Experimental and numerical analysis of polymeric surface damages during scratching process

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A better understanding of fracture mechanisms during scratching is of prior interest to prevent polymeric surface damages. In this study, a coupled experimental/numerical approach is used in order to identify criteria of damage initiation. After the description of scratch induced damages onto three bulk polymeric materials (PMMA, PC and CR39), corresponding initiation criteria have been derived by correlating the occurrence and location of events. The present considerations bring a new insight concerning the criteria associated to crazing, shear bands and cracking. This work opens possible prospects of improvements for the scratch resistance of polymeric surfaces.

Keywords: polymeric surfaces, damage, scratching, experimental and modelling.

1. Introduction

The mechanical origin of polymeric surface damages during scratching not being well understood, there is a real need to investigate the deformation behaviour and to introduce damage criteria. The experimental approach gives precious observations of phenomena which occur during scratching (deformation through the contact geometry, cracking, ...) and permits to assess the friction. However, it does not allow to get insight the stress distribution within the material, a key feature for crack initiation prediction.

2. Methods

The experimental device used is called "Micro-Visio-Scratch" test. It consists of a conventional scratch test: a normal force is applied by a spherical indenter onto a tested surface, and then a transversal displacement generates the scratching movement, inducing permanent deformation and damages, depending notably on the test conditions. The particularity of the setup is that it allows to visualize *in situ* the scratch if the tested material is transparent, and then to see where and when the damages appear. Moreover, the exact dimensions of the contact zone can be measured thanks to image analysis, which is not available *post mortem*. The coefficient of friction (COF) is also monitored and recorded all along the tests. The need of further analysis of investigated fracture mechanisms, leads to couple numerical calculations to those experimental investigations. A three-dimensional finite elements model was developed to study the mechanical response of polymeric surfaces during a scratch test. Those simulations were conducted with the software MSC MARC© for different contact configurations between a rigid sphere and bulk flat surfaces.

3. Discussion

First, a comprehensive outline of damage occurrence and kinetic is given thanks to experiments on the three substrates. Damages occur under the tip, within the contact area. Moreover, the damages are identified as being crazing, shear bands and cohesive cracking for the PMMA, CR39 & PC, respectively. Their occurrence and kinetics are described extensively and a particular attention was paid to report precisely the location of their initiation in the contact area during scratching.

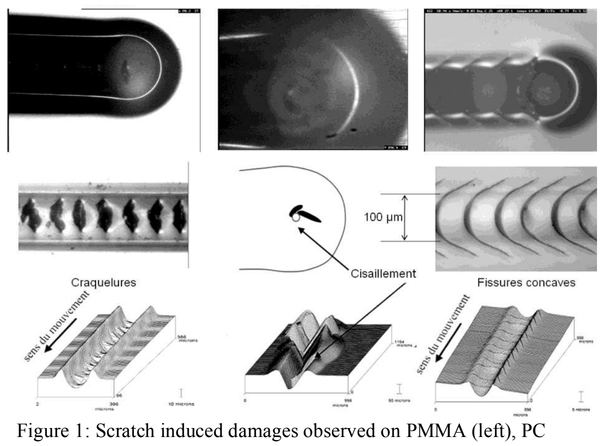

Figure 1: Scratch induced damages observed on PMMA (left), PC (middle) & CR39 (right) surfaces.

The main goal of this work was to identify damage criteria thanks to 3D Finite Elements modelling in order to understand and predict material failure in sliding contacts. With the help of the FE model, the local exploration on a large zone below and around the contact area permits to identify the locations exhibiting the most critical stress and/or strain states: shear, normal and principal stresses as well as critical strain gives precious insight in the material response to the sliding loading. It helps to build crack initiation criteria according to the experimental observations.