

Cosmetic Corrosion Test for Aluminum Autobody Panels: Final Report

2010-01-0726

Published
04/12/2010

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ABSTRACT

Over the past several years a task group within the SAE Automotive Corrosion and Protection (ACAP) Committee has conducted extensive on-vehicle field testing and numerous accelerated lab tests with the goal of establishing a standard accelerated test method for cosmetic corrosion evaluations of finished aluminum auto body panels. This project has been a cooperative effort with OEM, supplier, and consultant participation and was also supported in part by DOE through USAMP (AMD 309). The focus of this project has been the identification of a standardized accelerated cosmetic corrosion test that exhibits the same appearance, severity, and type of corrosion products that are exhibited on identical painted aluminum panels exposed to service relevant environments. Multi-year service relevant exposures

were conducted by mounting panels on-vehicles in multiple locations in the US and Canada. The accelerated tests have been ranked based on their relevance to the on-vehicle results and ASTM G85-A2 has been identified as the test method that most consistently replicates on-vehicle cosmetic corrosion performance. Comments concerning test reproducibility are included.

INTRODUCTION

Original Equipment Manufacturer's (OEMs) and their suppliers rely on various laboratory tests to assist in prediction of real life service performance, even though it is well recognized that many of these lab tests do not fully represent observed corrosion behavior. Part of the difficulty lies in the large number of variables in service that influence

corrosion rates and how to fully take all of these factors into account with one single test procedure. OEM's have also developed elaborate test tracks or proving ground tests in attempts to more closely simulate service conditions but in general the proving ground tests also have not correlated well with on-vehicle performance for painted aluminum [1,2,3,4,5].

In addition to variations in the real life corrosion conditions, there are also many factors in the OEM production process that influence the aluminum surface condition, chemical treatment and paint performance of a closure panel that are difficult to fully control on lab prepared panels. Despite these difficulties, the potential for time and cost savings that could be achieved by having a general agreement on a lab test capable of closely mimicking real life performance is highly desirable. Therefore, in 2000, a group of representatives from the aluminum industry, US automotive manufacturers, coating and other suppliers formed a task group within the Automotive Corrosion and Protection Committee of the Society of Automotive Engineers (SAE) to work together on identification of a test method that provides good correlation with on-vehicle cosmetic corrosion performance. Since then, a number of papers have been presented at the SAE Congress [1,2,3,4,5] to provide periodic updates on the findings of this group to the automotive corrosion community. In this report, the final results of this multi-year project are summarized.

EXPERIMENTAL

MATERIALS

The painted panels used in this program are listed in [Table 1](#). The substrate materials, metal finish and paint processing variables were selected to give a range of cosmetic corrosion performance. Several aluminum alloys used in the United States and in Europe, both current and historical, were included, with two alloys processed to simulate metal finishing in an automotive assembly plant body shop. Panels made from electro zinc coated steel and uncoated cold rolled steel were included as reference materials [6].

Two sizes of panels, 2" × 4" and 4" × 6", of each of the materials were painted with a typical automotive paint system. This paint system included zinc phosphate pretreatment, medium-build cathodic electrophoretic priming (E-coating), and spray painting with a primer surfacer and white basecoat/clear topcoat system for a total paint film thickness of approximately 100 µm. One set of 6111 panels (Panel Code B) was processed through the phosphate pretreatment with lower fluoride concentration (comparable to the fluoride level used for steel-only vehicles which results in lower phosphate coating weight). Also, since qualification testing is often done on panels that are processed only through the electrophoretic primer (E-coat) step, another set of 6111 panels (Panel Code C) was processed only through

the E-coat step (i.e., standard fluoride for Al but no basecoat or clear coat applied). Panel code C was evaluated in lab tests only (no on-vehicle or proving ground exposures).

<[table 1](#) here>

Panels were prepared as needed for testing with two parallel scribes penetrating through the coatings to the substrate. The panels were provided to the testing laboratories as fully prepared painted and scribed panels. Triplicate sets of the painted and scribed samples have been exposed in a variety of environments, including: laboratory, static outdoor exposure, proving ground, and on-vehicle exposure.

EVALUATION METHOD

For this study, an optical imaging system developed by Atlas Material Testing Technology, LLC was employed to quantitatively interpret the degree of cosmetic corrosion. The imaging system employs controlled illumination conditions, high-resolution digital image capture and advanced algorithm-based image and data analysis methodologies [6].

Four geometrical attributes of the cosmetic corrosion were measured: area of corrosion, maximum length, minimum length, and average length. The area of corrosion was found to be the most representative and comprehensive measurement. Because the size of the panels and therefore the scribe lengths for the lab tests were different from the other tests the corrosion area was normalized to the length of the scribe (i.e. area per length). The normalized corrosion areas for triplicate panels (2 scribes per panel) were then averaged and the results are reported as "normalized average area".

ON-VEHICLES EXPOSURES

It is critical when developing a laboratory based test that test-to-field correlation be performed. In an effort to capture real-world data in developing this test, it is preferable to expose these panels to severely corrosive environments that represent "worst case" real-world service environments. Suitable environments exist in the northeastern United States, southeastern coastal areas of the United States, and southeastern Canada. Two of these environments (northeastern United States and southeastern Canada) were part of this program. The sites selected for this study were: 1.) Detroit, Michigan, 2.) St. John's, Newfoundland, 3.) Montreal, Quebec and 4.) Cleveland, Ohio to Buffalo, New York truck route. Two sets of 2" × 4" test panels are exposed on each vehicle (two vehicles per site). Each set of 24 (three each of eight material variables) were attached to a mounting panel (16" × 12") using double-backed tape prior to mounting on the vehicle. At the Detroit, St. John's, and Montreal sites one set was mounted on the hood of each vehicle (horizontal orientation) and one set on the right front door of each vehicle (vertical orientation). For the Ohio-New York (OH/NY) truck route the panels were mounted beneath the trailer

frame behind the front wheels (vertical orientation only). Each panel contains 2 diagonal scribe lines which are 2" long and 1" apart. The panels were exposed for a total of 4 years of in-service exposure. Intermediate evaluations were conducted when possible.

LABORATORY TESTS

Several rounds of laboratory testing were conducted through the duration of this project [1,2,3,4,5]. All of the accelerated laboratory tests that were evaluated are listed in Table 2. After several rounds of laboratory tests and comparison of the results with results from on-vehicle exposures, the list of lab tests of interest was narrowed to the following two tests:

1. ASTM G85-A2 - Cyclic Acidified Salt Fog Test --- [8]
Test Cycle: 6 hr repetitive cycle with 3 steps/ cycle:

- 45 min. Spray
 - 2 hr. dry-air Purge
 - 3hr. + 15 min. Soak (RH gradually increases during soak)
- Test Solution: 5%NaCl acidified to pH = 2.8 - 3.0 with acetic acid
Temperature: 49°C (120°F)

2. ASTM G85-A4 - Salt/SO₂ Spray Test (Intermittent) [9]
Test Cycle: 3 hr repetitive cycle with 3 steps/cycle:

- 30 min. Spray
 - 30 min. SO₂
 - 2hr. Soak
- Test Solution: 5%NaCl acidified to pH = 2.5 - 3.2
Temperature: 35°C (95°F)

The ASTM G85-A2 test cycle was developed for use with standard water jacketed salt spray cabinets. A protocol for using automated cyclic cabinets to run this cycle has been developed to allow use of alternate equipment. If the relative humidity (RH) is properly controlled the cycle can be adequately replicated. The addition of this alternate protocol for automated equipment will be proposed as a revision to the ASTM standard.

CORROSION PRODUCT ANALYSIS

Corrosion product analysis was performed on panels A, D, G and I removed from on-vehicles in Detroit, St. John's and Montreal. In addition, the analysis of CLIMAT wire samples [10] from various locations was also conducted to evaluate atmospheric conditions in the areas where on-vehicle exposures were conducted.

Corrosion product analyses were performed using Leo 440 scanning electron microscope (SEM) equipped with a Quartz XOne energy dispersive X-ray (EDX) analysis system. The use of SEM/EDX allows not only for a measurement of the

chemical species present, but also for an analysis of the distribution of these species in and around the corroded area on the panel.

<table 2 here>

RESULTS

ON-VEHICLE EXPOSURES

Although the extent of corrosion in the on-vehicle exposures varied considerably from vehicle-to-vehicle for the various sites, panels D, G, and I typically exhibited significantly more corrosion than the other substrates, as illustrated by the images in Figure 1. The aluminum panels with metal finishing (D & G) generally have more corrosion than the other aluminum substrates, and cold rolled steel (I) has more corrosion than the electro-galvanized steel (H). Normalized average area results from on-vehicle service relevant exposures in Detroit, Montreal, St. Johns and the OH/NY Truck route are summarized in Table 3 and plotted in Figure 2.

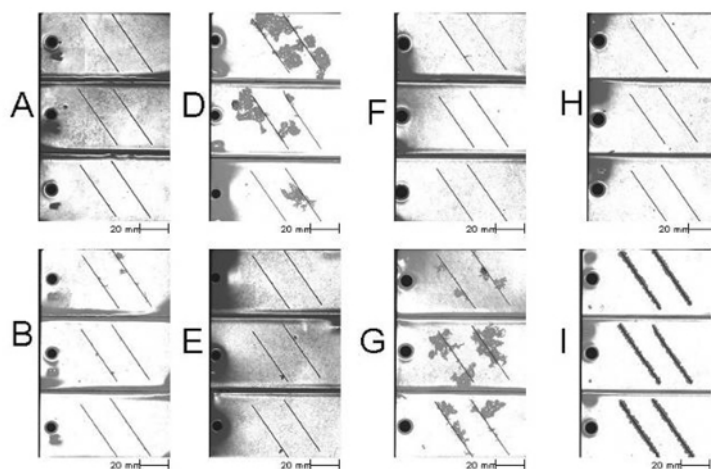


Figure 1. Images of the 3 replicate panels of each substrate from a Detroit on-vehicle exposure with ~2 years exposure.