Naumuk 6061-T6 Corrosion Problem


Image courtesy of B. Naumuk

Original Post from Matronics Zenith List:

> Z-Builders-
> For all of you touting the corrosion resistant qualities of T-6, look at the attached picture. This is the only original skin I still have- I keep it around to make L angle out of. The T-6 picture was taken in the garanger, "Other stuff" was taken in the basement. Not exactly severe conditions.
> My skins were stored standing upright against the panelled walls of my basement (Where a dehumidifier was running 24/7) in their paper wrapping. When was ready to install them, this is what I found when I unwrapped them. Consequently, I literally had to rebuild 75% of my factory supplied parts from scratch. And yes, the factory T-6 marks are on all the bad skins.
> Bill Naumuk
> Townville, Pa.
> HDS 601MG/Corvair 95%

http://forums.matronics.com/viewtopic.php?t=50611

Introduction

Bill was kind enough to cut off a small piece of the skin shown above and send it to me. I have degrees in materials engineering but I'm not an expert on corrosion. However, I thought that doing some basic characterization of the corroded parts might shed some light on this problem. I simply did what I would normally do when presented with a material-related problem I don't fully understand – characterize the sample, produce some data, and hope someone smarter than me can make sense of it all. What follows is an informal report of the results. At the end, I offer my opinion as to what caused the issue, how to prevent it, and risk associated with using parts that suffer similar attack. I welcome any additional comments or criticism others may have related to this corrosion issue and can be contacted at bcchurch(at)yahoo.com.

Disclaimer

Remember these are my opinions. I provide this information for entertainment and educational purposes only. Please do not use these data for anything that may impact your safety or the safety of others. I do not guarantee the accuracy or applicability of the information presented here. I assume no liability for this work or how you choose to use/interpret the content. I'm disheartened that I must include these statements. This information can be freely shared with others as long as 1) it is transmitted in its entirety, 2) I'm credited with the work, and 3) no monetary profit is gained in any way by anyone (including me). Please see the general conditions outlined in the creative commons license by clicking on the icon below.

Regards,
Ben Church

Sample: 6061-T6 sheet, 0.025"
Stored in dehumidified basement in contact with kraft paper on one side. I assume the sheet was in contact with a second sheet of aluminum on the rear side.

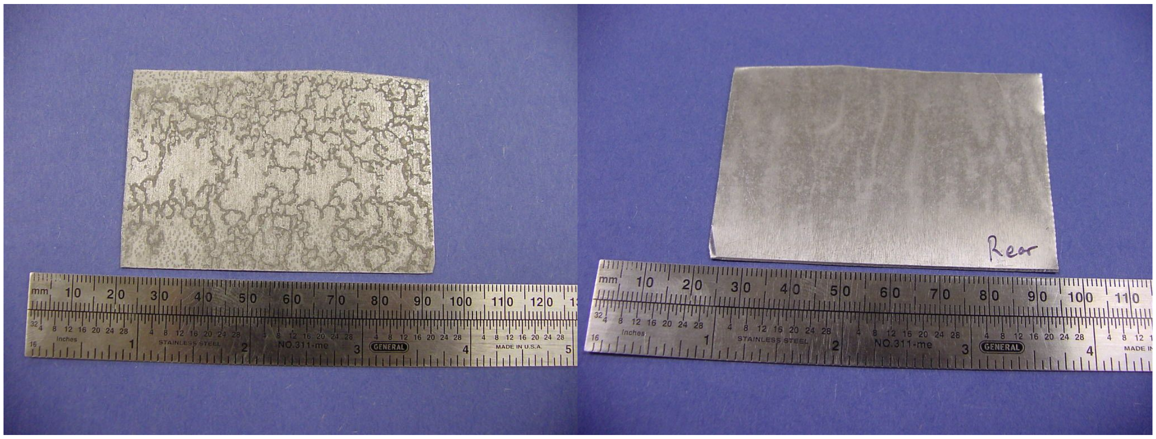


Figure 1: Front side: in contact with paper. Rear side: in contact with aluminum sheet.

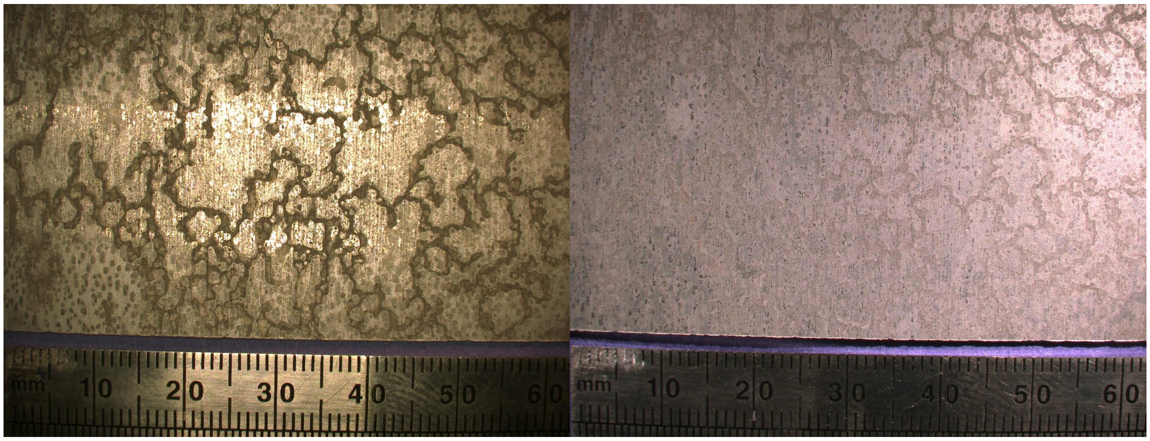


Figure 2: Close-up views of the front side with different lighting.

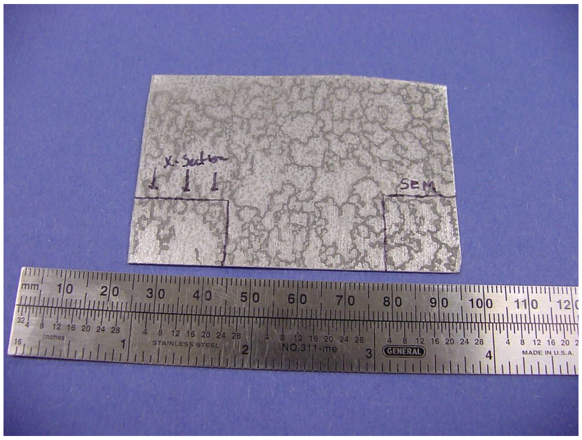


Figure 3: Two sections were removed from the sheet as indicated. The "x-section" portion was mounted in epoxy and polished to show the cross-section. The "SEM" portion was used for surface analysis in the scanning electron microscope.

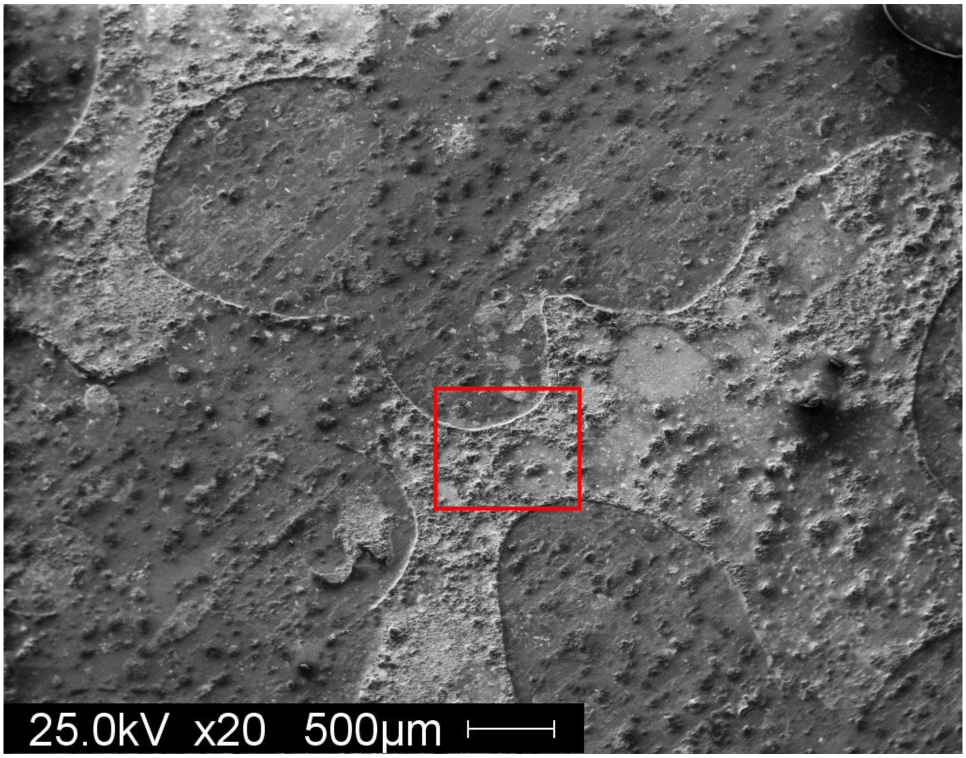


Figure 4: SEM view of the surface showing the areas of corrosion.

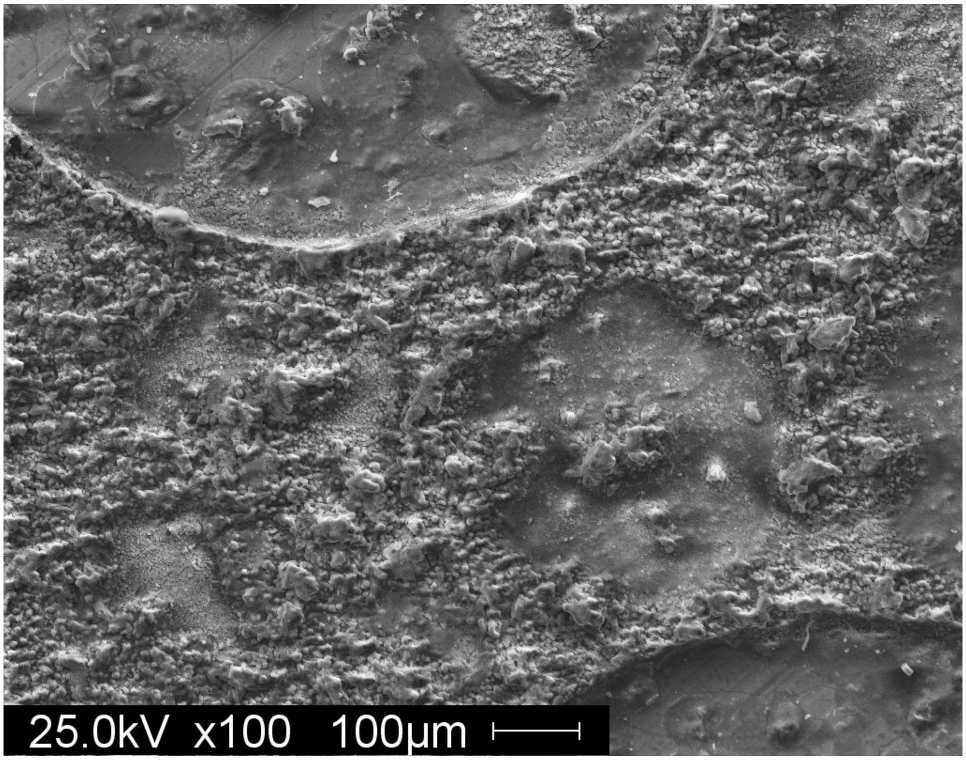


Figure 5: Enlarged view of the corrosion product shown in Figure 4.

Note: The information blocks in each image indicate, from left to right, a) accelerating voltage of the SEM (25,000 volts), magnification of the microscope at the time the image was captured, a “micron marker” in units of micrometers (25 microns is about 0.001”) used to show relative size of features in the image.

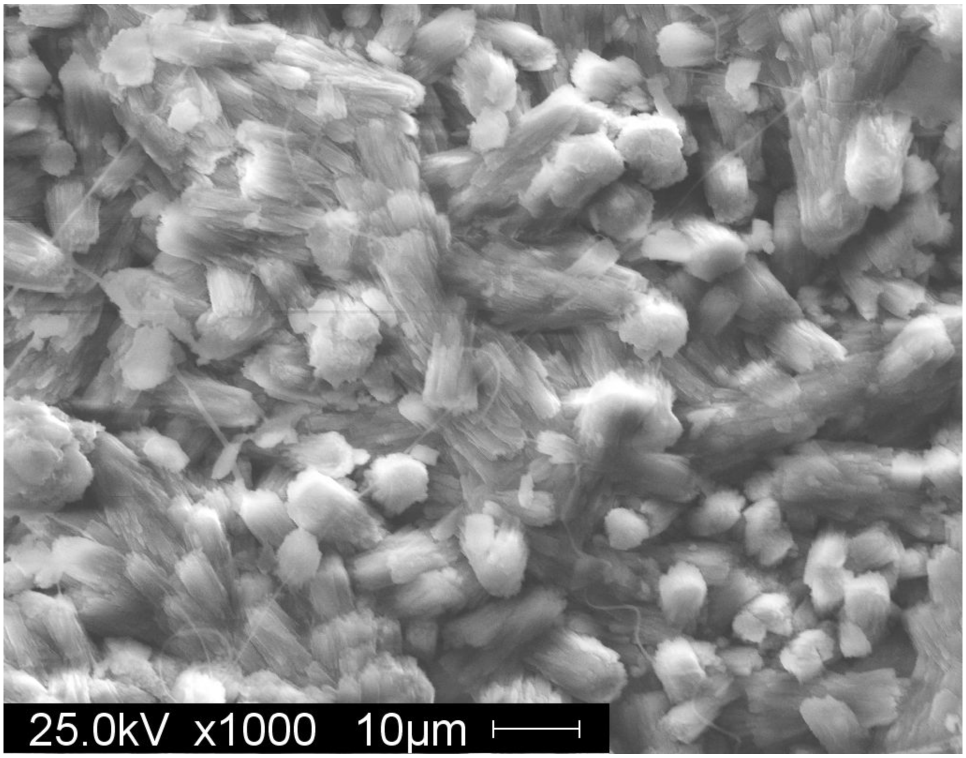


Figure 6: Corrosion product.

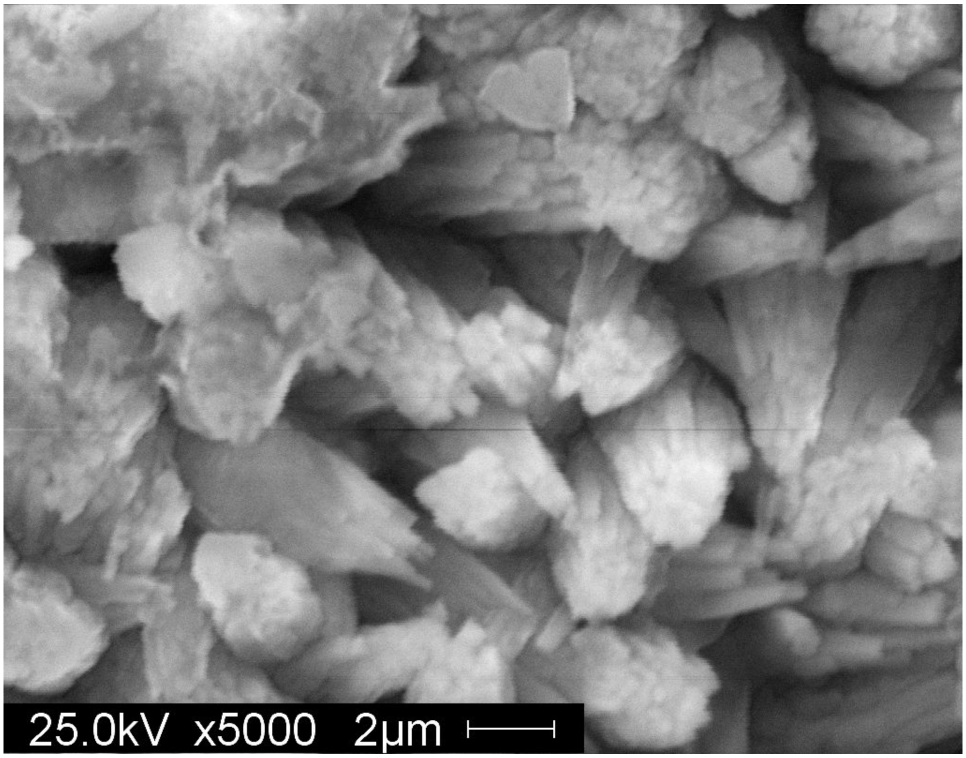
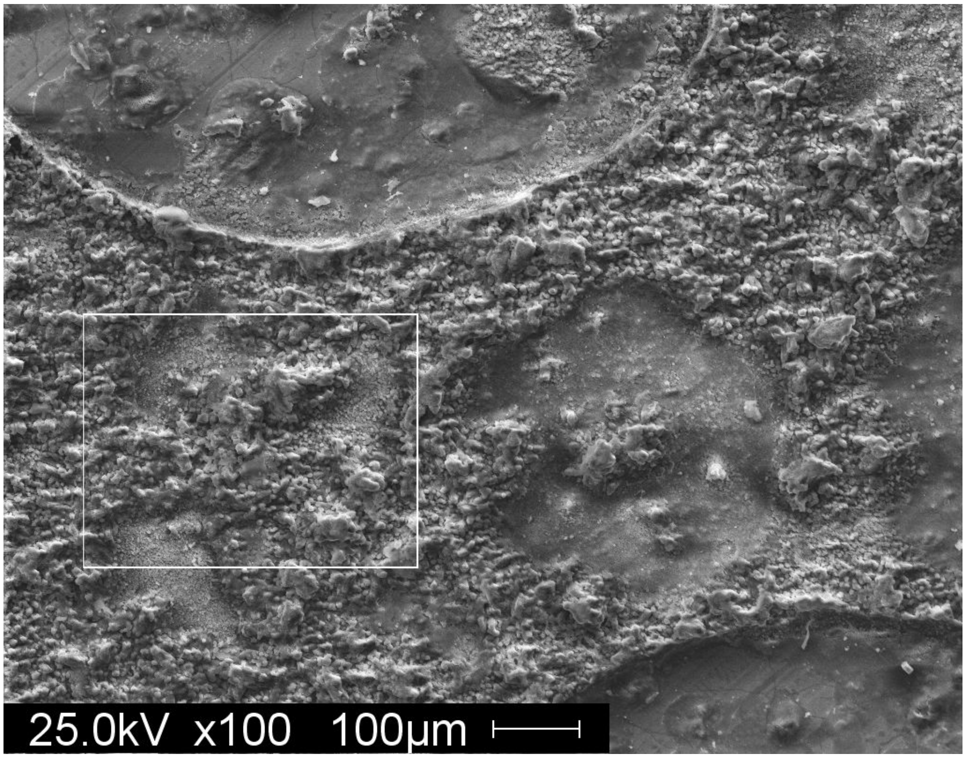


Figure 7: Close-up view of the corrosion product.



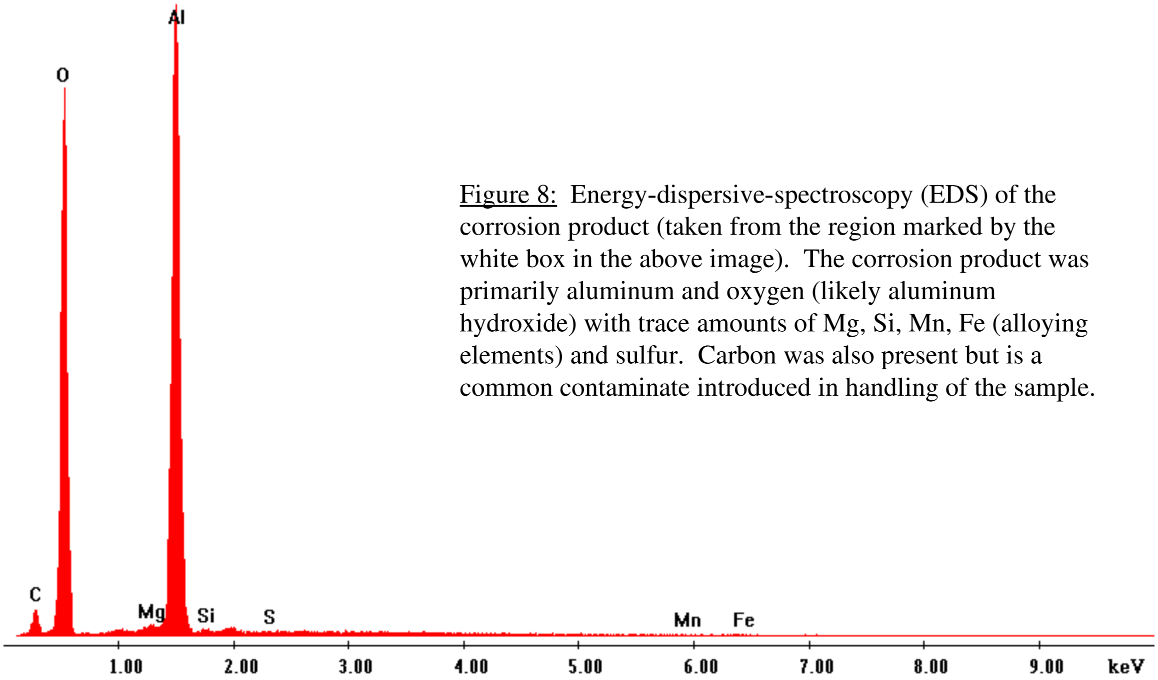
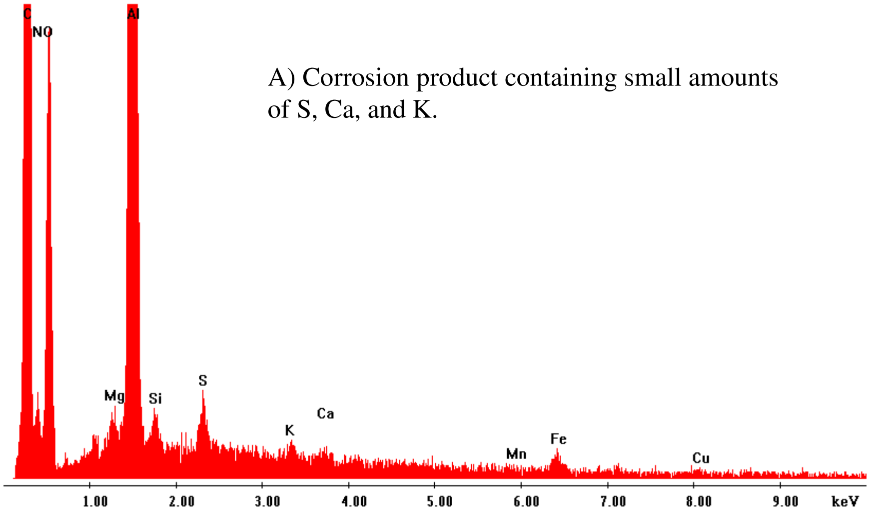
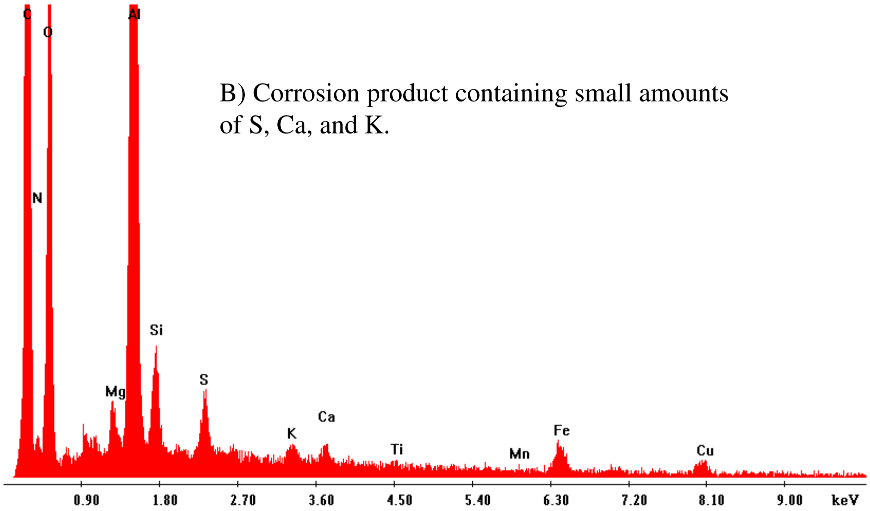


Figure 8: Energy-dispersive-spectroscopy (EDS) of the corrosion product (taken from the region marked by the white box in the above image). The corrosion product was primarily aluminum and oxygen (likely aluminum hydroxide) with trace amounts of Mg, Si, Mn, Fe (alloying elements) and sulfur. Carbon was also present but is a common contaminate introduced in handling of the sample.

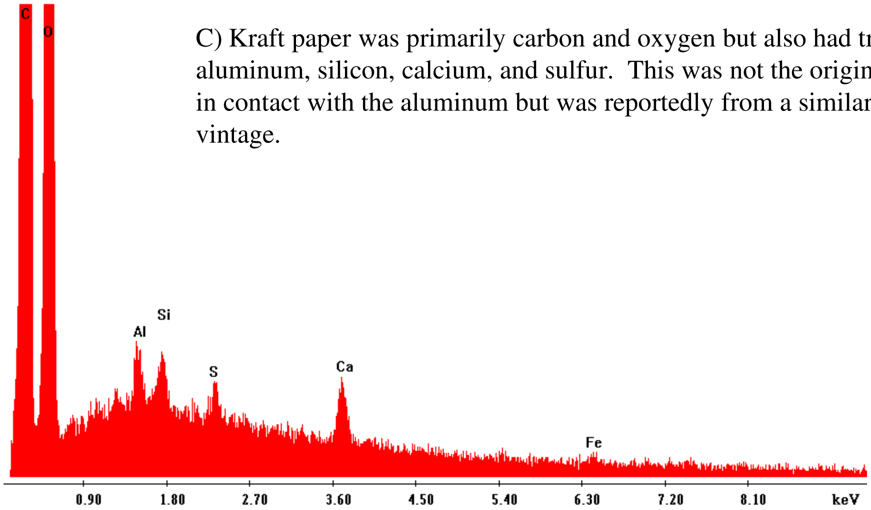
Note: More information on energy dispersive spectroscopy can be found here. In a nut-shell: each element has characteristic peaks. The higher the peak intensity, the higher the concentration of that element. EDS can not detect elements lighter than boron.



A) Corrosion product containing small amounts of S, Ca, and K.



B) Corrosion product containing small amounts of S, Ca, and K.



C) Kraft paper was primarily carbon and oxygen but also had traces of aluminum, silicon, calcium, and sulfur. This was not the original paper in contact with the aluminum but was reportedly from a similar vintage.

Figure 9: EDS patterns collected at several locations in the corrosion product. Some areas contained traces of sulfur, potassium, and calcium (in addition to the expected alloying ingredients).

A spectrum was collected from the kraft paper (bottom) which contained traces of calcium and sulfur.

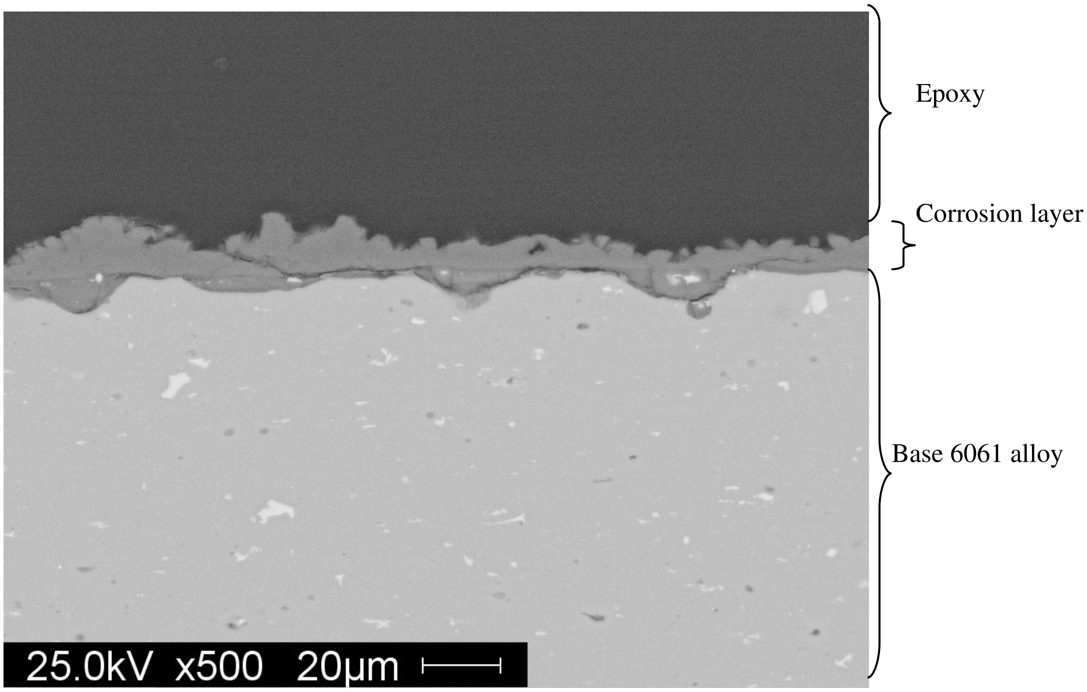


Figure 10: Cross-sectional view of the corrosion. Minor pitting extended ~10 microns into the aluminum. This image shows the most severe pitting / corrosion in the cross-section removed from the coupon. However, only one cross-section was taken and so it's likely that more severe attack could be found at other locations.

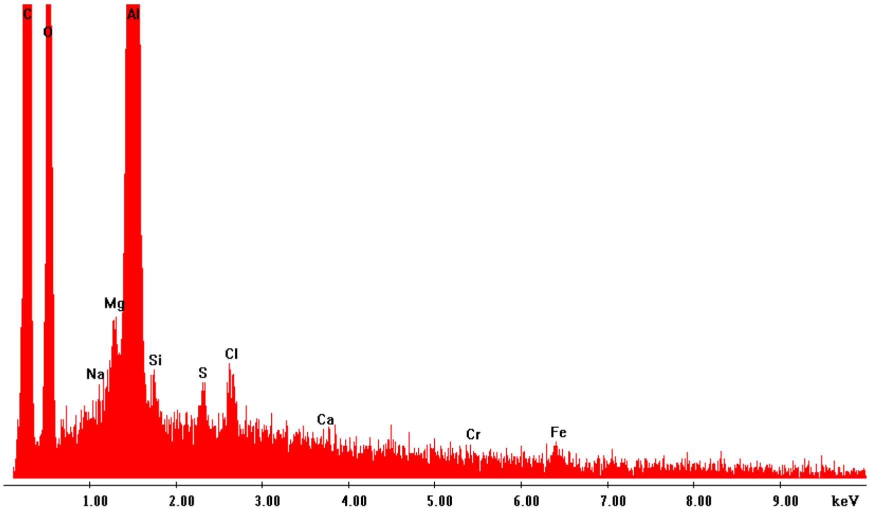


Figure 11: EDS spectrum taken from the corrosion layer shown above. Note the presence of sulfur and chlorine. Chromium and sodium, although labeled, were not present to any significant amount.

Discussion

So what does this all mean? The general appearance of the corrosion does not follow traditional filaform attack or common pitting attack from a contaminant. The pattern of the corrosion seems to indicate that water or moisture played a significant role. Although the parts were stored in a dehumidified area, it's still possible that water came into contact with the sheets at some point. For example, if the parts were originally stored outside and were relatively cold, bringing them inside to a warm (and more humid) area could cause condensation to accumulate on the surface. Kraft paper can easily serve as a condensation point and initiate condensation when otherwise it may not occur. Or, the sheets could have been exposed to water / condensation during shipping.

The majority of the corrosion product was aluminum and oxygen. This is typical of corrosion that occurs in the presence of humidity or water. Unfortunately, the SEM can not detect hydrogen so I can't differentiate between aluminum oxide and aluminum hydroxide. But, based on my (limited) experience with other corrosion failures, I believe this to be a hydroxide which indicates moisture / water based attack. The fact the sheets were stored in a dehumidified area suggests that the initial exposure to moisture occurred prior to the sheets being stored. But, once the corrosion starts, it would continue (slowly) even when moved to the dehumidified area.

The presence of sulfur and calcium in the corrosion product as well as the kraft paper suggests the two are connected. Calcium would not be detrimental to the aluminum but the sulfur does have the potential for initiating corrosion. That being said, water alone can cause problems if it accumulates in a crevice or other isolated location. The addition of sulfur would be an added accelerant. Chlorine was also found in the corrosion product and the source of that is not clear but could be from the use to cleaning products (laundry bleach, etc) nearby. The amount of chlorine was minor and only found in the cross-section so I think that was a minor factor. I did not find any significant amounts of other potential "bad actors" like particulates of copper, significant levels of chlorine / fluorine / nitrogen, particles of iron, etc. The source of potassium in the corrosion product is unclear.

Prevention of corrosion like this would hinge on eliminating humidity, temperature changes, and moisture. Separating individual sheets and increasing air circulation would help to eliminate the potential for condensation to occur in a crevice (between sheets). Taking sheets out of the kraft paper would eliminate sulfur from transferring to the aluminum if some moisture did form. In the extreme, one could apply Corrosion X or other spray inhibitors on the individual skins but in my opinion this is rather unnecessary if the skins are stored individually and with good air circulation.

Use of skins showing this type of corrosion should be avoided in structural applications subjected to fatigue. The pits that formed only penetrated about 10 microns (~0.0005 inches, or ~2% of the sheet thickness). This would not significantly reduce the load capacity of the sheet but could a) reduce ductility / elongation or b) act as a crack nucleation site for fatigue. I would not hesitate to use the sheet in non-structural applications. If the corrosion was removed and the surface sanded, I would consider using the material for reinforcements (like standard L's) with the understanding that the thickness of the sheet has been reduced.

For cleaning of skins such as this, I would use a combination of wet-sanding with 600 grit SiC paper followed by alumiprep / maroon scotchbrite. SiC paper can cause corrosion of the aluminum – which is why I would follow the SiC paper with the alumiprep and scotchbrite which would loosen and remove any residual SiC particles that became embedded in the aluminum.

- Ben Church