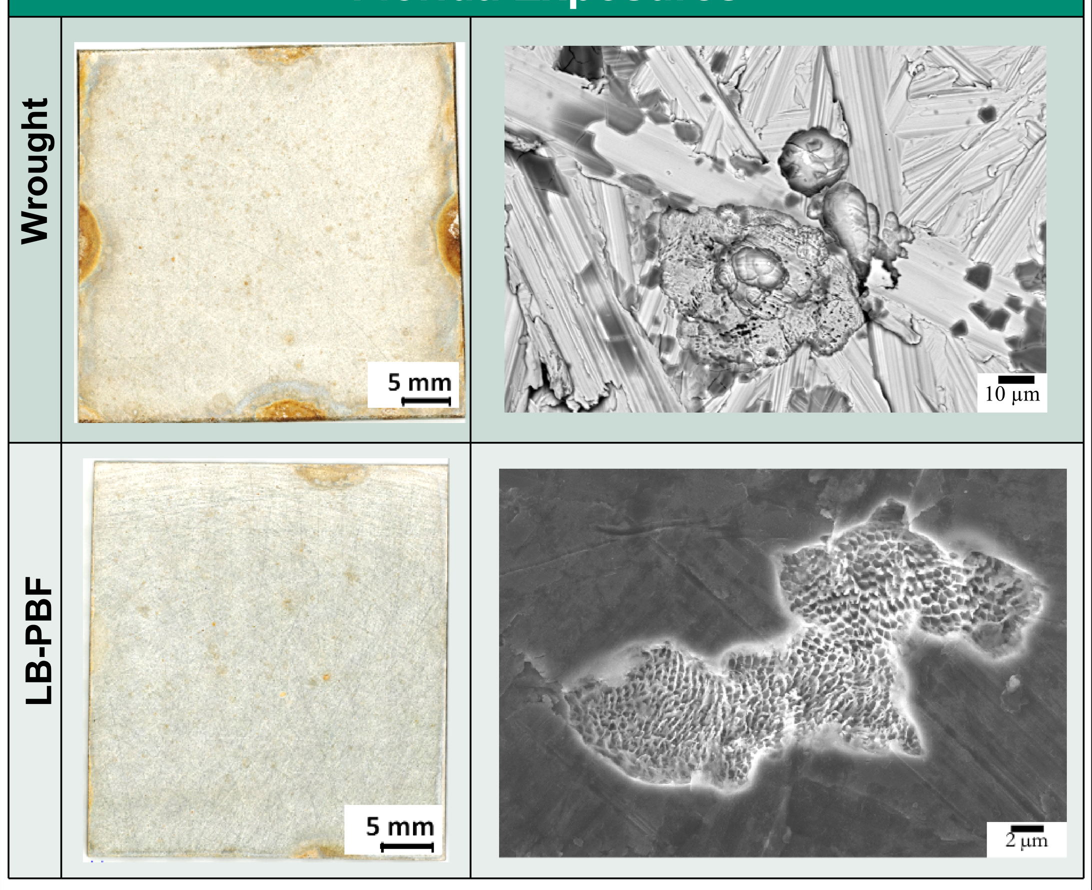
Sandia National Laboratories

Impact of Relative Humidity and Salt Loading Densities on the Localized Corrosion Behavior of Additively Manufactured and Wrought Stainless Steels

Kasandra

Background

Pit morphologies for wrought and LB-PBF Florida Exposures



Wrought stainless steels have been developed to exhibit good general corrosion resistance. When exposed to chloride containing environments, such as marine environments, they become susceptible to localized corrosion. The differences in local corrosion responses for wrought and additively manufactured Laser Beam Powder Bed Fusion (LB-PBF) stainless steels were highlighted in a study performed off the coast of Florida, as seen to the left[1]. Using laboratory tests, we hope to accelerate the process to help rapidly assess local corrosion susceptibility of wrought and LB-PBF 316L stainless steels.

Objectives

- To quantify the pitting damage found on wrought and LB-PBF 316L stainless steel after exposure to constant relative humidity (RH) and artificial sea water (ASW) contamination environments.
- Answer the question: can we accelerate the corrosion process with the constant RH and salt loading environments, relative to a real-world environment, while maintaining and mimicking the pitting mechanism/morphology.

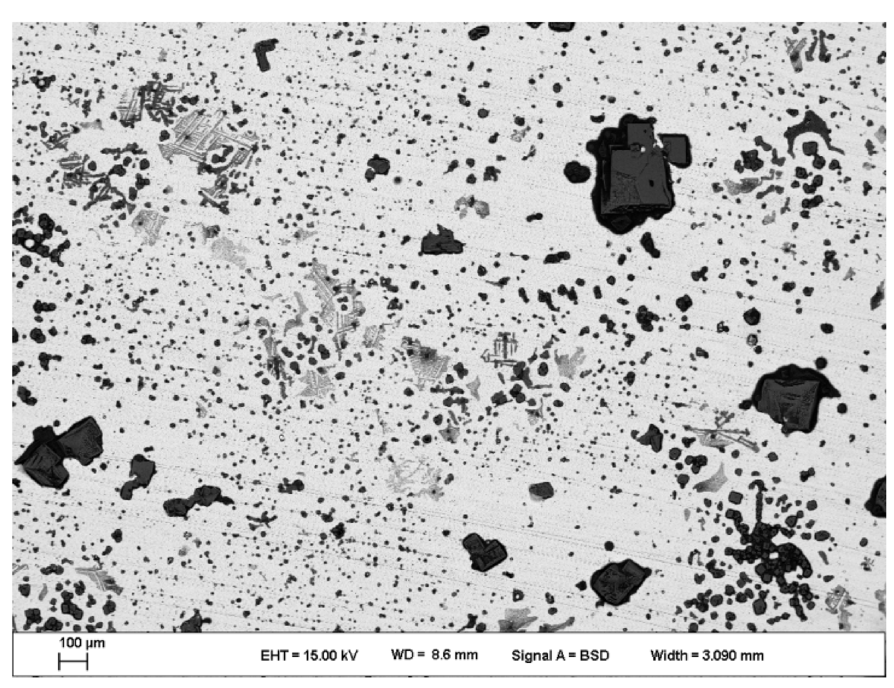
Exposure Conditions/ Experimental Setup

Coupons printed on a Renishaw AM 250 system under an Argon cover gas with a 1070 nm wavelength and 70 µm Yb fiber laser. The scan hatch distance was set to 85 µm with a layer thickness of 50 µm and scans were patterned in the "stripes" build mode. The scanning velocity was 750 mm/s and the laser power was 200 W.

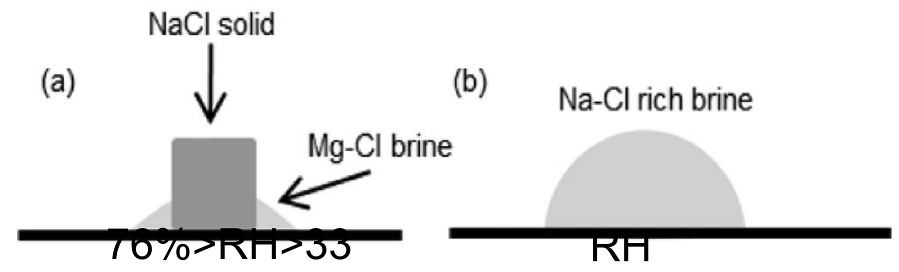
Sample surfaces were polished to 600 grit and salt was printed on them using an ink jet printer. LB-PBF 316L samples were exposed at a constant temperature of 35°C.

Exposure times were: 1 week, 1 month, 6 months, and 1 year.

Samples were exposed to RH of either 40% and 76% (deliquescence point of salts in ASW) and at a fixed contaminant level of 300 µg/cm² of ASW.



Example of 300 µg/cm² ASW loading



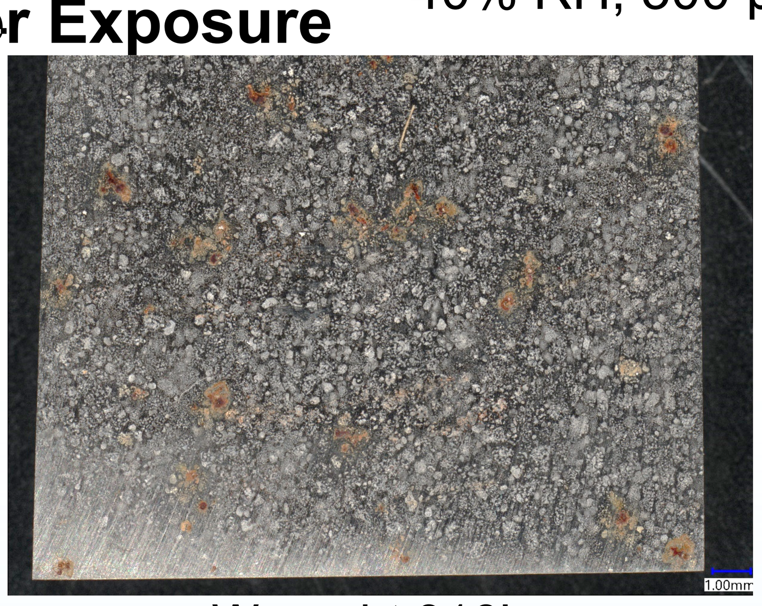
From Ref. 2

33% RH – Deliquescence point of $MgCl_2$

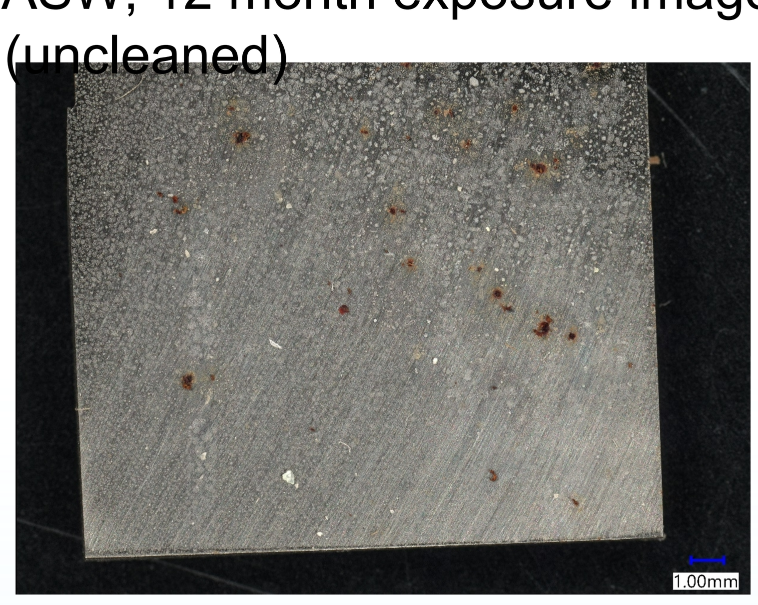
76% RH – Deliquescence point of NaCl

After Exposure

40% RH, 300 µg/cm² ASW, 12 month exposure images (uncleaned)



Wrought 316L

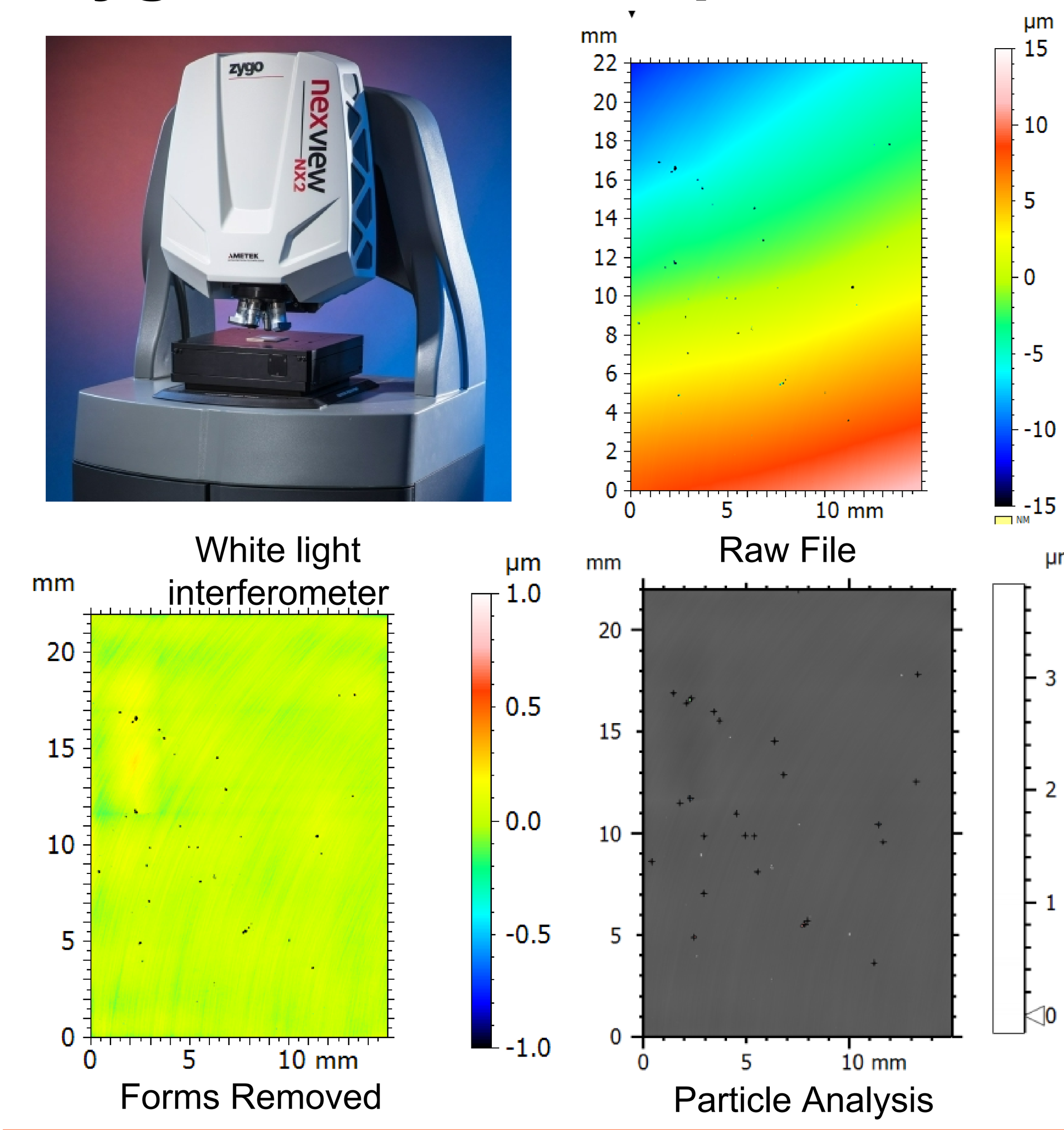


LB-PBF 316L

Samples were then cleaned with dilute Nitric acid solution to remove any corrosion product. Immediately before measuring, samples were wiped once more with water and a wetted Politex polishing cloth to remove dust, etc.

Data Acquisition/Processing

Zygo/ Mountain Maps Process



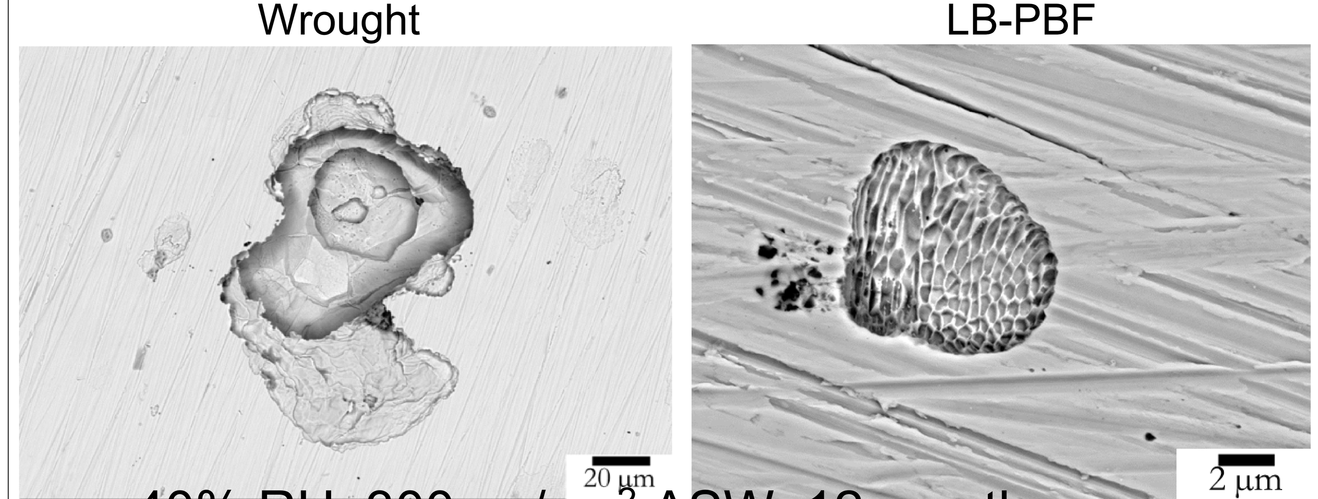
- Extracted area used to minimize edge effects.
- Surface is smoothed using a polynomial multi-form removal.
- Non-measured points are filled in and measurement is mirrored in the z-axis to convert pit depth into height
- Particle Analysis performed on the surface with a planar threshold at 0.5 µm.

Data Filtering

The Particle Analysis results were filtered based these parameters: height > 0.5 um and height/area > 0.02 1/um. The particles are filtered in order to weed out "false pits" that are most likely due to lack of fusion pores.

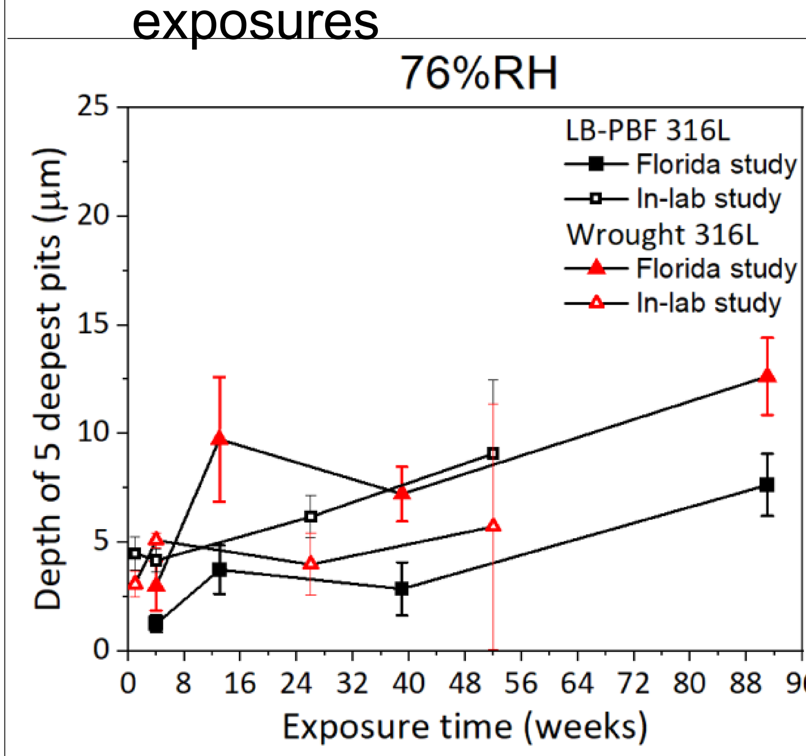
Results and Conclusions

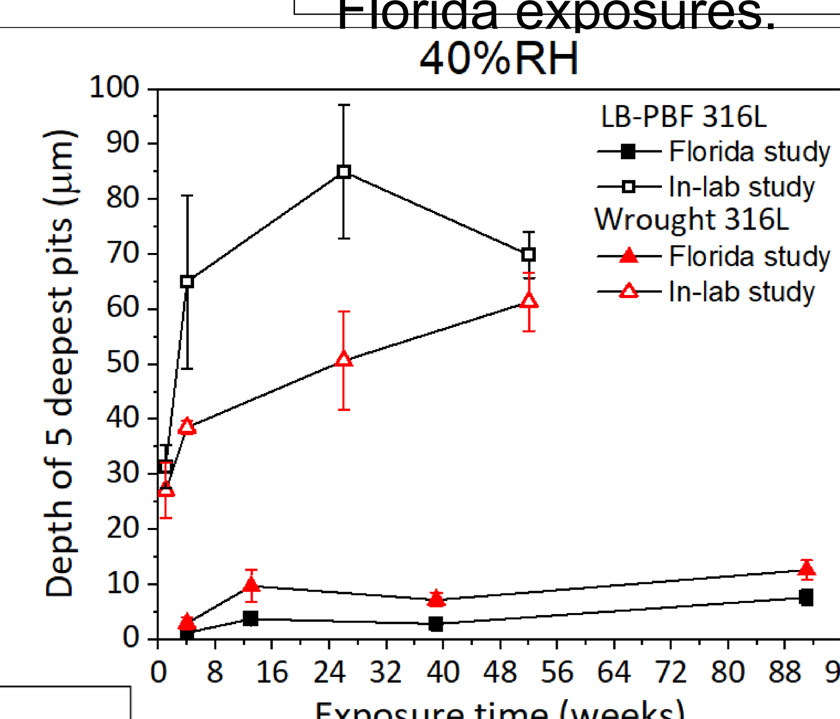
Accelerated Lab Exposures

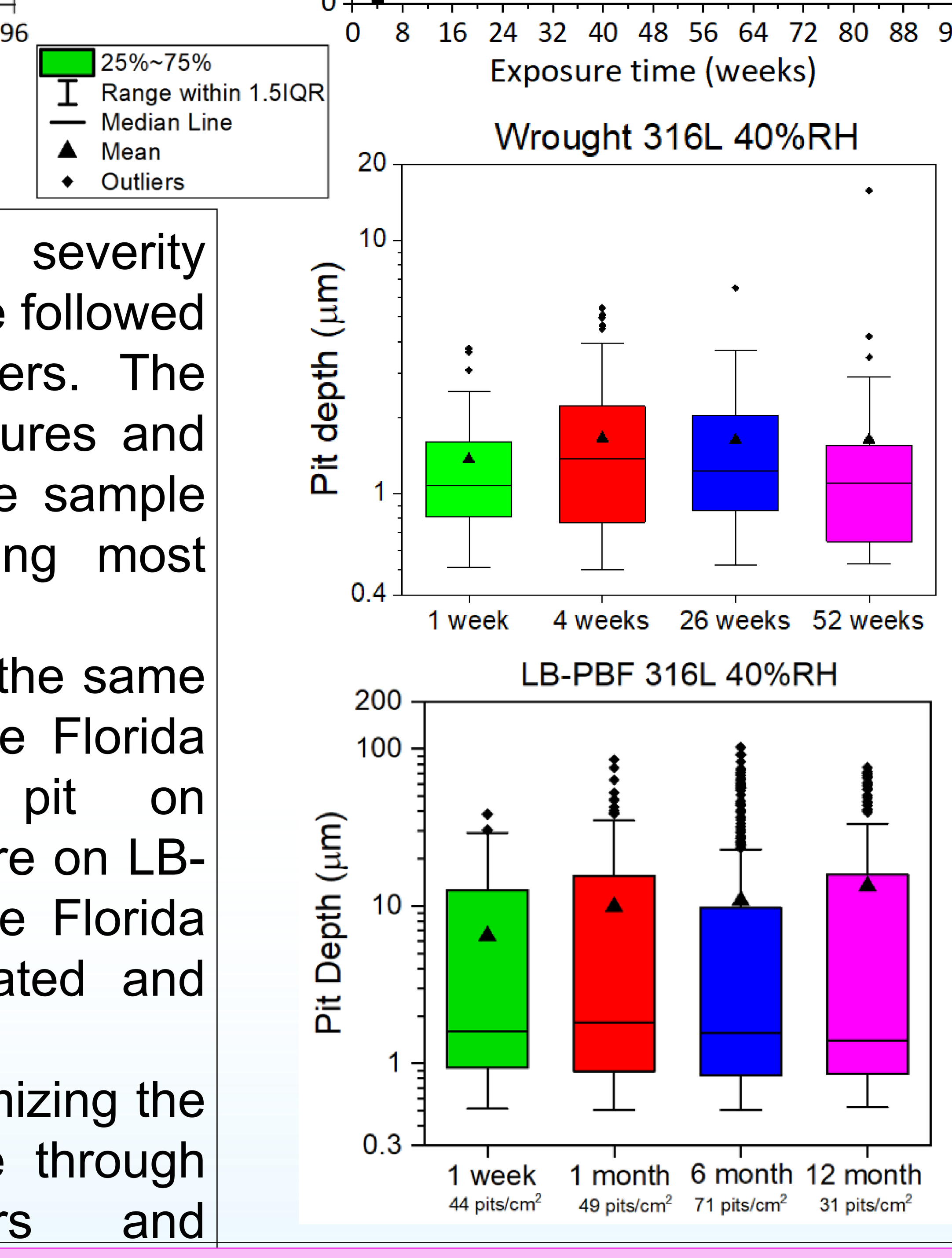


40% RH, 300 µg/cm² ASW, 12 month exposures

- 40% RH lab exposure resulted in accelerated corrosion compared to the Florida exposures.
- 40% RH resulted in deeper pits than 76% RH.
- 76% RH mimicked the corrosion rate of the Florida exposures.







Conclusions:

This study quantified pitting severity using MountainsMap software followed by spatial filtering parameters. The method we developed measures and analyzes pitting across entire sample surfaces while also removing most false pits.

The lab exposures exhibited the same corrosion mechanisms as the Florida exposures (deep/smooth pit on wrought, etched microstructure on LB-PBF). The results proved the Florida experiment could be replicated and accelerated in a lab setting.

Next steps will focus on optimizing the proficiency of this technique through greater sample numbers and

References

[1] M.A. Melia, et al., Marine Atmospheric Corrosion of Additively Manufactured Stainless Steel, CORROSION, 77 (2021)

[2] T.D. Weirich, et al., Humidity Effects on Pitting of Ground Stainless Steel Exposed to Sea Salt Particles, J. Electrochem. Soc., 166 (2019) C3477-C3487.

Acknowledgments

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