# Chapter 4 – CORROSION MORPHOLOGY: DOCUMENTING CORROSION

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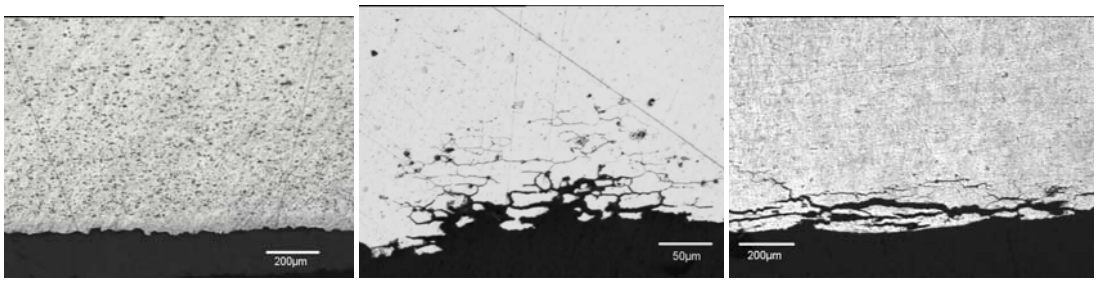
## 4.1 INTRODUCTION

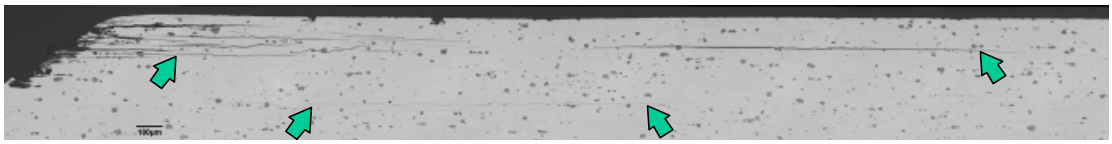
Since corrosion can evolve from initial discontinuity states (e.g., constituent particles) present within metallic materials, these modified states have to be taken into account when carrying out a structural life assessment since they can affect both crack nucleation and growth. Therefore, it is necessary to carry out a damage characterization on naturally corroded components. Thus once a corroded aircraft component is disassembled and the corrosion products removed (depending on the type of corrosion), the damage that is present can be determined using a number of different techniques; optical microscopy, laser scanning confocal microscopy, scanning electron microscopy and x-ray. This section reviews the methods typically used in this characterization work and illustrates the type of information that can be obtained.

## 4.2 OPTICAL METHODS

The only technique that is capable of characterizing the different damage states present for all types of corrosion (pitting, exfoliation, intergranular, etc.) is optical microscopy [1],[2]. To document the damage, sections should be taken from the affected areas, cold mounted and progressively polished using standard metallurgical practices, examples of which are shown in Figure 4-1. It is essential to mount the sections for polishing using a cold resin in order not to affect the corrosion damage.




**(a) Images from naturally corroded 2024-T3 fuselage lap joints.**



**(b) Image from exfoliated 7178-T6 upper wing skins.**

**Figure 4-1: Optical Micrographs Showing the Modified Discontinuity States from Naturally Corroded Components that were Progressively Polished.**

From this type of study, the growth of different types of damage can be estimated, which could then be used to more accurately predict the life of components that are susceptible to corrosion. For example, a damage characterization study was carried out on corroded lap joints in which sections were taken and progressively polished [1]. From the different images, corrosion pit sizes were measured taking into account the presence of intergranular attack. The results, shown in Figure 4-2, indicated that as the thickness loss increased the pit shape tended to become elongated (shallow but long). As can be seen from this figure, as the thickness loss increased, the pit shapes tended to take on a high aspect ratio, shallow but long. The exception to this trend was the pits that were present at the base of environmentally assisted cracks, which occurred in the presence of a sustained stress, $EAC_{ss}$, and have been referred to as pillowing cracks. Previous studies have shown that these cracks usually occurred in areas where the thickness loss was small and only a small pit was present at the faying surfaces. Since the material thinning was high in the area examined during this study, it is assumed that these large pits developed over time after the environmentally assisted crack had nucleated.

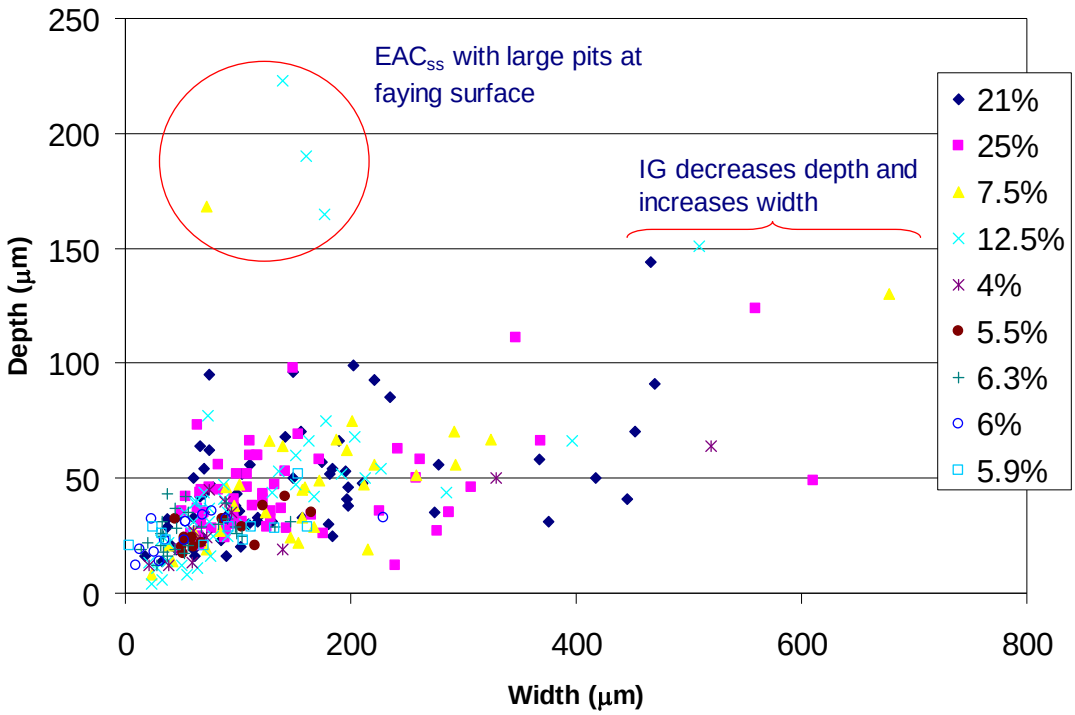
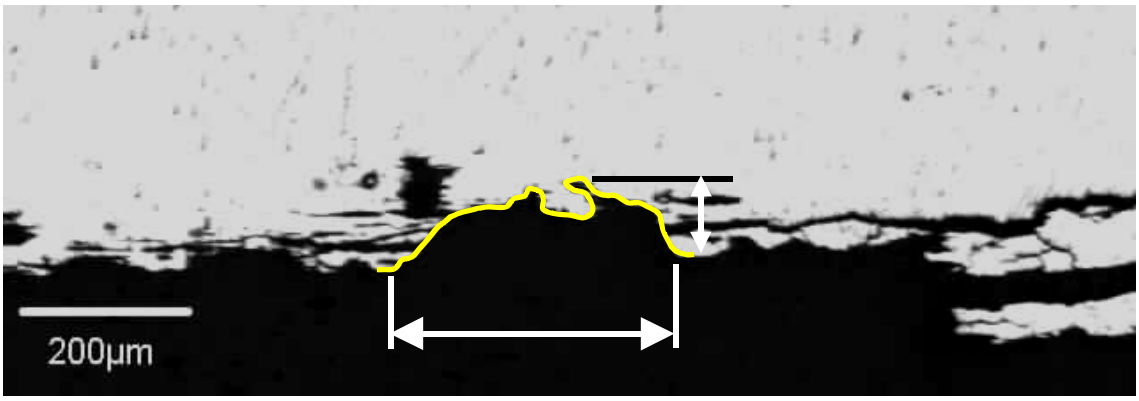
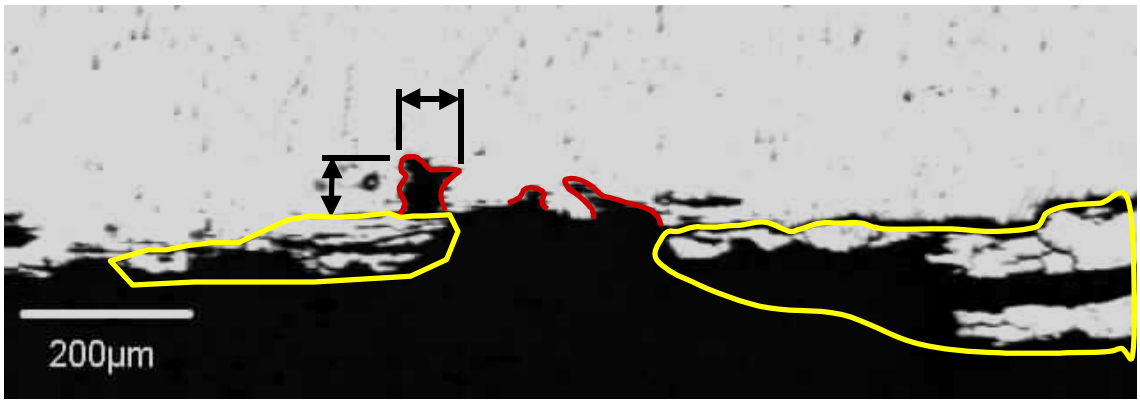



**Figure 4-2: Corrosion Pit Sizes Measurements from Optical Micrographs of Naturally Corroded Components Progressively Polished.**

The other microscopic techniques, laser scanning confocal microscopy and scanning electron microscopy are capable of determining small changes in the surface topography. However one disadvantage to using these techniques is that the damage that is present must be on a direct line of sight in order to measure its size, which means intergranular cracking or corrosion cannot be detected. This type of cracking must be taken into account since the material affected by it is incapable of carrying any stress. Therefore this material would not have an influence on any pits in the immediate vicinity of the intergranular cracking and thus the stress concentration at the base of each pit would be lower than if the material surrounding the pit was undamaged. For example, as can be seen from Figure 4-3, if the intergranular crack is not taken into account the pit width and depth would be 346 μm (0.0136 inch) and 159 μm (0.00626 inch), respectively. However, the presence of the intergranular crack would increase the number of pits from one to three and the dimensions of the largest of these "new" pits would be 74 μm (0.00291 inch) wide and 64 μm (0.00252 inch) deep, which is a significant decrease. This decrease would tend to delay the onset of cracking by reducing the stress concentration at the base of the pit.




**(a)**

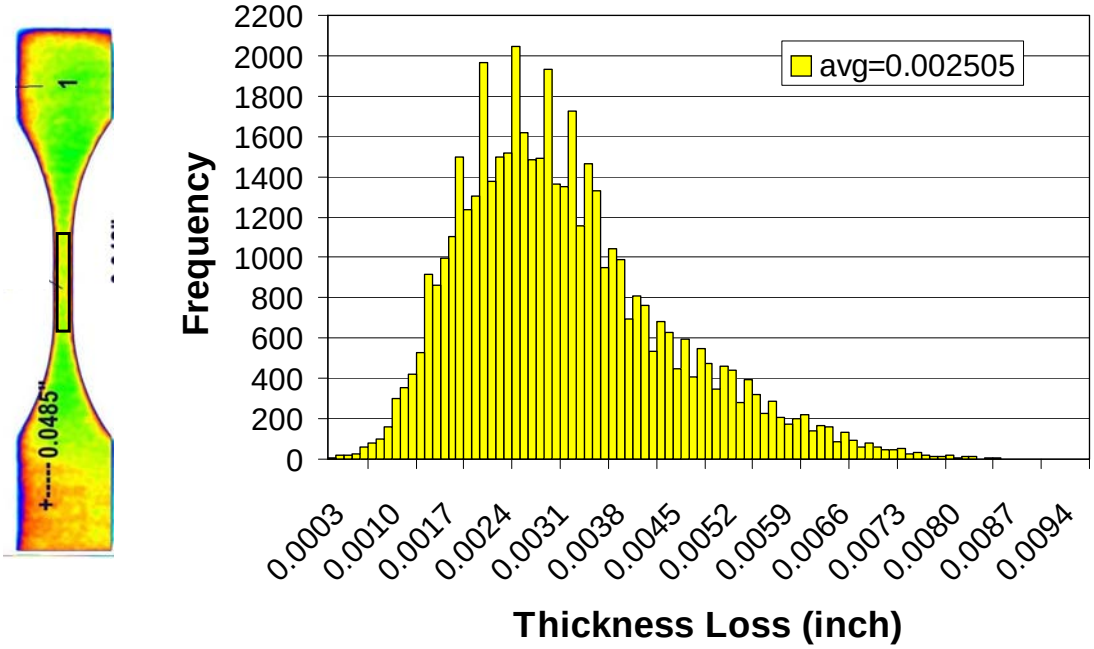



**(b)**

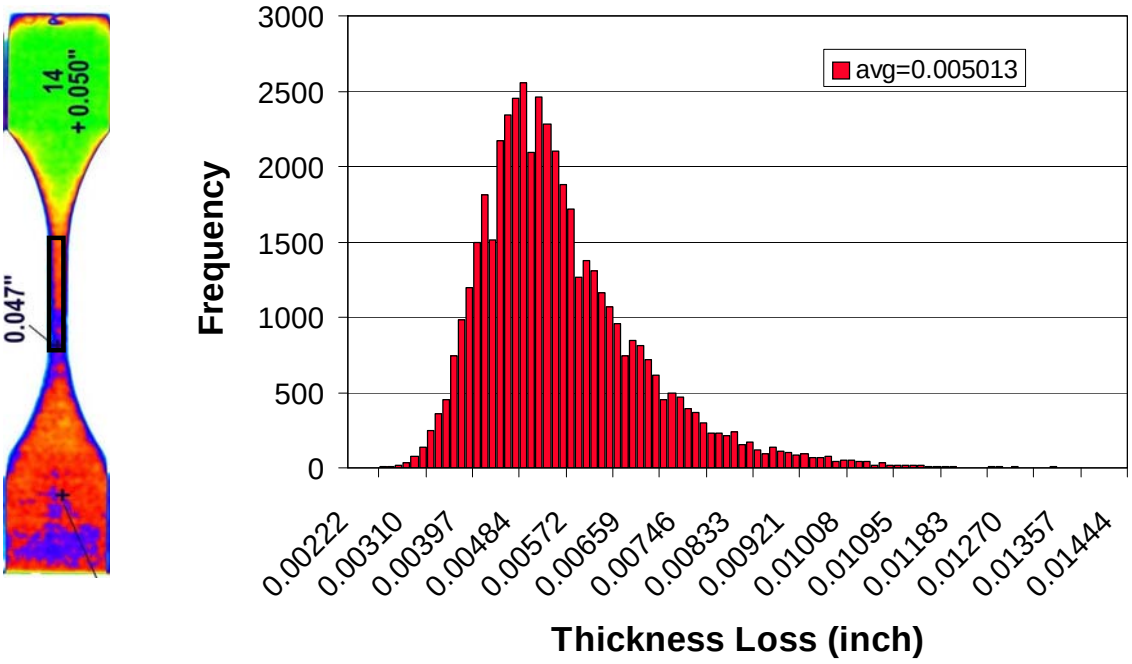
**Figure 4-3: Difference in Pit Depth and Width Due to Presence of Intergranular Cracks – (a) Shape of pit if intergranular cracks ignored (pit shape determined by laser scanning confocal); (b) Shape of pits when intergranular cracks are taken into account (assume the material circled has been removed either by flaking or dissolution).**

## 4.3 X-RAY CHARACTERIZATION

The final technique, x-ray, can only be used to document the surface topography and thickness loss associated with corrosion pitting. By using the cleaning process mentioned above to ensure that the corrosion products are removed from the pits in the affected areas, x-ray techniques can accurately document the surface topography present. After digitizing the radiographs and with the aid of the appropriate software, the average and maximum thickness loss can be determined in the affected area as well as the pit distribution, as shown in Figure 4-4. From these types of plots, trends can be determined for the mode of pit growth. For example, the pit distributions shown in Figure 4-4, obtained from 2024-T3 corroded lap joints, demonstrate that as the average thickness loss within an aluminum skin increases, the scatter in pit size decreases, indicating that the pit shape becomes more uniform.




**(a) Average thickness loss on gauge length of 4.85% in a 0.0516 inch thick skin.**




**(b) Average thickness loss on gauge length of 7.60% in a 0.0516 inch thick skin.**

**Figure 4-4: Histogram Plot of Thickness Loss of Different Coupons.**

## 4.4 REFERENCES

[1] Bellinger, N.C., Forsyth, D.S. and Komorowski, J.P., "Damage Characterization of Corroded 2024-T3 Fuselage Lap Joints", Proceedings of the 5th Joint NASA/FAA/DoD Conference on Aging Aircraft, Kissimmee, FL, USA, 10-13 September 2001.

[2] Bellinger, N.C., Komorowski, J.P., Liao, M., Carmody, D., Foland, T. and Peeler, D., "Preliminary Study into the Effect of Exfoliation Corrosion on Aircraft Structural Integrity", Proceedings of 6th Joint FAA/DoD/NASA Conference on Aging Aircraft, San Francisco, CA, USA, 16-19 September 2002.