

Fluorescent Coatings for Corrosion Detection

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ABSTRACT

Coatings are used extensively to provide protection for structures in marine and offshore environments. Some of these coatings can be modified to incorporate corrosion indicators in the formulation. As a result of this, corrosion can be identified before it can be seen with the naked eye. Such coatings can include corrosion indicators that exhibit non-fluorescent to fluorescent states as a result of oxidation or other interactions with metal ions, or pH changes from corrosion processes. The coating systems typically contain the primer and a topcoat, and the corrosion indicator is usually added to the primer.

In this investigation, the corrosion indicator was a positive indicator for 1018 steel. It was initially non-fluorescent upon application, but glowed over areas of corrosion. The corrosion indicator was a negative indicator for 2024 aluminum. It was normally fluorescent when applied initially and that fluorescence was later quenched in the presence of corrosion. Steel and aluminum alloy coupons were exposed to saltwater conditions for a period of days to weeks. Electrochemical impedance spectroscopy (EIS) was used to complement the exposure tests and provide information on the integrity of the coating as a function of time and exposure to chlorides.

This paper will provide a description of comparisons between the exposure, electrochemical, and fluorescence results. In addition, results of microscopic examination of the coated specimens will be presented in an effort to understand the mechanisms associated with the corrosion-induced changes in fluorescence.

KEY WORDS: Coatings; fluorescence; corrosion; EIS; steel; aluminum

INTRODUCTION

One method of achieving corrosion protection of metals for offshore applications is by using a coating that will serve as a protective barrier. In addition, that barrier could incorporate indicators that could provide corrosion sensing. Two corrosion sensing developments involve (a) paint systems with color-changing compounds that respond to pH

changes due to corrosion processes and (b) coating compounds that exhibit non-fluorescent to fluorescent states as a result of oxidation or other interactions with metal ions. For example, Frankel and Zhang worked on paints that could detect changes in acidity and alkalinity resulting from electrochemical reactions that produce ions that change the pH (Frankel and Zhang, 1997). The investigators also examined acrylic mixed with a compound that would fluoresce under ultraviolet light above a certain pH (Frankel and Zhang, 1999).

In the present investigation, the authors examined families of coatings that incorporate corrosion indicators that change their fluorescent state in the presence of corrosion; a positive indicator for steel and a negative indicator for the aluminum alloy. The indicators for steel are non-fluorescent upon application and glow over areas of corrosion. The indicators for the aluminum alloy are fluorescent upon application and that fluorescence is quenched in the presence of corrosion

As a complement to the electrochemical testing being conducted in this investigation, there is a Fluorescent Corrosion Indicator (FCI) system for use in paint primer and overcoat coatings on steel and aluminum alloys. Systems & Processes Engineering Corporation (SPEC) developed the prototype scanner system and paint additives to provide an early warning corrosion system based on the use of fluorescent indicators distributed throughout the paint.

Electrochemical impedance spectroscopy (EIS), an electrochemical technique commonly used on coated metals, is being used in this investigation. In this technique, coated metal specimens can be subjected to small-amplitude alternating potential signals of a wide frequency range. The response of coated specimens to such signals can be analyzed and used to determine parameters that are related to electrochemical kinetics (Jones, 1999). The resulting impedance behavior can be displayed in Nyquist and Bode plots. In Bode plots, the absolute value of the impedance and/or the phase angle are plotted as a function of frequency. Changes in kinetic parameters as a function of exposure can often be determined from these plots.

In many cases, the data for certain coated metals in corrosive media can be modeled using an equivalent circuit similar to the one in Fig. 1a (Mansfeld, 1995), where R_{Ω} is the uncompensated resistance between