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Visual appearance durability as function of natural and accelerated ageing of electrophoretic styrene-acrylic coatings: Influence of yellow pigment concentration

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ABSTRACT

Organic coatings are extensively used in many fields of engineering such as automotive or architectural industries for protection of the metallic structure against corrosion and to deliver visual aspects to the coated item. High quality paints either for outdoor or indoor applications require longer stability of their visual appearance alongside maintenance on the corrosion protection ability. In the present work, the total color variation and corrosion protection efficiency of waterborne styrene-acrylic paints loaded with different contents of organic yellow pigment has been studied. The paints have been deposited via cathodic electrodeposition on cold rolled steel. The visual aspect's stability of the paints was monitored as function of field exposure wherein the painted panels were naturally aged throughout one solar year in the alpine environment of Trento – northern of Italy. Color measurements were conducted according to the CIEL*a*b* color standard and gloss measurements alongside FT-IR spectroscopy were used to assess variations on the surface topography and chemical structure of the coated panels. It has been observed that solar radiation, the relatively humidity and temperature played a role on the surface roughness as well as on the lightness aspects of the coated panels. The electrochemical impedance spectroscopy outcomes revealed a dependency of the barrier properties of the paints with the pigment concentration. Superior barrier properties were verified for the paints with pigment content lower than 1.0 wt.%.

1. Introduction

Organic coatings are extensively used for metal structures protection against corrosion. Besides their protective property against corrosion, organic coatings also have an important role related to the visual appearance, for example, cultural heritage [1], household appliances [2], façades paintings [3], wood substrates paintings [4,5], etc. In the majority of coating technological case, color and anticorrosive pigments play important roles, respectively as design element, e.g. aesthetical appearance, and durability properties. Organic pigments, manufactured using petroleum-based (carbon) chemistry, can achieve bright, bold colors, but their carbon-based chemical structures typically degrade more quickly than inorganic pigments [6]. The coating film creates a barrier layer between the metal surface and the corrosive environment. The protective properties of coating are related to a complex mechanism which includes synergic action of different factors: the dielectric properties, oxygen and water uptake, ions penetration, environmental conditions and many complex electrochemical corrosion processes between the metal/coating interface after permeation of aggressive species [7–10]. If the coating is a continuous film and is sufficiently impermeable, it provides efficient protection however during their life time these systems are exposed to sunlight, moisture and temperature which promote damage to the coating. Moisture impact negatively the durability of organic coating due to water's role in many destructive mechanisms such as hydrolytic degradation, etching, and creating large changes in the stoichiometry and concentration of oxidation products [11–13]. Another important factor which causes greatest changes on painted surfaces during outdoor exposure is sunlight. U.V radiation represents 5% of the solar spectrum and UV-B rays cause the most significant damage to polymeric materials [14].

Nowadays, environmental regulations and public health hazards preventions limited the use of organic solvents in certain

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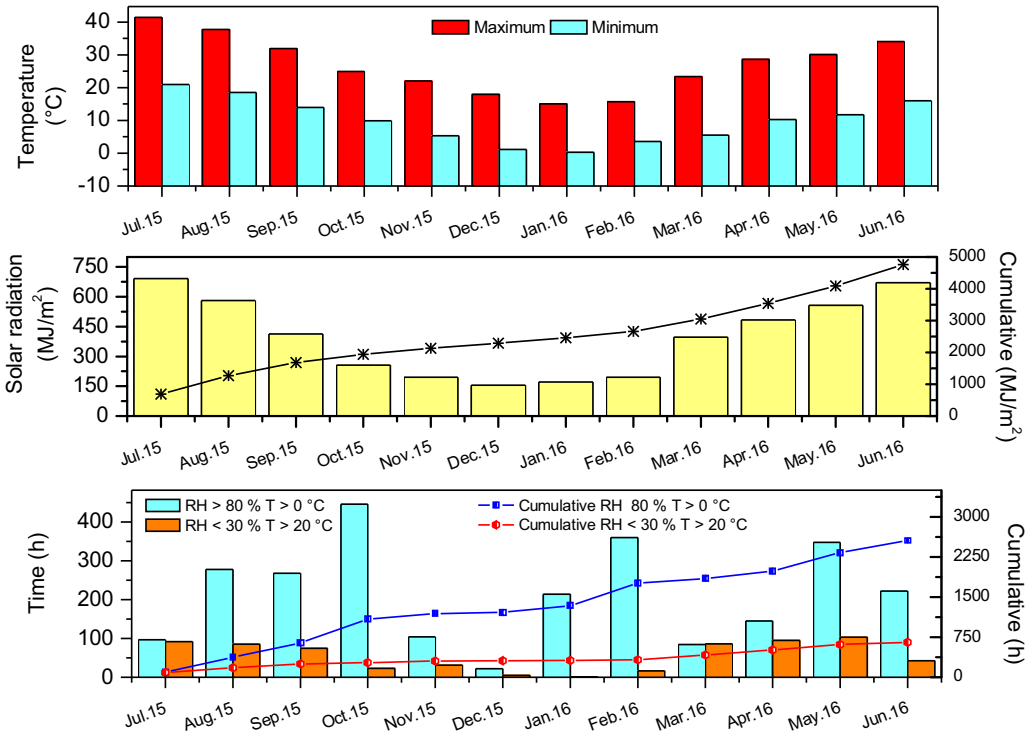

Fig. 1. Meteorological data of Trento from 01/Jul/2015 to 30/Jun/2016 [30].

activities and installation in order to reduce the emissions of volatile organic compounds (VOC) in the atmosphere [15,16]. Consequently, there was an increase on the use of solvent free formulations of paints or solvent less technologies with respect to the traditional solventborne paints [17].

Amongst paint technologies to coat metals, the cathodic electrodeposition, i.e. cataphoretic coatings, can be categorized as an environmentally friendly method, formulations are solvent less and heavy-metals free [14]. Several metallic substrates can be coated via cathodic electrodeposition, for instance, hot/cold laminated and galvanized steel, copper and aluminum alloys. This process permits the deposition of a uniform film associated to a precise control of the film composition and structure. The chief example of successful application comes from the automotive industry wherein cathodic electrodeposition technology was implemented to coat the automobile bodywork in the 70′s and is still widely used in present days [18–20]. In addition to automotive industry, the advantages of cathodic electrodeposition of paints associated with formulations containing color pigments permit a present-day growing variety of products which can be coated by cataphoretic coatings. Applications such as indoor furniture, household appliances and jewelry industry [21] where a single paint layer in the range of tens micrometers, simultaneously, delivers visual aspects and offers protection against corrosion to the coated item and are potential markets for colored cataphoretic paints.

The color perception itself is the chief factor which predominates on the visual aspects delivered by a colored object or surfaces. In this context, color measurements appear as a powerful tool to quantify the color perception of a random object and the CIE *(Commission Internationale de l'Eclairage 1976*) adopted a set of color-matching functions as an international standard. Besides coatings technology, many fields of science are concerned to the color theory. As an example, for architecture and interior design purposes the influence of color and surface finishing on the perceived warmth delivered by an indoor wall was investigated by means of color measurements [22]. For decorative coatings either for indoor or outdoor application, both color perception and brightness are elements in which the visual appearance of coated item is defined. To a certain extent, the preservation of the visual appearance states about the lifetime of decorative coatings, thus it is important to explore the color perception of coated materials and to comprehend the color perception stability in order to predict the lifetime of decorative coatings [23,24].

The selection, development and qualification of organic coating for specific environment require a thorough characterization of the most important coating properties. Field and accelerated ageing approaches are widely used to test the coatings performance [25–27]. The lifetime of the paints themselves consequently those of the coated item is accurately and properly estimated by field exposure wherein the testing and application conditions are equally reproduced [28,29], i.e. sunlight, ambient outdoor temperature and moisture. This method includes broad range of timescales such as rainfall and day/night cycles which introduce typical timescales in the order of hours and days, while humidity variations due to seasonal change have timescales in the order of months [26]. However, field exposure tests may last for several years before a reasonable conclusion could be drawn and for research and development purposes there is the need to obtain these outcomes in shorter period of time. In this view, accelerated test could be an alternative method for testing coatings. One root of performing accelerated weathering in laboratory condition consists to expose the samples to UV light, heat, humidity.

This study assessed the influence of yellow pigment concentration on the color perception and paint finish of a steel coated styrene-acrylic paints produced via cathodic electrodeposition. The changes on the visual appearance of the paint systems were studied as function of exposure to accelerated UV-B radiation for 650 h as well as during natural weathering ageing for the duration of one solar year in the alpine environmental exposure site in Trento, northern of Italy. Completing, EIS measurements were carried to evaluate the influence of the colored pigment on the corrosion protective properties of the paint systems. At the deposition stage, the