes and largely dissymmetric.

2. Methods

Even if for such research work, one should discuss first (a) the way the material is pre-oriented (b), how the rheology becomes anisotropic (i.e., plasticity surface and hardening) (c), how the rheology will be modelized in a numerical FE software, in this contribution, we only focus here on the contribution of the anisotropic bulk rheology in the none-circular shape of the contact area during a scratch experiment.

For this first approach, the local friction intensity was assumed to be the one at low contact strain and assumed constant whatever was the rate of yielding [2]. In this contribution, one tried to modelize the scratch experiment using the FE Analysis. The rheology of the polymer was calibrated at best on experimentally pre-oriented PC samples and using an elastic-perfectly plastic constitutive equation, the plasticity criterion being modelized by Hill or Barlat plastic potential function. Since we are able to decorrelate the ploughing part from the interfacial part in the measure of the apparent friction, a local friction coefficient was estimated to be between 0.2 and 0.4. For that reason, one decided to investigate "Global" and "Local" remeshing capabilities of our commercial software.

3. Discussion

The final objectives of this work are to compare experimental *in-situ* observations to what stress and strain fields are to provide in term of global quantities directly measurable. As a first example, one was able to nicely reproduce the shape of our *in-situ* observations in term projected level-set cartography, see Fig. 2.

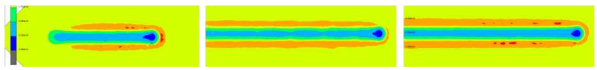

Figure 2: iso-value lines of the total vertical displacement field for scratch simulations, where the sliding direction is oriented at 0°, 45° and 90° from the pre-orientation direction (from left to right).

Our simulations results are also able to provide information on the asphericity and prolateness of the von Mises stress function under the contact, see Fig. 3.

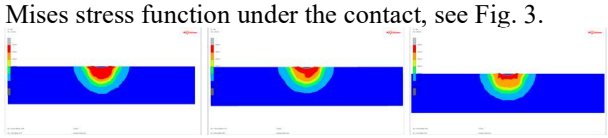

Figure 3: iso-value lines of von-Mises equivalent stress function, the simulations being in the same order.

4. References

[1] Gauthier C.et al., "Elastic recovery of a scratch in a polymeric surface: experiments and analysis", Tribology International, 34 (7), 2001, 469-479.

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