8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineeering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

Computational modelling of scratch test on solid polymers

*** N.Aleksy[1,2], G.Kermouche[1], A.Vautrin[2] and J-M.Bergheau[1]**

[1] LTDS UMR 5513 CNRS ECL/ENISE/ENSM-SE
58 rue Jean Parot 42023 Saint-Etienne Cedex 2
nicolas.aleksy@enise.fr

[2] LTDS UMR 5513 CNRS ECL/ENISE/ENSM-SE
158 cours Fauriel 42023 Saint-Etienne Cedex 2
vautrin@emse.fr

Key Words: *Numerical modelling, scratch test, Polymers.*

ABSTRACT

The polymers constitute recent materials widely used in several industrial sectors. For instance, amorphous glassy polymers are nowaday employed as thin films deposited on surface to be protected. More particularly in the optical industry, the glasses are covered by layers which high resist against scratches. The main feature looked for concerns the high capability of the glassy polymers to remove a wide part of the deformation.

In this context several work dealing with the study of the scratch test on solid polymers have already shown that their response depends strongly on three major parameters : the mechanical behavour of the material, the temperature and the friction taking place between the scratching piece and the scratched surface. Here is proposed a finite element approach of this complex problem.

The first part deals with the mechanical behaviour of the glassy polymers. Previous experimental works Briscoe [2] and Gauthier [3] have already shown that these materials behave both viscoelastic and viscoplastic during scratch tests. The viscoelastic viscoplastic models, specially dedicated to the materials, existing in the litterature are not enough adapted to our case study and involve the identification of a high number of parameters. Our solution is the association of two more simple models, one being viscoelastic and the other viscoplastic. The litterature gives a wide enough number of such models. To easly test different combinations of them and above all to be able to associate two behaviour models, we have develop a specific algorithm in the finite elment code Systus®. This latter allows to assembly in series two models, in the general case of high transformations, as long as they are available in the finite element code and the formulation of their constitutive equations are in the same framework (update lagrangian, total lagragian,...). Here is proposed an original assembly composed by a classical viscoelastic model, type Voigt, where the viscous element depends no linearly on the strain rate. The second models refers to the Arruda-Boyce model [1], which has been develop specially to the galssy polymers in particular the PMMA and the PC. The obtained model is then used to perform numerical simulations of scratch tests. A specific value, there called healing, is observed versus the scratching velocity. It is defined as the ratio between the depth of the residual groove, left on the scratched surface by the sliding indenter, and the penetration depth of the tip. Through the analysis of it, the importance to account for both the viscoelasticity and the viscoplasticity is highlighted.

The temperature represents the second parameter which strongly acts on the response of the polymer. Jardret [4] has already shown via experimental approach that the temperature influences the scratch properties such as scratch resistance, hardness, fracture resistance... In general case, higher the ambiant temperature, better and faster the healing phenomenon. More precisely, the temperature acts on the different properties of the material. Our numerical model is thus improved by a thermo mechanical approach. First, the materials properties account for the ambiant temperature, and thus the mechanical behaviour could be affected by a change in the temperature. Then, the mechanical dissipated power coming from the viscoplastic strain provides entirely the thermal power leading to a significant and local increase in the temperature which modifies the material properties and thus the mechanical behaviour. Here again, the evolution of the healing phenomenon with the scratching velocity is observed. Several simulations have been carried out for different ambiant temperatures. Two major apsects are highlighted there : the influence of the scratching velocity at a fixed value of the temperature, and the influence of the temperature at a fixed value of the scratching velocity. The importance to account for such thermo-mechanical coupling is thus here underlined.

Finally, the third main parameter affecting the response of the material is the friction phenomena taking place in the contact zone between the indenter and the surface. An apparent friction is already accounted since it is defined as the ratio of the normal load, applied on the indenter to keep a constant penetration depth along the scratch test, on the tangential load, applied on the indenter to keep a constant scratching velocity for each simulation. A classical definition type coulomb is here used to model a real friction, the phenomenological study presented just aims at showing the influence of the friction. It has been already shown that the fact of accounting for the friction affects the position in the thickness of the maximal equivalent cumulated plastic strain. Higher the friction coefficient and closer this zone to the top of the scratched surface and above all higher the value of the maximal plastic strain. Moreover the sliding contact between the tip and the surface is in charge of a significant heat source. Through the analysis of the healing versus the tip velocity, the friction shows its influence on the response of the glassy polymers.

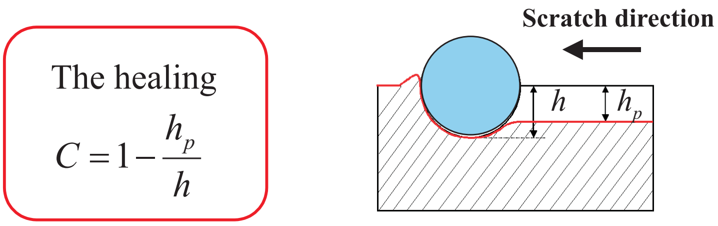

Figure 1: Representation of the healing definition

REFERENCES

[1] E.M. Arruda and M.C. Boyce. “Evolution of plastic anisotropy in amorphous polymers during finite straining”, *International Journal of Plasticity*, **9**, 1993, pp. 697-720.

[2] B.J. Briscoe, P.D. Evans, S.K. Biswas and S.K. Sinha. “The hardnesses of poly(methylmethacrylate)”, *Tribology International*, **29**, 2 1996, pp. 93-104.

[3] C. Gauthier, S. Lafaye and R. Schirrer. “Elastic recovery of a scratch in a polymeric surface : experiments and analysis”, *Tribology International*, **34**, 2001, pp. 469-479.

[4] V. Jardret and P. Morel. “Viscoelastic effects on the scratch resistance of polymers: relationship between mechanical properties and scratch properties at various temperatures”, *Progress in Organic Coatings*, **48**, 2003, pp. 322331.