Accelerated environmental testing of painted galvanized steel sheets

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Painted galvanized steel sheets are hybrid laminates which find applications in construction (such as facades and roof elements), the automotive, and the white goods industry. Especially in outdoor applications, such laminates are subjected to environmental factors like moisture, heat, and UV radiation and superimposed mechanical stresses due to temperature cycles. A common failure mode is blistering or local debonding of the coating in a brittle manner. The main objective of this study was to develop a lab test methodology which allows for accelerated, but service-relevant testing of coated galvanized steel. Therefore, an environmental fracture mechanics test facility was concepted and implemented. Due to service-relevant brittle failure mode, a linear elastic fracture mechanical fatigue method was employed. A model primer and top coated galvanized steel grade was examined. Double cantilever beam (DCB) specimens were fabricated by stacking and laminating pre-painted galvanized steel sheets with partially removed coating, a titanium reinforcement, and a non-polar polyolefin elastomer (POE) film adhesive. A PTFE release layer was inserted as a well-defined defect and crack starter. To assess the potential impact of pre-ageing on the environmental fracture mechanics crack growth kinetics, coated galvanized steel sheets were exposed to moist heat (condensation), UV-irradiation or hot QUVA weathering. Environmental stress corrosion fatigue tests in artificial acidic rain at an initial pH of 4.5 and a temperature of 60°C, allowed to induce a service-relevant brittle failure at the metal/primer interface, even for the non-pre-aged reference coating. Condensation pre-ageing of the coated steel above a hot water bath temperature controlled at 50°C, was more critical than hot QUVA or just UV-irradiated pre-ageing. Both, the debonding rate in the stable crack growth regime and the strain energy release rate in the threshold regime (Gth), were affected by pre-ageing. For example, the G_{th} values were reduced from 18 J/m^2 for the non-pre-aged coating to just 6 J/m^2 after 2000h of condensation pre-ageing. Using laser confocal microscopy, FTIR and Raman spectroscopy, the brittle failure at the metal/primer interface was confirmed. Moreover, it was shown that both, condensation or hot QUVA pre-ageing and environmental fracture mechanics testing in artificial acidic rain was associated with hydrolysis of urethane groups of the investigated primer. After successful implementation of a service-relevant lab test methodology, future research will deal with the establishment of structure-property-correlations varying the galvanization layer (e.g., Zn vs. ZnMg), the conversion coating or the polyester urethane primer formulation.

Keywords: painted galvanized steel sheets, environmental fracture mechanics, accelerated testing