Multi-scale scratch resistance analysis of floor covering materials

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Floor covering materials are daily solicited mechanically by walking, cleaning, sliding chairs… all of them liable to cause wear, degrading the visual aspect of the product. One particularly severe wear mechanism is scratching. In order to increase the scratch resistance, a 20 µm thick, hard polyurethane coating is deposited on the soft PVC flooring. However, the way the structure is mechanically solicited depends on the scale at which this multimaterial is scratched. We carried out a multi-scale study by scratching the material using tips with radii of curvature from 2 µm to 100 µm. Experimental results are described and further analyzed by FEM simulations, showing hard coating efficiency to depend on scratch scale.

Keywords: tribology, polymers, scratch, FEM.

1. Introduction

On bulk materials, the mechanical response during a scratch test does not depend on the tip size, only on the ratio between the contact radius and the tip radius (for spherical tips) [1]. However, for coated materials, the tip size is of prime importance, because of a "structure effect". In this case, the mechanical response is also a function of the ratio between the coating thickness and the tip size [2]. This presentation analyzes, for a given coating thickness (20µm), the way the structure is mechanically solicited. By using different spherical tips, the efficiency of the coating is shown to depend on the scale of the solicitation.

2. Methods

Scratch tests are performed on a Nanoscratch Tester CSM Instruments (Anton Paar GmbH). Spherical tips are used, with radii of curvature 2 µm and 100 µm, under loads respectively up to 50 mN and 3 N.
The numerical model was developed on the finite elements software Forge NxT 3.0 (quasi-static, implicit integration). The whole system is meshed as a single domain with a coincident mesh along the interface, preserved during remeshing. Perfect adhesion is thus modelled, in agreement with experimental results.

3. Results

Depending on the solicitation scale, different deformation and rupture modes appear during the scratch tests. These different mechanisms were finely analyzed thanks to the numerical simulations.
Moreover, numerical simulations allow to understand how the structure is deformed depending on the scale:
- At low scale, a 2µm tip is used with scratch load F_n = 2.5 mN and depth d = 1 µm. Only the coating undergoes significant mechanical solicitation (figure 1.a). In other words, at this scale, the mechanical response does not depend on the substrate rheology.
- At larger scale (100µm tip, F_n = 1.7 N, d = 50 µm), the whole structure (PVC+PU) is solicited (figure 1.b) and the mechanical response of the material depends on both the PVC and the PU mechanical behaviors. At this scale, the coating does not decrease the indentation depth under load. However it reduces the attack angle thanks to a sink-in effect, hence a lower plastic deformation under load. The elastic springback is also larger, so that the residual groove depth is smaller and the scratch is less visible.

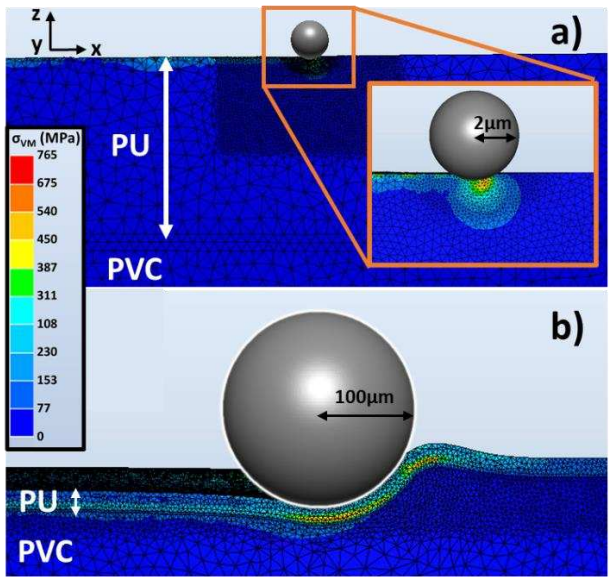

Figure 1: von Mises maps from numerical simulations done with a 2µm (a) and a 100µm (b) radius tip.

4. References

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