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### Defect Characterization of Additively Manufactured Parts

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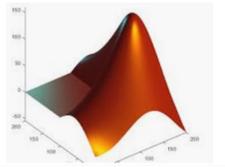
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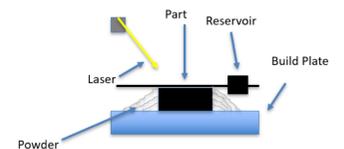
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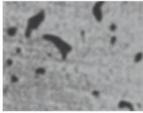
## Introduction

- **Additive Manufacturing (AM)** is an iterative process in which parts are built in a layer by layer fashion. Materials like plastics and metals are very commonly manufactured by AM in the modern scientific era.
- **Laser Powder Bed Fusion (LPBF)** is a type of AM that is most commonly used to print metal parts. The LPBF process starts with the coating of metal powder on the build plate. The powder is spread a couple microns thick and is then melted by a laser in the shape of the part. This is then repeated iteratively until the part is built. This style of manufacturing makes rapid prototyping possible, has low waste, and is relatively low cost.
- LPBF can have various disadvantages such as slow print time and size limitations, but its layer by layer nature causes it to produce defects at a higher rate. This will be explored further by this research.

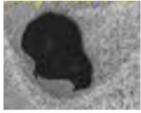
### LPBF Machine



## Defect Characterization

- **Defect Characterization** is the method of classifying aspects of a material that could be damaging to its overall performance. This could include inclusions, cracking, and pores, which is the focus of this experiment. Below are examples of pores in metal AM parts.
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dsiac.org, 2019



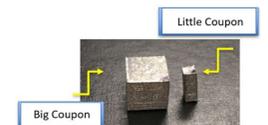
Mcfalls, Travis, 2018



giessereilexikon.com, 2019
- **Image processing** is the use of software or programming to manipulate images of a material to classify the material's defects. From the manipulation of the images different statistics and conclusions can be drawn.
  - **Computed Tomography (CT) Scanning** is a series of x-rays taken from different angles of a material, which produces thousands of images of the cross sectional area. This allows for the inner geometry to be viewed, so defects like pores can be characterized.

## The Experiment

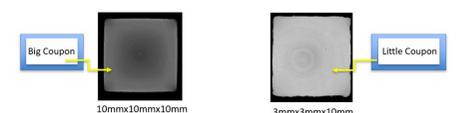
- This experiment utilized cameras and sensors to gather data about the LPBF printing process in-situ. To understand the changes in porosity from changing the part geometry a small and large coupon was printed. It was imperative to use the same parameters in order to only get the relationship between porosity and geometry.
- Material: Alloy 718
  - Small coupon dimensions: 3mmx3mmx10mm.
  - Big coupon dimensions: 10mmx10mmx10mm.
- **CT Scans**
  - Performed by Engineering Solutions
  - Software: VGStudio Max 3.2.5.
  - **Voxel size:**
    - Small Coupon: 3μ
    - Big Coupon: 9μ



### CT Scanning Process

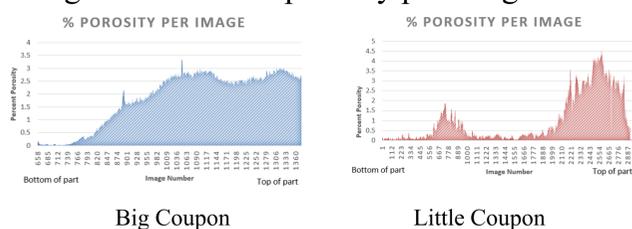


### Coupon CT scans



## Results

To manipulate the data, the cross sectional images were ran through image processing software to prepare them for analyzing from programming. To “prep” the images they needed to first be cropped to all be the same size to allow for proper comparisons between images. Next the “noise” or blurriness in the image was mitigated by applying a median filter. This gave all the pores a defined edge. Then the images were converted from grayscale images to binary images. This made the material black and all the pores white. In images this assigns a 0 to all black pixels and 255 to all white pixels. In MATLAB the %porosity was then calculated for all the images by counting the number of white pixels per image and dividing by the total pixels in the image. This gave an output of a matrix of the image number of % porosity per image. From here excel was used to visually show the differences in porosity in graphical form.



The little coupon had a build stop around 30% in the initial build which is corroborated by the data show. It is expected for the porosity to rise since the material had time to cool down. It was also expected to have different porosity due to the change in geometry, which the data highlighted.

## Conclusions

- Porosity changes as geometry different in AM parts with the same parameters.
- This can be examined by image processing and data analysis techniques such as CT scanning, programming, and visualization software.
- CT Scanning shows the internal geometry of AM parts and provides data about the material's defects.
- In-situ monitoring this allows for real-time quality assurance to help with the mitigation of defects in metal additive manufacturing.