The Use of Electrochemical Impedance Spectroscopy (EIS) to Measure The Corrosion of Metals in Contact With Wood

Samuel L. Zelinka,[1] Douglas R. Rammer[1]

[1]USDA Forest Service, Forest Products Laboratory; One Gifford Pinchot Drive; Madison, WI 53726, USA

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Abstract

Although preservative treatments prolong the life of wood, they can also contribute to the corrosion of fasteners. The corrosion of fasteners merits further study because it can affect the long-term durability of structures and fundamental knowledge of corrosion in wood is limited. The goal of this study is to determine the viability of electrochemical impedance spectroscopy (EIS) as an accelerated testing procedure for determining the corrosion rate of metals in water-saturated wood.

Problem

Waterborne preservatives, such as chromated copper arsenate (CCA) and ammoniacal copper arsenate (ACA) have been used to treat bridges, wood foundations, and other exposed wood products. While some of the preservative bonds to the wood and becomes “fixed,” a small percentage of CCA or ACA remains in ionic form in the wood. These ionic components serve to protect the wood; however, they also increase the corrosiveness of the wood environment. If the wood has not had enough time to fixate before being put into service, there are more ions present, which makes the environment even more corrosive.

Many designers are choosing to use alternatives to CCA, including ammoniacal copper quat (ACQ-B) and ammoniacal copper zinc arsenate (ACZA). Very little research has been published on the effect of these ammonia-based preservatives on the rate of corrosion, although ACQ and other new preservatives are believed to be much more corrosive than CCA since the percentage of copper in these preservatives has increased. In addition, CCA contains hexavalent chromium, which typically acts as a corrosion inhibitor. In contrast, ACQ and other new preservatives do not contain such inhibitors and some formulations of ACQ contain chlorides, which can increase the conductivity of the wood, increase the corrosion rate, and cause pitting corrosion. Unfortunately, there is no readily available procedure to quantitatively evaluate the change of corrosion rate with these alternative preservatives. Further information about the effect of new wood preservatives on corrosion as well as a review of test methods used to measure corrosion in wood was published previously [1].

State of the Art

To the authors’ knowledge, only one standard, AWPA E–12, attempts to rapidly assess the corrosion of metal in wood [2]. This standard, developed by the American Wood Preservers’ Association, accelerates corrosion through placement of a metal coupon between two pieces of preservative-treated wood. The wood/metal assembly is then placed in a conditioning chamber of 49°C ± 1°C (120°F ± 2°F) with a relative humidity of 90% ± 1% for a minimum of 240 hours. While this test gives rapid results, it is unclear how the measured corrosion rate relates to performance at ambient temperatures and humidities.

Research Objective

Electrochemical impedance spectroscopy (EIS) appears to have great promise for measuring the corrosion rate in wood [1,3,4]. The reasons for using EIS measurements are numerous. They include the ability to maintain moisture content and temperature at conditions encountered in service; to measure the corrosion rate even if the reaction is diffusion controlled; to design a cell that simulates actual fastener placement; to test preservative and fire retardant treated wood without polarizing the preservative salts; and, most importantly, to create an equivalent circuit that models the corrosion process in wood. For these reasons, EIS was investigated as an accelerated test method to determine the corrosion rate of metals in contact with wood.

The goal of the current study was to prove that EIS could indeed measure the corrosion of metals in contact with wood. Thus, only one condition was tested: untreated wood that was saturated with water.

Experimental

A schematic diagram for the EIS cell used in our experiment is shown in Figure 1. The cell was fabricated from a piece of untreated nominal 4- by 4-inch (89- by 89-mm) Southern Pine (*Pinus* spp.) lumber. Before fabrication, the wood was saturated with water in a pressure chamber. The wood was maintained in this saturated state throughout fabrication and testing. Because the alternating current caused no permanent polarization of the wood, several tests were run in the same wood sample.

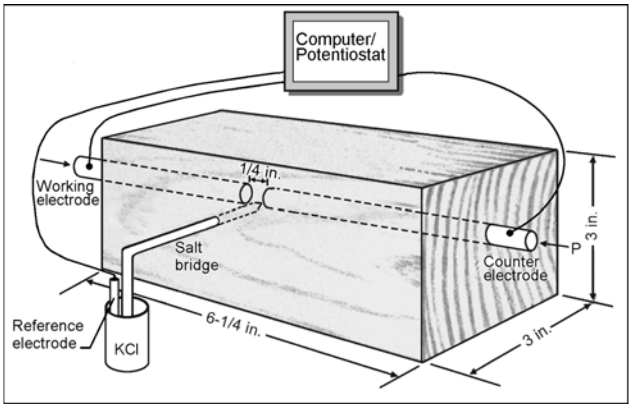

Figure 1: Visual representation of EIS experiment. 1 inch = 25.4 mm.

The working electrode was made from a plain carbon steel (UNS # G10180) rod with a diameter of 0.5 inch (12.7 mm) and was only partially exposed. The remainder of the steel rod was covered in polytetrafluoroethylene (PTFE) tape so that the surface area over which the reaction was taking place could be easily measured. The PTFE tape was held in place by polymeric heat-shrink tubing. The counter electrode was made from a 0.5-inch- (12.7-mm-) diameter graphite rod covered with PTFE tape and heat-shrink tubing. A saturated calomel electrode (SCE) was used as a reference electrode. The salt bridge was filled with a saturated potassium chloride solution. The test was run along the grain of the wood because this represents the worse-case scenario for corrosion.

The specimens were conditioned and the EIS tests run at 27°C (80°F). The tests were run with a Gamry potentiostat. The root mean square amplitude of the applied voltage was 10 mV and the range of frequencies tested was 10 mHz to 300 kHz.

Results and Conclusions

The impedance from several identical tests confirmed that repeatable data could be obtained using EIS (Figure 2). Currently, the authors are working on fitting an equivalent circuit model to the data to further understand the corrosion mechanism in wood. Once a preliminary model is generated, a larger study will commence to investigate the effects of temperature, moisture content, preservative treatments, and metals on the corrosion rate of metals in wood.

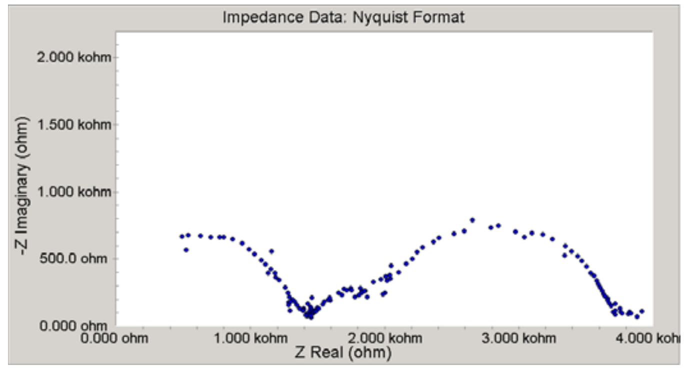

Figure 2: Nyquist plot for plain carbon steel inserted into Southern Pine saturated with water.

Acknowledgments

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