



Analysis of

PAINTED ALUMINUM HOOD AND ASSOCIATED CORROSION AT HEM

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ALUMINUM HOOD CORROSION

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HOOD SAMPLE FROM SERVICE VIA REPAIR FACILITY

A sample from the front of a hood containing the hem, with extensive paint blistering near the hem was received for examination. The hood was an original OEM hood, which had not been repaired. The vehicle (2012 Model Year) had been in service for approximately four years in the northeastern United States, with proximity to the ocean. The repair facility obtained the sample with the intent of getting a better understanding of the corrosion mechanism.

The hood inner and outer were determined by chemical analysis to be AA6111. This alloy was in wide spread use at this time and was supplied to many OEMs. Alloy AA6111 is a mid-Cu level (0.7 wt%) alloy, with excep-

tional strength and good forming characteristics. Hence the hem is a rope hem and the outer panel does not completely flatten against the inner along the entire hem. (Section approximately 12-15mm in length perpendicular to hood outer edge.) This alloy is no longer used as a closure alloy, having been replaced by slightly less strong, much lower to Cu free alloys that are flat hemmable.

The hood appears to have been “painted” in a traditional manner with a Zn-Phosphate layer, an e-coat layer, a primer coat, a color or base coat including some metal flake, and the clear top coat. The clear coat appears to have been sprayed with 2 applications in some regions (See Figure 3). All paint layer thicknesses appear to be

FIG. 1: CROSS SECTION THROUGH HEM

Cross section depicting the hem sealant, hem adhesive and rope hem.

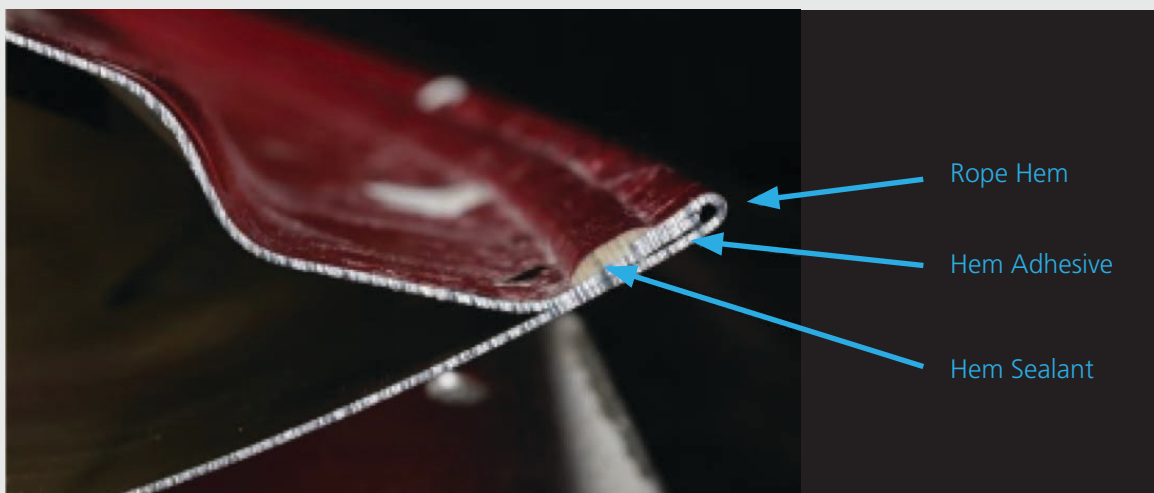
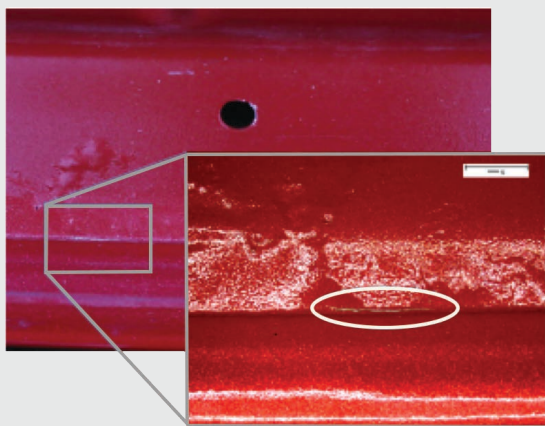


FIG. 2: PAINT BLISTER

General observations of "paint blister" at front edge of hem, hood underside.



Observation:

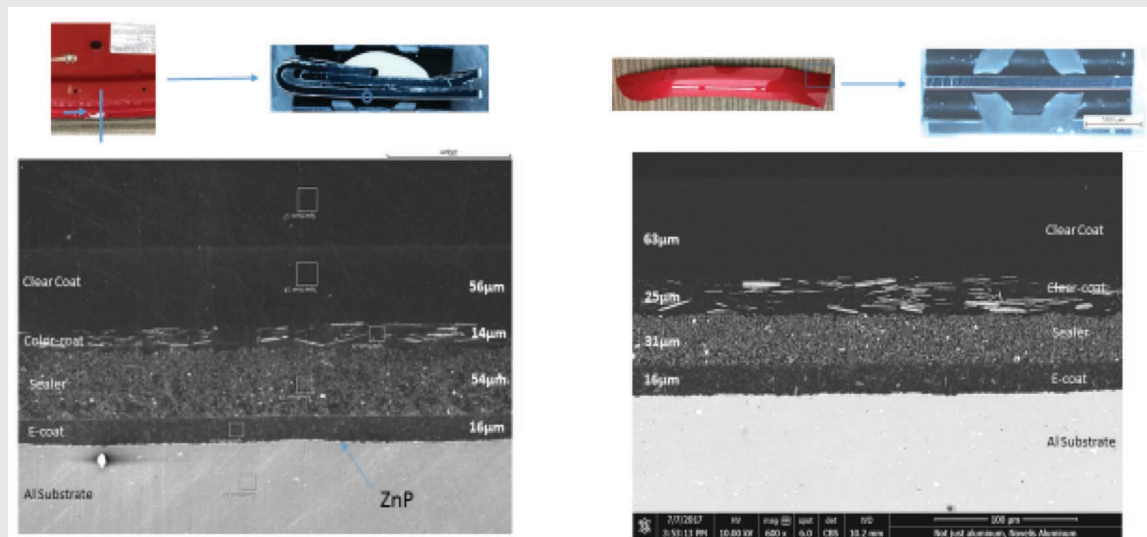
- Evidence of cracks in paint/sealant are observed in regions where corrosion is apparent under paint
- Cracks seem to appear along edge of sealant bead

typical, and some non-uniformity in paint thicknesses is to be expected. However, as depicted in Figure 4, the Zn-Phosphate coverage close to the hem edge is less complete with gaps in the surface coverage.

As shown in Figure 4, the general coverage of the ZnP applied coating is uniform and quite compact in areas away from the local hem geometry. This layer of coverage should provide excellent corrosion protection. Closer to hem detail itself, the ZnP coating becomes less uniform with gaps in the coverage. This has been previously observed on other hood samples, but the exact reason for this lack of coverage is not known. It might be difficult to get the ZnP to adequately etch and to nucleate in these regions, or the local metal working operations, leave a region with a "smeared" oxide that requires an additional degree of metal cleaning.

FIG. 3: PAINT STACK COMPARISON

Paint system layers away from hem surface.



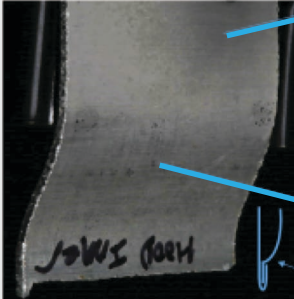
Paint Stack in affected region.

Paint Stack in region away from affected region shows a slightly thinner sealer and a thicker top coat.

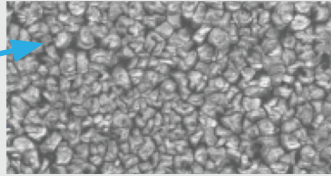
FIG. 4: ZnP UNIFORMITY

Regions of complete vs. incomplete phosphate coverage.

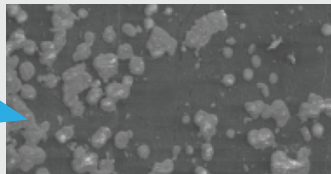
Good



Poor



Further away from hem ZnP response is acceptable.

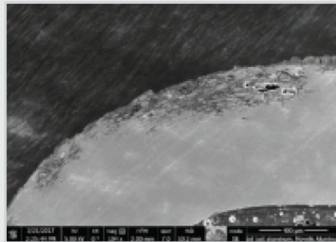


Discontinuities in the ZnP layer are found closer to the hem.

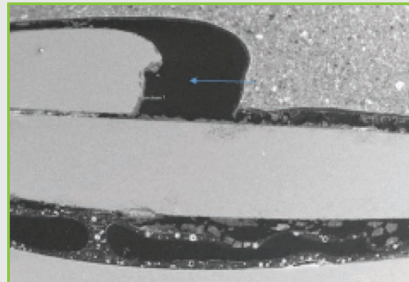
A section of the hood was removed and the paint stripped off using Bonderite S-ST 301, this has been shown to not affect the ZnP layer in the past.

FIG. 5: CROSS SECTIONS THROUGH HEM

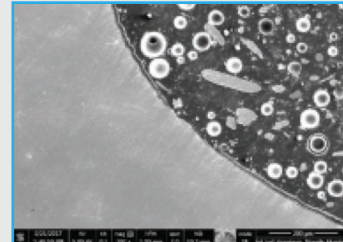
Cross section depicting the hem sealant, hem adhesive and rope hem.



Significant IGC observed in region where paint has been removed due to corrosion.



- Hem sealant bead is observed to have pulled away from the Hem
- Voids in hem adhesive are indicative of excessive moisture in the adhesion
- Delamination of hem sealant bead as well as adhesive within the hem is observed.



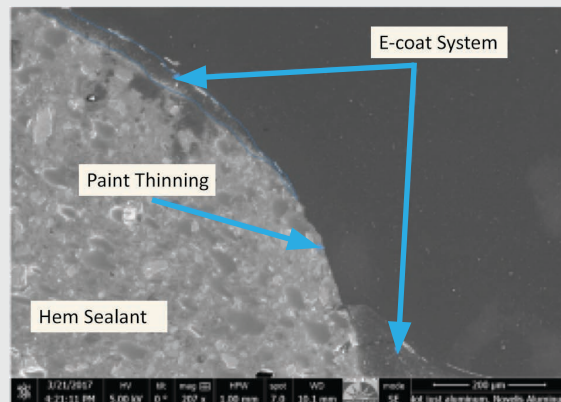
Poor adhesion of Adhesive to Hem outer is observed.

Figure 5 depicts several features that are likely to contribute to the formation of the paint blisters. In some regions the hem sealer appears to have pulled away from the edge of the outer material (center photo). Additionally, the hem adhesive appears to contain a high void content which moisture entered the adhesive prior to the cure.

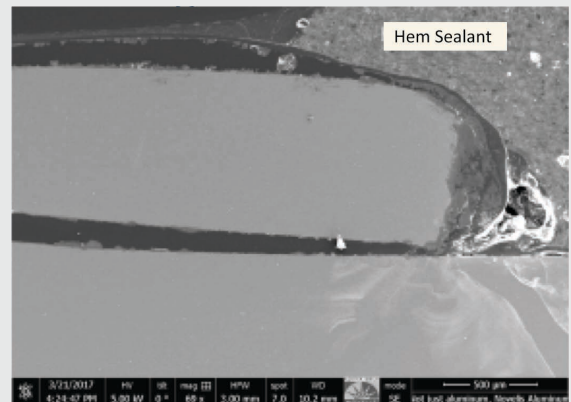
There are regions where the adhesive bonding did not adhere well to the aluminum surface. The LH photo depicts a region of intergranular corrosion which is a secondary corrosion product after the filiform corrosion front had passed "over" this region.

FIG. 6: CORROSION ONSET

Section through the hem sealant indicating presence of e-coat and delamination and onset of corrosion.



Edge of hem bead reveals thinning of paint system which may compromise the paint system integrity leading to breaches and environment ingress.



Under-film corrosion is observed undercutting the paint system and the Hem Bead is delaminated due to corrosion

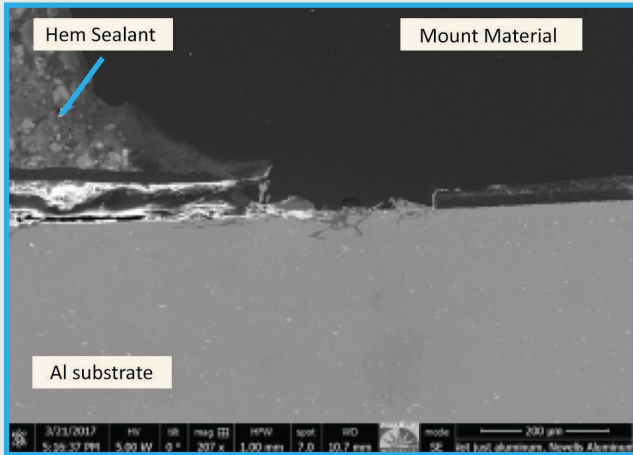
The hem adhesive appears to be more porous, containing more voids than typically observed. This could be a result of the adhesive absorbing moisture prior to the application, or a sign that the level of residual oil on the formed part exceeded the adhesive's ability to absorb. All epoxy adhesives contain fillers and toughening particles, and to a certain degree voids, but a large number of voids accelerates the rate of in-service moisture uptake. Eventually, this moisture migrates to the metal adhesive interface, which may initiate filiform corrosion. If the metal surface is well pretreated, filiform corrosion is mitigated.

A bead of hem sealer was applied. This sealer appears to have been applied during the hood assembly. Extensive corrosion has been observed under the sealer and as a result, some of the un-

derlying layers are difficult to observe. The layers on top of the sealer suggest it was applied at the assembly stage. As previously shown, there are regions where the sealer pulled away from the metal surface, and filiform corrosion is observed at the edges of the sealer. It should be noted that once filiform corrosion has been initiated at the various defects, such as under the hem sealer, it may grow away from this initiation site and under the paint layers. The lack of ZnP or e-coat under the hem sealer, places all corrosion preventative measures to be provided by: the quality of the hem sealer, the cleanliness of the underlying metal, and the uniformity and integrity of the sealer application. This particular example appears to suggest the sealer was unable to provide the necessary level of protection to the underlying metal.

FIG. 7: CORROSION PROPAGATION

Depicts corrosion propagating under the hem sealant, with associated secondary corrosion.



Breach in paint system and under hem sealant leads to undercutting, IGC, as well as delamination due to corrosion is seen.

FIG. 8: OPTICAL CROSS SECTION ANALYSIS

Initiation of corrosion at hem sealant "front edge."

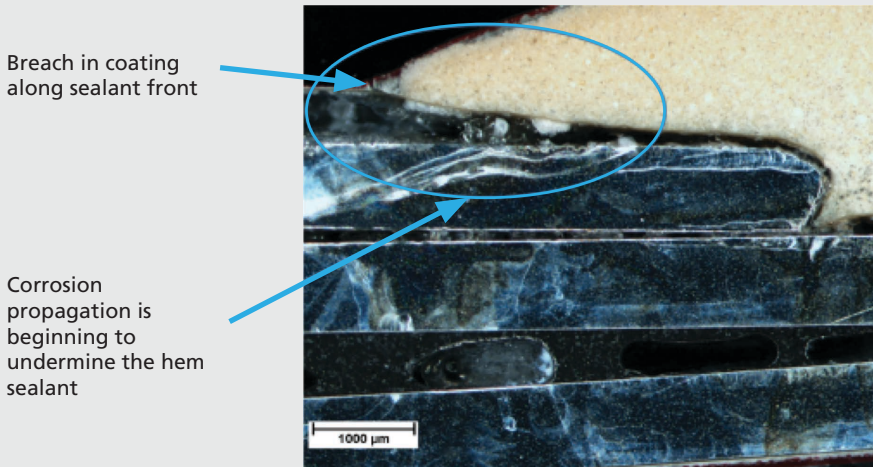
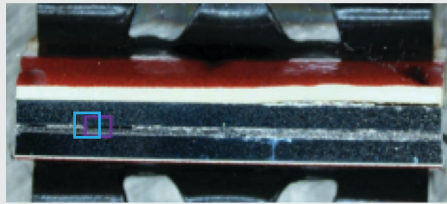
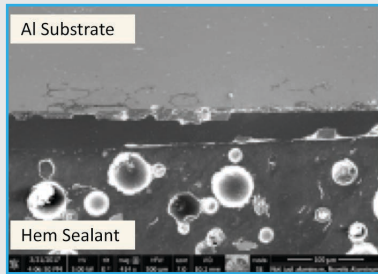


FIG. 9: PARALLEL SECTION

Depicting filiform corrosion migrating under the hem adhesive.

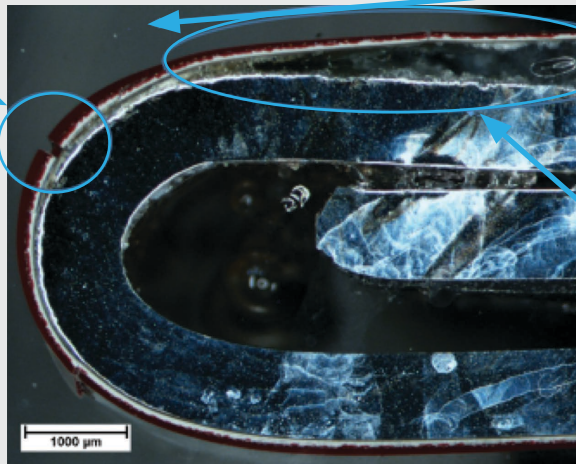


Delamination of hem adhesive is observed accompanied by evidence of IGC and residual corrosion product.

FIG. 10: OPTICAL CROSS SECTION ANALYSIS

Advanced stages of filiform corrosion migrating to hood outer surface.

Crack in coating most likely a result of the corrosion propagation around the hem.



Corrosion appears to propagate from sealant bead.

Coating delamination with corrosion product.

SUMMARY

Filiform corrosion is observed under the hem sealant and at the adhesive interface, propagating away from these initiation sites under the adjacent paint layers. Gaps in the hem sealant, porosity in the hem adhesive, and non-uniform coverage in the ZnP layer adjacent to the hem have been observed. Various forms of secondary corrosion have also been observed that are a result of corrosion occurring after the filiform "front" has passed over the metal surface at the interface between the ZnP to metal surface.

The source of the paint blisters, which are a manifestation of the filiform corrosion, likely started first at the hem sealant "edge" and then migrated into the hem. Once the filiform corrosion was initiated and allowed for the ingress of water/electrolyte additional filiform corrosion events likely began. It is certainly possible that many of these filiform corrosion events began almost simultaneously as the water ingress proceeded under the hem sealant. The porosity of the adhesive and the non-coherent ZnP layer adjacent to the hem probably contributed to the rapid "spread" of the filiform corrosion event(s).

Corrosion, once initiated from a paint defect or hem sealant edge, can either be arrested by the pretreatment layers or, if the pretreatment and surface conditions are not robust, transition to filiform corrosion and migrate under the paint layers. Effective prevention usually requires that the corrosion initiation events are minimized or delayed; though in practical terms, it is very difficult to eliminate all initiation sites. The rate of filiform corrosion is mitigated with a strong paint to surface interface which causes the growth rate to become insignificant.

OEMs have recognized that the overall hem conditions need to be more robust with regards to corrosion. Newer, more appropriate alloys have been introduced and the hem geometry has

been significantly tightened to reduce movement and water ingress. Newer pretreatments have also been introduced and improved testing conditions are under development, which should improve the overall susceptibility. With such a multifaceted engineering problem, additional samples should be obtained to quantify the effectiveness of the corrosion preventative measures.

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