ORIGINAL ARTICLE

Investigation of the cut-edge corrosion of organically-coated galvanized steel after accelerated atmospheric corrosion test

Reşit Yıldız *, İlyas Dehri

Department of Chemistry, Cukurova University, 01330 Adana, Turkey

Abstract The cut edge corrosion of organically coated (epoxy, polyurethane and polyester) galvanized steel was investigated using electrochemical impedance spectroscopy (EIS). Measurements were performed on specimens that had been tested in an accelerated atmospheric corrosion test. The samples were subjected to 10 s fogging and 1 h awaiting cycles in an exposure cabinet (120 and 180 days) with artificial acid rain solution. According to the investigation, the coatings were damaged from the cut edge into the sheet, this distance was about 0.8 cm. These defects were more pronounced at after 180 days in proportion to after 120 days.

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1. Introduction

Atmospheric corrosion is mostly due to the presence of salt and gases dissolved in a thin layer on a metal surface. The atmospheric corrosion rate of metals depends on the thickness of the electrolyte layer (Tomashow, 1964). Changes in the thickness of the layer affect the rate of oxygen transport through the electrolyte layer and solubility of corrosion products and, hence, the metal corrosion rates (Nishikata et al., 1995).

The use of organically coated steel products in a wide variety of industries has grown dramatically, recently, which has led inevitably to increasing demands on performance. As a result, it is vitally important, both from a commercial and environmental perspective, to optimize products' lifetime by minimizing degradation. In organically coated galvanized steel materials used in the construction industry, one of the most frequently reported modes of failure is corrosion at the metallic cut edges (Ryan et al., 1994). Coil coatings have long been used to protect metals and alloys against corrosion. In spite of the fact that such coatings form a barrier against diffusion of ions, water and oxygen are considerably more permeable and, therefore, are able to be present at the metal/coating interface. This can lead to substrate corrosion and coating delamination under the same conditions. Profiled galvanized steel sheet is commonly used for roof and wall cladding. This material is mostly factory-coated in coil; firstly, with a primer layer containing corrosion inhibitors such as strontium chromate and after that with a thicker top coat for additional barrier

* Corresponding author. Tel.: +90 (322) 3386084 2465; fax: +90 (322) 3386070.
  E-mail address: ryildiz80@gmail.com (R. Yıldız).

protection and the desired esthetic appearance. At the cut edge, however, the bare metal is exposed to the atmosphere, and corrosion may occur. There is a considerable interest in limiting this problem as it accounts for a significant proportion of the failures of coil-coated cladding according to recent industry surveys (Cox et al., 1985; Jones and Nair, 1985). One of the failure mechanisms that must be evaluated in organically coated galvanized materials is a form of localized corrosion, occurring at cut edges of the organic coated substrate, where sheets have been cut to size (Ryan et al., 1994). The undermining of the organic coating as a result of anodic zinc dissolution (1) is a frequent, although not exclusive, cause of cut edge corrosion. In this case, cathodic oxygen reduction (2) is localized on the steel. Previous workers have shown that under these conditions the rate of reactions is controlled by a mass transport of oxygen to the metal surface (Jones and Nair, 1985; Berke et al., 1985).

$$Zn_{(s)} \Longleftrightarrow Zn^{+2}_{(aq)} + 2e^- \tag{1}$$

$$1/2O_{2(g)} + H_2O_{(1)} + 2e^- \Longleftrightarrow 2OH^-_{(aq)} \tag{2}$$

Strontium chromate has been clearly seen to reduce the galvanic corrosion of zinc and steel in a model cell arrangement that simulates a cut edge (Howard et al., 1996). EIS has been used in a lot of studies to analyze the general degradation of organic coatings (Bastos et al., 2011; Bastos and Simoes, 2009; Mansfeld and Tsai, 1991; Zubielewicz and Krolikowska, 2009; Mansfeld et al., 1982; Ranjbar et al., 2004; Walter, 1986; Touzain, 2010; Deflorian et al., 2005; Penney et al., 2007; Niknahad et al., 2010; Zin et al., 2005; Gonzalez-Garcia et al., 2007; Rossi et al., 2005), the impedance response of an organic coating with artificially-produced defects (Geenen et al., 1990) and the impedance response of cut-edge corrosion of organically-coated galvanized steel (Howard et al., 1999a,b,c; Elvins et al., 2008; Simoes et al., 2009).

In this work, the degradation of the paint film by artificial acid rain solution at the cut-edge of the organic coated galvanized steel was studied with EIS. Measurements were performed at the end of the 120th and 180th days. The experimental data were fitted to appropriate equivalent electrical circuits with ZView program.

2. Experimental

Specimens of hot dip galvanized steel (HDG), with a zinc coating 20 μm thickness on steel were obtained. Sections of galvanized steels, with dimensions of 5×10 cm, were first coated with 10 μm of wash primer (polyvinyl butyral), and then 35–40 μm of epoxy, polyurethane and polyester paint were applied separately as a top coat. Then organic-coated galvanized steels were cut 1 cm from edge. A test cell was prepared, with dimensions of $50 \times 75 \times 40$ cm and made from Plexiglass, the samples were placed at an inclination of 45° relative to the horizon (Fig. 1), then these samples were exposed to the artificial acid rain solution according to test conditions. The experiments were performed in ambient laboratory air and temperature (25 °C). The corrosion tests were performed on these materials. In order to simulate fogging an experimental set up was constructed for the laboratory investigation. Fogging intensity was regulated by introducing clean compressed air into an orifice of a thin tube with flowing artificial rain, hence, forming small drops leaving the orifice.

The samples were exposed to a 10 time concentrated artificial acid rain solution (pH 3.5) to simulate fogging/awaiting test cells. The composition of a 10 time concentrated artificial acid rain solution is as follows (Dehri et al., 1999):

Sulfuric acid (1.84s.g.)	31.85 mg/L
Ammonium sulfate	46.2 mg/L
Sodium sulfate	31.94 mg/L
Nitric acid (1.42s.g.)	15.75 mg/L
Sodium nitrate	21.25 mg/L
Sodium chloride	84.85 mg/L

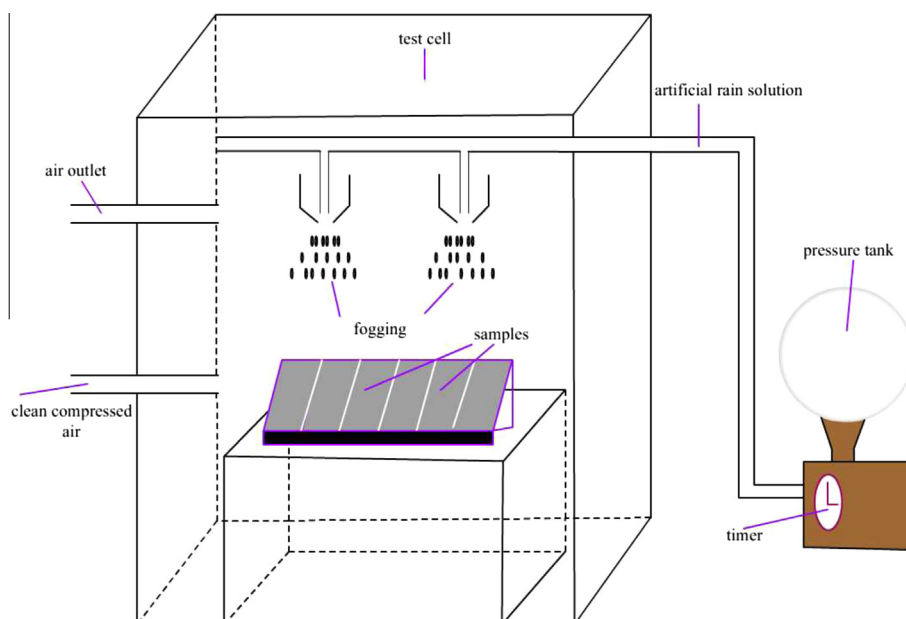(pH adjusted to 3.5 with sodium carbonate).

Figure 1 Experimental test cell set-up.