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Automated Void Detection for SEM Images of Fracture Surfaces

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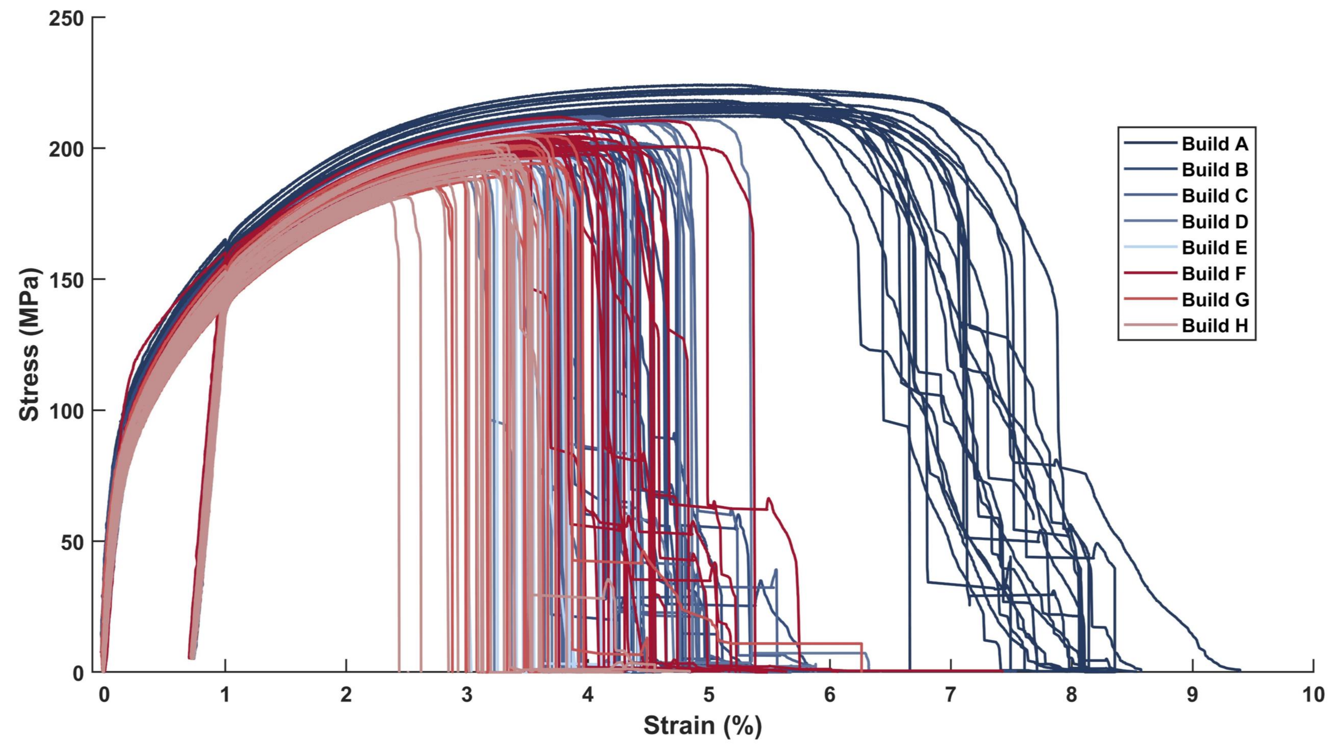
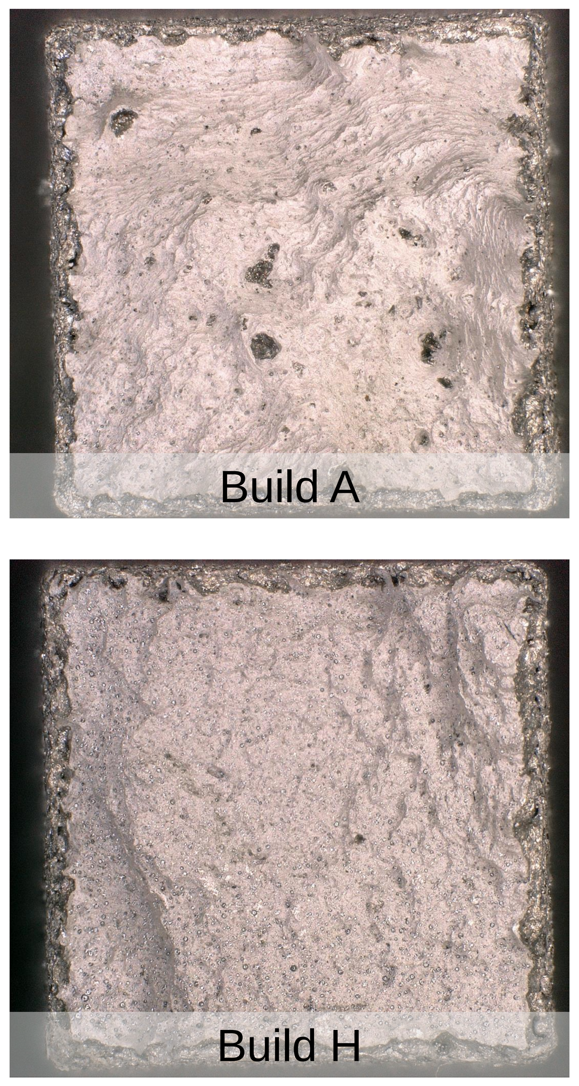
INTRODUCTION

Metal additively manufactured (AM) parts typically exhibit higher porosity than their conventionally manufactured counterparts. While porosity is thought to influence the physical properties of the material, the relationship is not well defined. To explore this relationship, we are interested in describing the porosity at the fracture surface of AM parts. Scanning electron microscopy (SEM) images were collected for hundreds of tensile dogbone samples of $AlSi_{10}Mg$. We then developed an image analysis algorithm to automatically detect the voids present at the fracture surface, enabling us to estimate the void fraction porosity at the fracture surface.



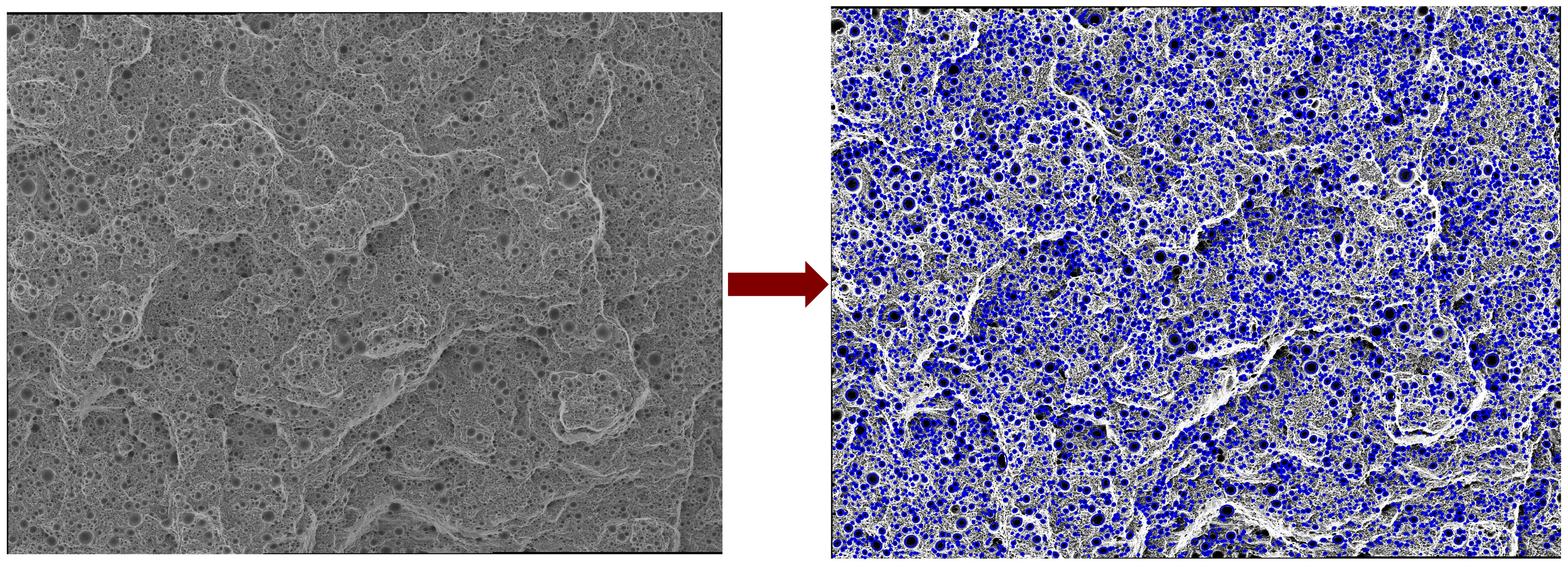
Optical Images of Fracture Surfaces



Above are the stress-strain curves used to obtain the physical properties of each tensile dogbone sample. There are 11 sets of 2 bars for each of the 8 build plates. Builds A-E are build with powder used 0-4 times, and F-H are built with powder used 0-2 times. The curves show variability both between and within builds. Is this related to porosity and its effect on cross-sectional area?

VOID DETECTION

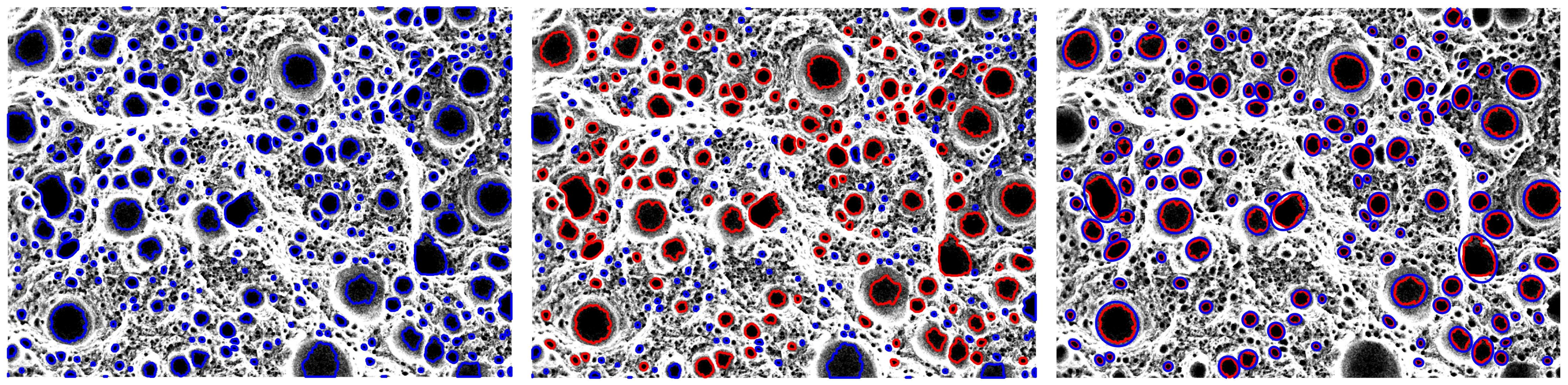
SEM Images of fracture surfaces are collected in variable pressure mode, which effectively flattens the surface and enables better detection of voids consistently across samples with widely varying surface morphologies.



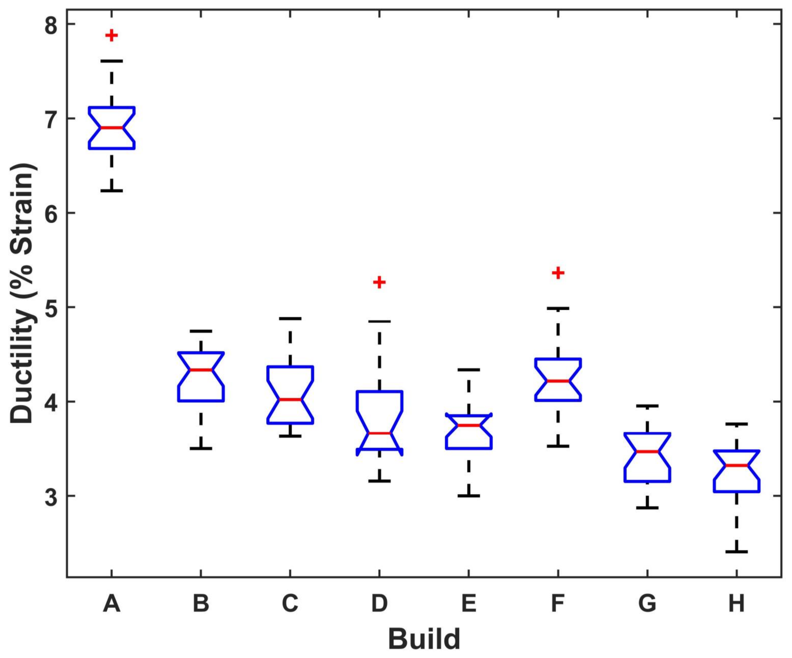
Step 1: Adjust contrast and perform binary thresholding.

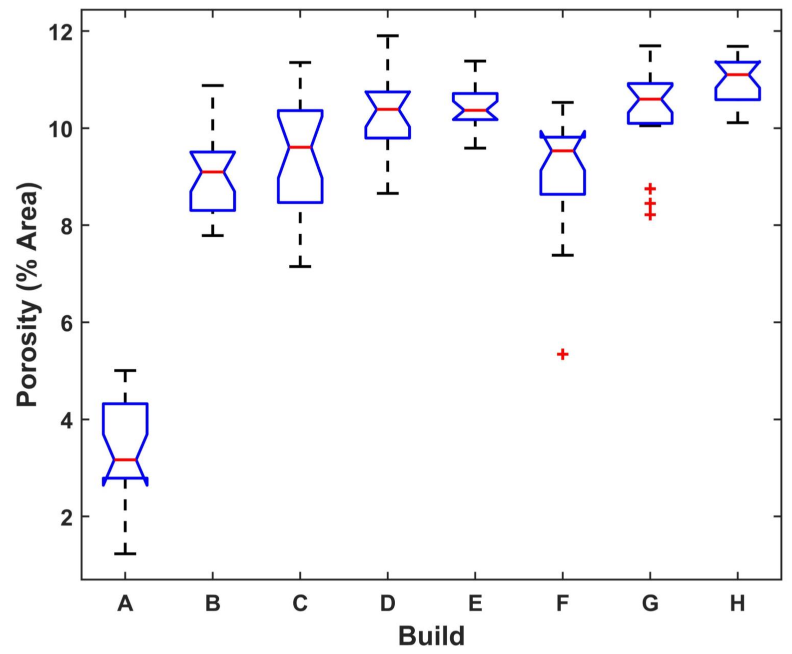
Step 2: Filter by criteria defining a void.

Step 3: Fit an ellipse to the voids and expand the perimeter.

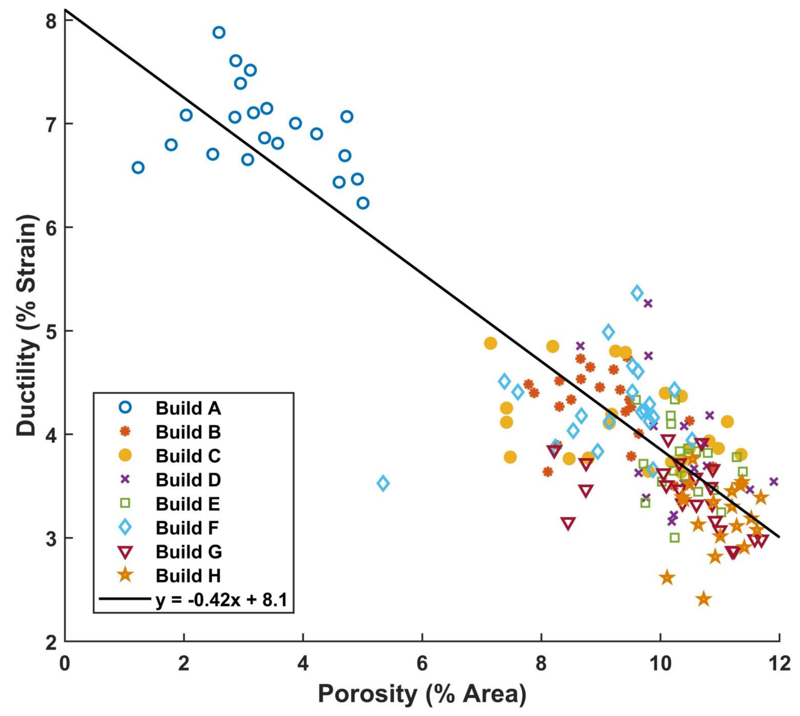


RELATING POROSITY TO DUCTILITY





Ductility values clearly vary with build plate. Builds A and F, virgin powder, show greater ductility than build reusing powder, though F has a ductility close to half that of A. Porosity also appears related to build, with the inverse relationship from ductility.



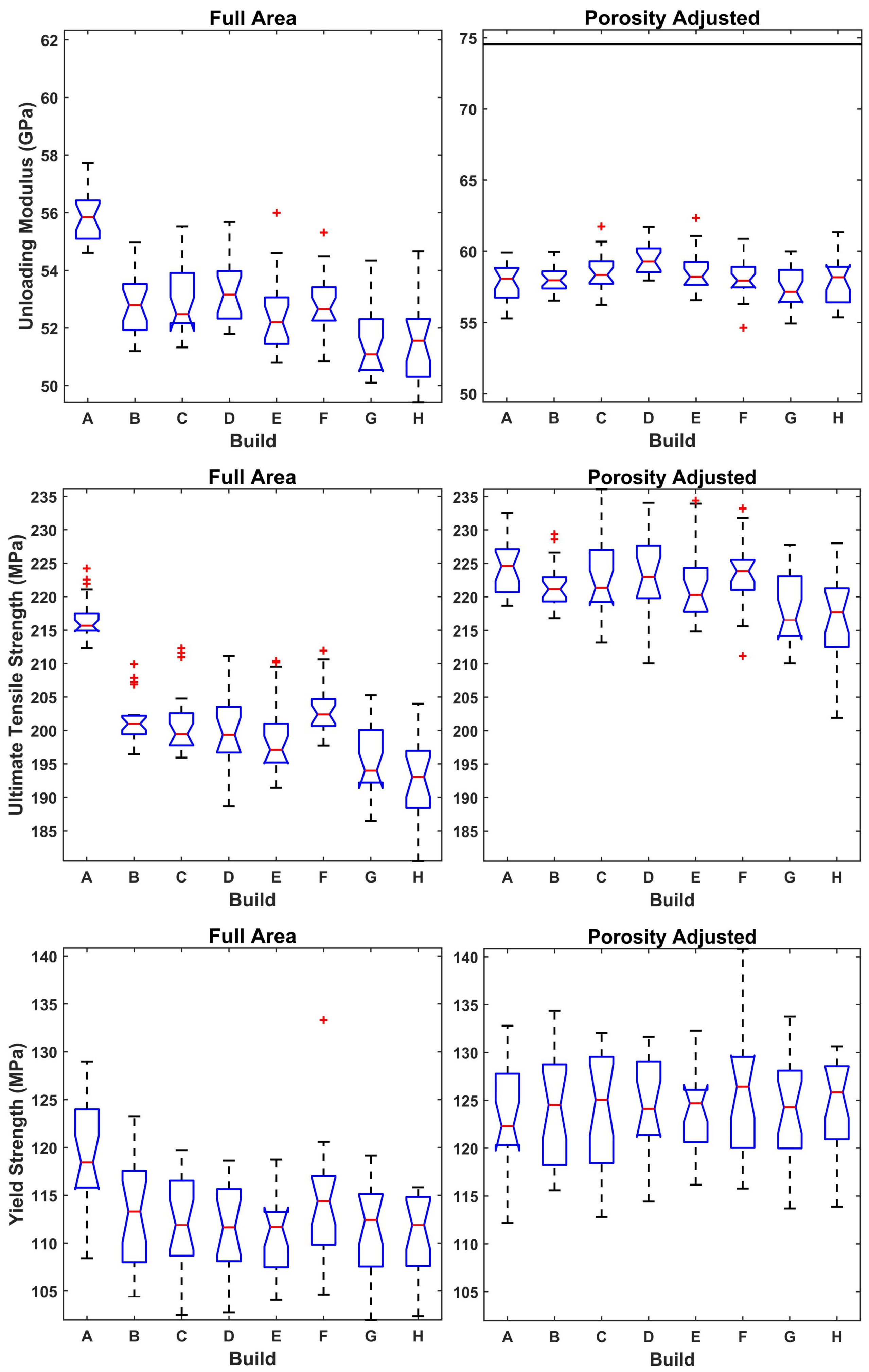
Plotting porosity against ductility suggests that 1% of ductility is lost for every 0.5% increase in porosity at the fracture surface. The distance between Build A and the others might be skewing the relationship, but none of the builds demonstrated porosity/ductility values in the intermediate range. The variability within each build plate also suggests other factors contributing to the poor performance of these AM materials relative to the expected performance of the materials.

CORRECTING AREA BY POROSITY

The stress of dogbone samples as shown to the left is defined as the measured force divided by the cross-sectional area:

$$\varepsilon = \frac{F}{A}$$

If A is incorrect, the strength values will be incorrect. For comparison, we examine physical properties with and without correcting for porosity in the area value. Area corrections reduce the variability between build plates but not the variability within builds. The unloading modulus obtained from ultrasound measurements (which do not rely on area values) is marked at 74.55 GPa (top, right). A complete area correction would adjust unloading modulus values close to this value. This suggests that the reduction in area attributed to porosity is not the dominant effect in reducing material performance.



CONCLUSIONS

- Algorithm determines fracture surface porosity automatically for ~200 samples
- Porosity is inversely related to ductility
- Reduction in effective area due to porosity does not fully account for reduction in material properties

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