3rd International Conference on Self-Healing Materials
Bath, UK. 27-29 June 2011

A MECHANICAL MODEL FOR THE SELF HEALING RESPONSE OF COATINGS BASED ON EXPANSIVE PHASES

R. Rey[1], E. Javierre[1,2], M.A. Pérez[1], S.J. García[3], S. van der Zwaag[3] and J.M. García-Aznar[1]

[1]Aragón Institute of Engineering Research, Universidad de Zaragoza.
Edificio Betancourt, C/ María de Luna s/n, Zaragoza 50018. Spain.
Email: rrey@unizar.es, angeles@unizar.es, jmgaraz@unizar.es

[2]Centro Universitario de la Defensa – Academia General Militar.
Ctra. Huesca s/n, Zaragoza 50090. Spain.
Email: etelvina.javierre@unizar.es

[3]Faculty of Aerospace Engineering, Delft University of Technology.
Kluyverweg 1, 2629 HS Delft. The Netherlands.
Email: s.j.garciaespallargas@tudelft.nl, s.vanderzwaag@tudelft.nl

Keywords: Coating, Self-healing, FEM simulation, Mechanical modelling

ABSTRACT

Coatings are frequently used as barriers protecting an underlying substrate from the surrounding environment. In order to reduce their recurrent maintenance cost, industrial efforts are addressed towards the design of self healing coatings, capable of reacting actively wherever damage occurs. Most frequently, self healing coatings are based on conveniently stored healing agents which react with the primer when the propagating crack releases them [1-2]. Such systems shall deal with the proper healing agent's storage and catalyst, in addition to long distance mobilization, in order to optimize their performance.

An alternative approach consists of using an external source to activate the healing of non enhanced coatings, such as self sealing coating based on expansive phases [3]. The experimental coating to be modelled in this work consists of an Amercoat 4093 clear topcoat and a montmorillonite clay inner layer on a rigid Menzel glass substrate. Environment moisture ingress through a crack induces the expansion of the montmorillonite clay which fills the crack. However, only when the water repellent topcoat is scratched, the system becomes active.

We use a thermo-elastic analogy to model the inner layer expansion by moisture absorption. The topcoat is modeled as a hyperelastic material, whereas the montmorillonite clay layer is assumed to behave as a linear elastic material. The underlying substrate is treated as a rigid body. In a first stage, we assume that the different layers of the system (substrate, inner and outer layers) remain permanently bonded during the whole process. Only at the substrate/expansive phase interface near the crack contact is lost over a prescribed length due to damage (see Figure 1). On this delaminated length contact without friction is imposed.

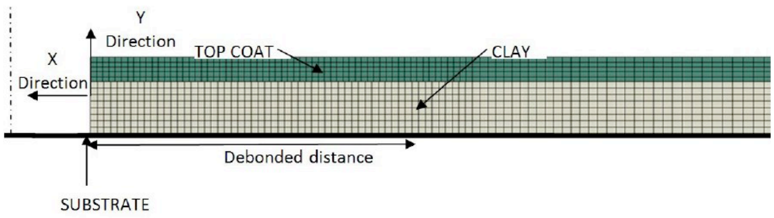

Figure 1: Numerical model configuration: the scratch is taken at the left of the configuration and a debonded distance between the clay and the substrate is assumed to originate from the crack inwards.

This simplified model, which depends on a reduced number of parameters, allows us to study through finite elements simulations the influence of several basic parameters on the system healing response. The healing capacity is measured from the combined horizontal and vertical displacement of the free edge of the system (see Figure 2). The horizontal displacement (U_x) serves as an estimate of the maximal crack width that can be filled, whereas the vertical displacement (U_y) gives a measurement of the negative impact of bending.

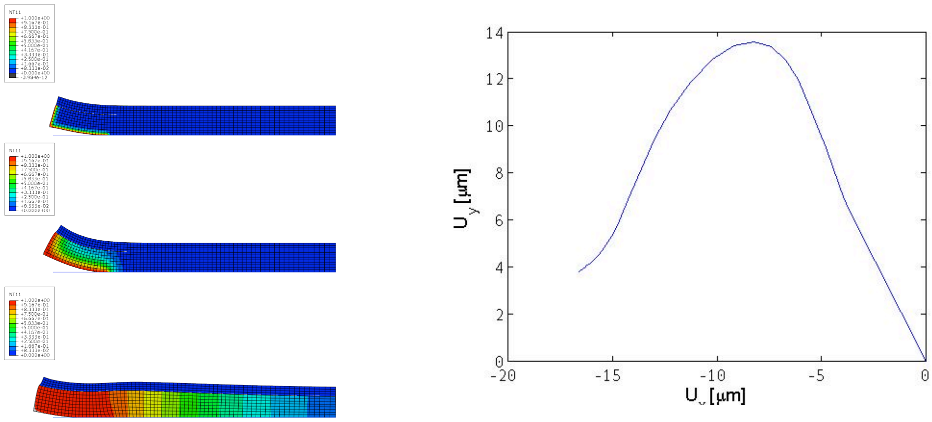

Figure 2: Left: moisture content and deformation of the exposed coating in time. Right: horizontal and vertical displacement of the lower-left corner of the coating along time.

The proposed model permits us to identify the key design parameters, such as the layer's thickness and Young modulus ratios, that characterize the healing trends.

The hypothesis of local delamination near the scratch turns out to be essential for the model to predict the expansion process. Without it, the expansive phase remains anchored to its original position and accumulating unphysical stresses. Hence, in a next stage, an interface damage model will be introduced to incorporate the inner stress state in the system evolution.

REFERENCES

[1] S.R. White, N.R. Sottos, P.H. Geubelle, J.S. Moore, M.R. Kessler, S.R. Sriram, E.N. Brown and S. Viswanathan, Autonomic healing of polymer composites, *Nature*, **409**, 2001, pp. 794-797.

[2] H.R. Williams, R.S. Trask, A.C. Knights, E.R. Williams and I.P. Bond, Biomimetic reliability strategies for self-healing vascular networks in engineering materials, *Journal of the Royal Society Interface*, **5**, 2008, pp.735-747.

[3] F. Micciche, H. Fischer, R.J. Varley and S. van der Zwaag, Moisture induced crack filling in barrier coatings containing montmorillonite as an expandable phase, *Surface & Coatings Technology*, **202**, 2008, pp. 3346-3353.