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A MULTI-PHYSICS MODEL FOR CHEMO-MECHANICAL DEGRADATION OF HISTORICAL OIL PAINTINGS.

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Degradation of historical oil paintings is a major concern for cultural heritage conservators. An enormous percentage of oil paints in museum collections, ranging from the sixteenth century to the present time, suffers from degradation phenomena, primarily due to metal soap formation. Metal soaps result from the chemical reaction between metal ions released from pigments and fatty acids, which are degradation products of the oil binder [1]. They appear as large protrusions that disfigure the surface texture and trigger mechanical damage and flaking of the painting. Despite largely observed, the interaction between chemical and mechanical degradation is far to be understood. This work proposes a chemo-mechanical model to predict metal soap formation and the associated chemical and mechanical damage in historical oil paintings. To this aim, a diffusional-mechanical formulation coupled with a discrete crack approach is developed. The chemical process is described by means of a diffusion-reaction model [2]. Metal soap crystallization and growth, driven by the diffusion of fatty acids and metal ions, causes chemically-induced volumetric strains. These lead to compressive stresses in the oil binder, ultimately initiating micro-cracks and delamination in the paint. Crack nucleation and propagation is achieved through the cohesive zone modelling approach, based on interface elements provided with a traction-separation law [3]. This is consistently extended to describe the multi-physics coupling, by incorporating mass flux-concentration relations at the interfaces. A series of numerical simulations enable to predict metal soap crystallization and growth and the consequent onset of micro-cracks in the paint. The study finally reveals the influence of different chemical and mechanical parameters (e.g. fracture toughness and elastic properties, growth strain and reaction rate) on the extent of the developed panting damage.

REFERENCES

[1] J.J. Hermans, K. Keune, A. van Loon, A., P.D. Iedema, The crystallization of metal soaps and fatty acids in oil paint model systems, Physical Chemistry Chemical Physics, Vol **18**, pp. 10896-10905, 2016.

[2] T.S. Hille, T.J. Nijdam, A.S.J. Suiker, S., Turteltaub and W.G. Sloof, Damage growth triggered by interface irregularities in thermal barrier coatings, Acta Materialia, Vol. **57**, pp. 2624-2630, 2009.

[3] M.V. Cid Alfaro, A.S.J. Suiker, C.V. Verhoosel, and R. de Borst, Numerical homogenization of cracking processes of thin fibre-epoxy layers, European Journal of Mechanics, A/Solids, Vol. **29**, pp. 119-131, 2010.