
A thermodynamically consistent constitutive model for hydrolytic degradation of oil paint

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Abstract

In this study, a thermodynamically consistent hygro-chemo-mechanical model is proposed to describe the hydrolytic degradation of oil paint. Oil paint has been used throughout centuries as a painting medium in historical artworks and consists of a drying oil binder with embedded pigment particles that forms a durable film upon curing. Oil paint is particularly vulnerable to chemical and physical degradation over time, driven by environmental factors such as humidity and temperature changes. These aging phenomena may ultimately lead to cracks and delamination, affecting the integrity and durability of historical paintings (1). The chemical processes responsible for oil paint degradation include hydrolysis, which consists in the cleavage of ester bonds within the oil binder when exposed to moisture, forming carboxylic acids and alcohols. Considering the cross-linked polymeric network structure of the oil paint binder, a diffusion-reaction model is formulated to predict the extent of the hydrolysis reaction. The diffusion-reaction model is coupled with a mechanical analysis, where a viscoelastic constitutive model for oil paint is proposed and calibrated using experimental data obtained from the literature (2). A hydrolytic degradation model based on continuum damage mechanics is further developed to capture the effects of moisture diffusion on the degradation process. The sequentially coupled chemo-mechanical model is implemented within the commercial finite element software Abaqus. A comprehensive parametric study is conducted to investigate the influence of different model parameters affect the degradation behavior of oil paints, providing insights into the key factors driving deterioration. This work aims to enhance the understanding of degradation mechanisms in heritage oil paintings and lay the groundwork for developing predictive tools to support efficient conservation strategies.

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(2) Hagan, Eric WS. "Thermo-mechanical properties of white oil and acrylic artist paints." Progress in Organic Coatings 104 (2017): 28-33.

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