Progress in Organic Coatings 59 (2007) 230–238

PROGRESS IN ORGANIC COATINGS

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Effect of powder painting procedures on the filiform corrosion of aluminium profiles

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Received 20 June 2005; received in revised form 11 January 2006; accepted 15 February 2006

Abstract

In this work, the filiform corrosion behaviour of powder painted aluminium profiles was studied, and the coating barrier properties together with adhesion to the substrate were analysed. Samples coated with a traditional painting procedure (one powder layer application followed by curing), and other samples coated using a special cycle to obtain wood grain effect were compared using accelerated filiform corrosion tests. Moreover, in order to better understand the degradation mechanisms of painted metal substrates, thermal stresses were applied to accelerate the natural weathering. The effects of the thermal aging were analysed by electrochemical impedance spectroscopy.

Wood grain effect coatings showed to better resist, with respect to a traditional coating, to filiform corrosion when testing was performed following the DIN 65472 standard. On the contrary, electrochemical impedance measurements showed better barrier properties against water uptake for the traditional coating after thermal ageing.

Different barrier properties were found to depend on the microstructure of the two coatings after curing. The traditional one has a homogeneous microstructure, with completely fused powder grains and very fine size pigments. On the contrary, wood grain effect coating possesses a “defective” microstructure with a widespread distribution of partially fused powders grains determining a dense network of grain boundaries, moreover coarser size pigments are present.

This microstructure decreases the coating barrier properties, but also can determine a loss of plasticity and the coating under mechanical stress can crack modifying the filiform corrosion behaviour.

Keywords: Aluminium frames; Filiform corrosion; Thermal aging; Powders paint

1. Introduction

Corrosion resistance of aluminium alloys is greatly improved by painting and lacquering and aluminium profiles used to produce blind, frames, doors and windows are frequently protected by powders coatings. Such an environmentally friendly process allows obtaining thick and homogeneous coatings with a very good appearance due to the continuous development of new powder products with almost unlimited colour and texture possibilities.

Powder coatings to simulate a wood grain effect have been around for many years. The graining effect is very realistic, and the appearance is like wood grain veneer. Wood effect is usually obtained by depositing two layers. It can be achieved by two ways either by applying a first powder coating layer and curing it to lower limit, then by applying a coloured paper or plastic membrane that is already prepared for this job (heat transfer technology); the other method is by applying a second layer with a slightly different colour also made of powder paints and before curing an automated brush shapes the requested wood effect finish. The second layer of powder penetrates into the first layer creating a compact and uniform coating.

Polyester powders have been developed to create different types of realistic surface “textures”, like wood fibres, with no limit to creativity and design freedom, imitating various colours, and to obtain in the meantime organic coatings that should allow durability, quality and resistance to weathering conditions and outdoor UV exposure. In fact, the aesthetic appearance of wood must be combined with the outdoor performance and durability of painted aluminium. Blind and frames must be protected

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doi:10.1016/j.porgcoat.2006.02.011

against corrosion, mainly filiform corrosion, in order to preserve the finished articles usefulness and appearance too. Filiform corrosion is a cosmetic type of attack because it does not weaken or destroy metallic components but only affects surface appearance. It occurs under protective coatings and has been observed, as a network of corrosion products trials, on different kind of metal substrates such as steel, magnesium and aluminium alloys [1–4].

In this work, the filiform corrosion behaviour of powder painted aluminium profiles was studied, and the coating barrier properties together with adhesion to the substrate were analysed. Samples coated with a traditional painting procedure (one powder layer application followed by curing), and other samples coated using a special cycle to obtain wood grain effect were compared using accelerated filiform corrosion tests. Moreover, in order to better understand the degradation mechanisms of painted metal substrates, thermal stresses were applied to accelerate the natural weathering [5,6]. The effects of the thermal aging were analysed by electrochemical impedance spectroscopy (EIS).

2. Experimental

Aluminium alloy 6060 profiles were powder painted in an industrial plant following two different procedures:

(A) a traditional one consisting of spraying a polyester paint and curing at 190 °C for about 20 min;
(B) an innovative process performed to obtain wood grain effect and consisting of three steps using the same powder:
   (1) spraying and curing at about 115 °C for about 10 min,
   (2) spraying, rolling and curing at about 115 °C for about 10 min,
   (3) spraying, rolling and curing at about 190 °C for about 20 min.

All the aluminium profiles were pretreated as follows: degreasing, alkaline pickling and chromatizing. The same industrial polyester powders were used to coat the aluminium substrates and a final coating thickness of about 140 μm was obtained. Samples of type A (traditional spraying) and of type B (wood grain effect) were obtained from different production batches.

Some panels were submitted to a classical Loockheed test (DIN 65472 standard) in order to assess resistance to filiform corrosion. Scratches were made in the paint according to the standard then samples were firstly exposed to HCl vapours and successively exposed in a humid chamber. Filiform were observed and ranked following the standard recommendations.

Other samples were aged by thermal cycling. This test is the repetition, for several times, of a thermal cycle consisting in heating the samples in oven up to 75 °C (above the glass transition temperature of the paint), permanence at this temperature for 4 h and then cooling from 75 °C to room temperature. Cooling was obtained just turning off the oven. A thermocouple was used to monitor the coating temperature during all the sequences (Fig. 1). During the thermal cycles the samples remained always in contact with the electrolyte.

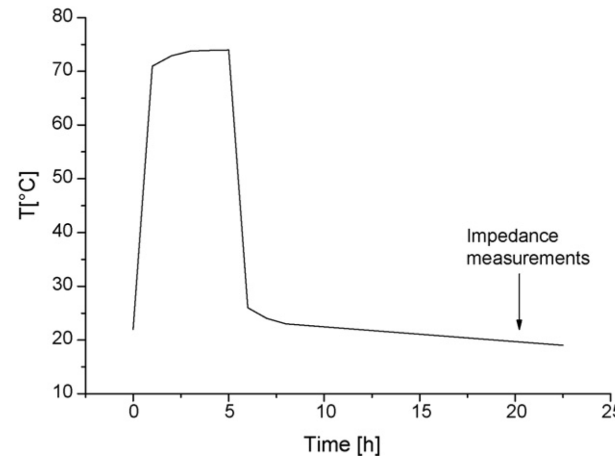

Fig. 1. Thermal cycle temperature profile.

Electrochemical impedance spectroscopy (EIS) measurements were carried out at room temperature after each thermal cycle. For testing, glass cylinders were glued to the surface and filled with a 0.3% Na_2SO_4 solution. The exposed area was about 20 cm^2. The electrochemical measurements were carried out by a Solartron 1255 SI Frequency Response Analyser connected to a PAR 273 potentiostat in the frequency range of 10^5 to 10^{-2} Hz; a sinusoidal signal with an amplitude of 50 mV was applied and eight points per decade were registered. The impedance data were fitted by Boukamp software through a proper equivalent circuit. An Ag/AgCl reference electrode and a platinum counter electrode completed the electrochemical cell. In order to minimize external interferences to the measuring system all the measurements were made in a Faraday's cage.

Prior to and after corrosion tests, the coated samples were observed by scanning electron microscopy (SEM) both on cross-sections and on top view. Energy dispersive X-ray spectroscopy analysis (EDXS) was also carried out to evaluate the coating chemical composition.

FT-IR measurements were performed in reflectance using a Bio-Rad FTS 165 spectrophotometer to analyze chemical bonds and structure of the organic coatings.

The glass transition temperature of the coatings was measured using differential scanning calorimetry (DSC) on cured and detached coatings. For this purpose the samples were submitted to linear heating from −20 to 220 °C, at a heating rate of 3 °C/min. For each sample two temperature scans were made. The measures were performed by a Mettler DSC 30 cell with a Mettler TC 10A interface.

3. Results and discussions

Resistance to filiform corrosion was assessed after 40 days exposure to humidostatic chamber. Filaments morphologies are shown in Fig. 2 and in Table 1 the number of filaments and averaged filaments length data are collected. According to DIN 65472 standard, both samples (traditional and wood grain effect coatings) possess a good resistance to filiform corrosion as the