Measurements and Analysis of Process Signatures in Laser Powder Bed Fusion Metal Additive Manufacturing

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Abstract

The 3D metal additive manufacturing processes such as Laser Powder Bed Fusion (L-PBF) requires measurement and characterization of process signatures in layer-to-layer, stripe-to-stripe, and tract-to track fusion of powder material with geometric parameters (width, length and overlap), powder material particle distribution, and the pores and defects from the digital optical, scanning electron or focus variation microscopy techniques. The goal of this research project is to conduct post-process measurements and analysis of the quality of 3D fabricated metal parts by the development of image processing, pattern recognition, and statistical learning methods to correlate the process input parameter to the evaluated quality of the fabricated parts.

Background

LPBF technology is a type of additive manufacturing process, involves the use of a laser to locally melt and fuse a metal powder bed on a layer by-layer basis, to produce parts whose structural properties and shape complexity prevent from the use of conventional processes.

1. A thin layer of metal powder is deposited on a flat substrate via a powder deposition system.
2. Then, the laser melts and fuses the powder to realize the first slice of the part by following a predefined scanning path.
3. When the scan of the first layer is complete, the substrate is lowered, a new layer of powder is deposited, and the process is repeated to realize the following slice.
4. This process is repeated until the product is completed in the powder bed and part is removed.

Research Approach

This research focuses on measurement and analysis of process signatures in layer-to-layer, stripe-to-stripe, and tract-to track fusion of powder metal material with geometric parameters (width, length and overlap), characteristics of powder material particle distribution, and the pores and defects that can be obtained using digital optical, scanning electron, or focus variation microscopy techniques.

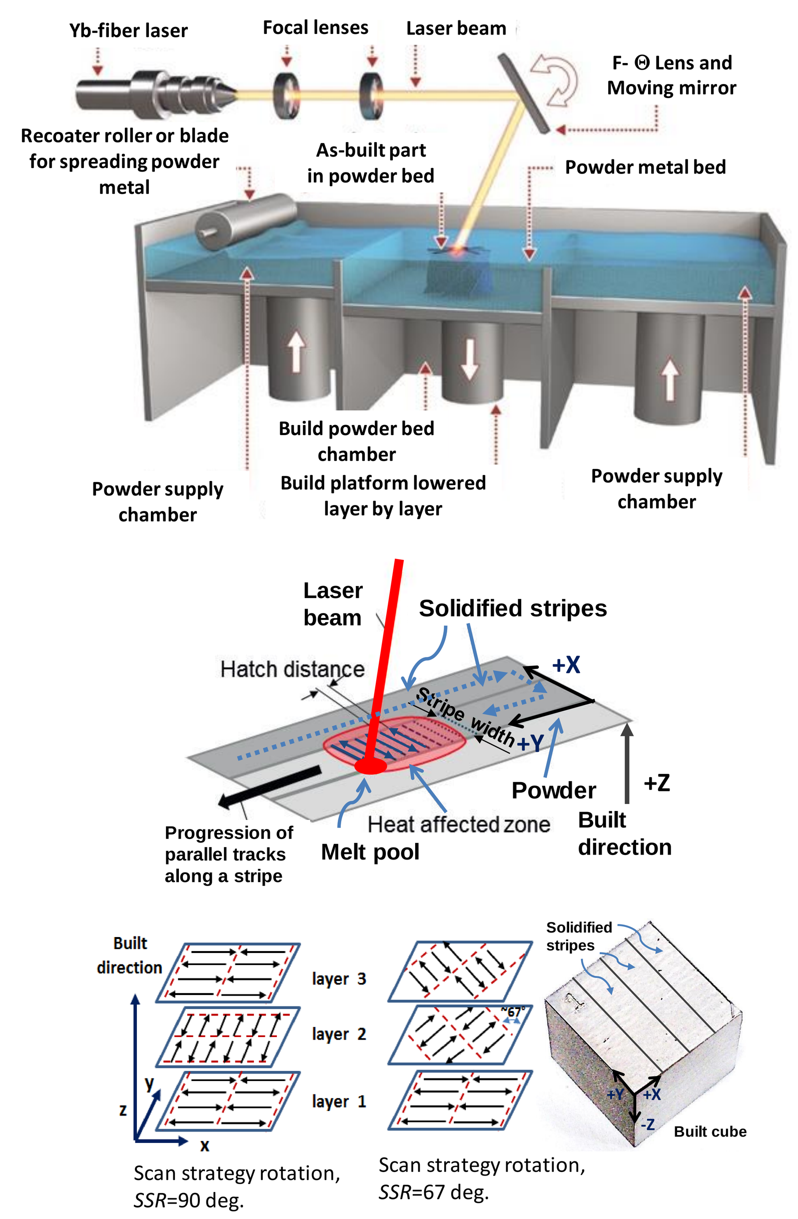

Fig. 1: L-PBF machine and the process .

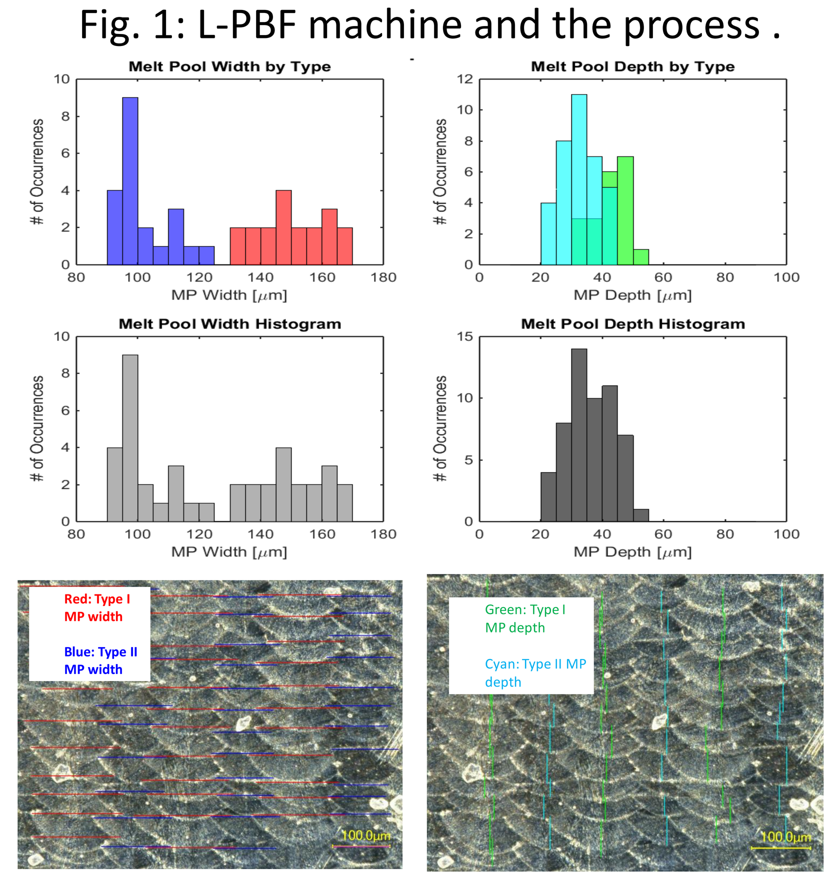

Fig. 2: Measurement of process signature.

The research team investigated the images collected from the surfaces of the 3D fabricated parts. These images could be 2-D intensity maps or 3-D areal surface maps that are obtained through various techniques including digital optical microscopy (DOM), scanning electron microscopy (SEM) or focus variation microscopy (FVM).

Steps for analyzing the process signatures include:

- Process input parameters include powder metal particle size distributions, stripe width, layer thickness, and ambient gas (Nitrogen or Argon).
- Controllable process parameters include laser power, P [W], scan velocity, v_s [mm/s], hatch distance, h [mm], scan strategy rotation, *SSR* [90° or 67°].
- Process signature measurements include; meltpool type, Type I or Type II, meltpool width, MP_w [μm], and meltpool depth, MP_D [μm].
- Melt pool width and depth measurements for Type-I and Type-II from DOM images (Fig. 2). These are done for scan strategy rotations of 90° and 67°. Porosity measurements using image processing are done (Fig. 3).

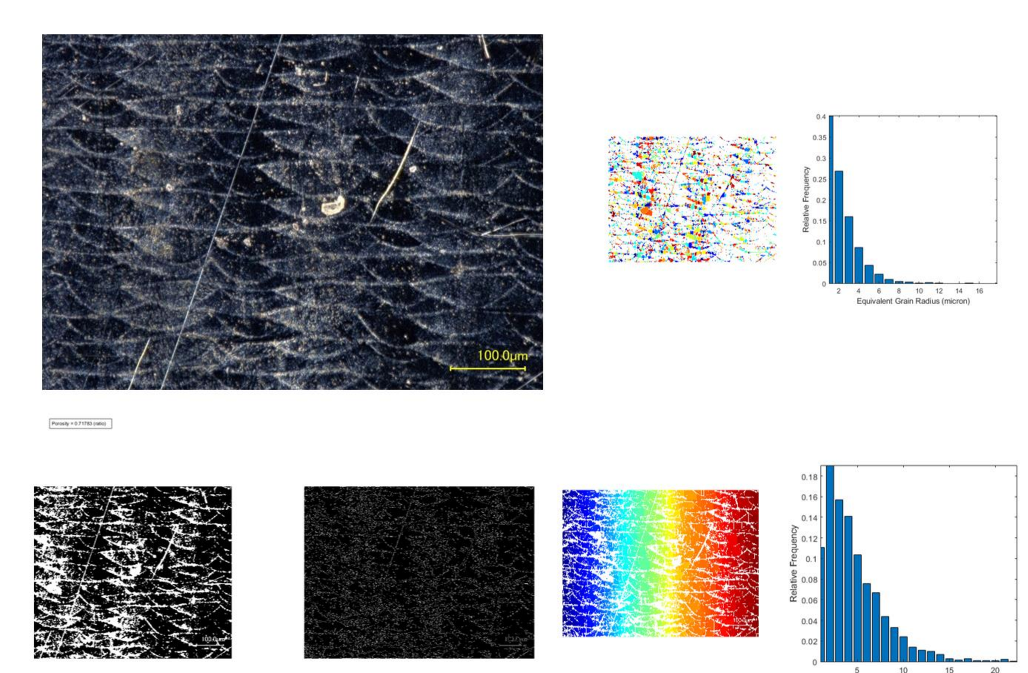

Figure 3: Porosity measurements: GSD, PSD and SPS.

Results

Image processing and analysis codes developed with MATLAB were utilized to compute meltpool width and depth, porosity and defect sizes with distributions from the optical images obtained from additively fabricated and polished metal surfaces. The data involves both of the 90° and 67° scan strategy rotations and is analyzed based on the input parameters (Fig. 4).

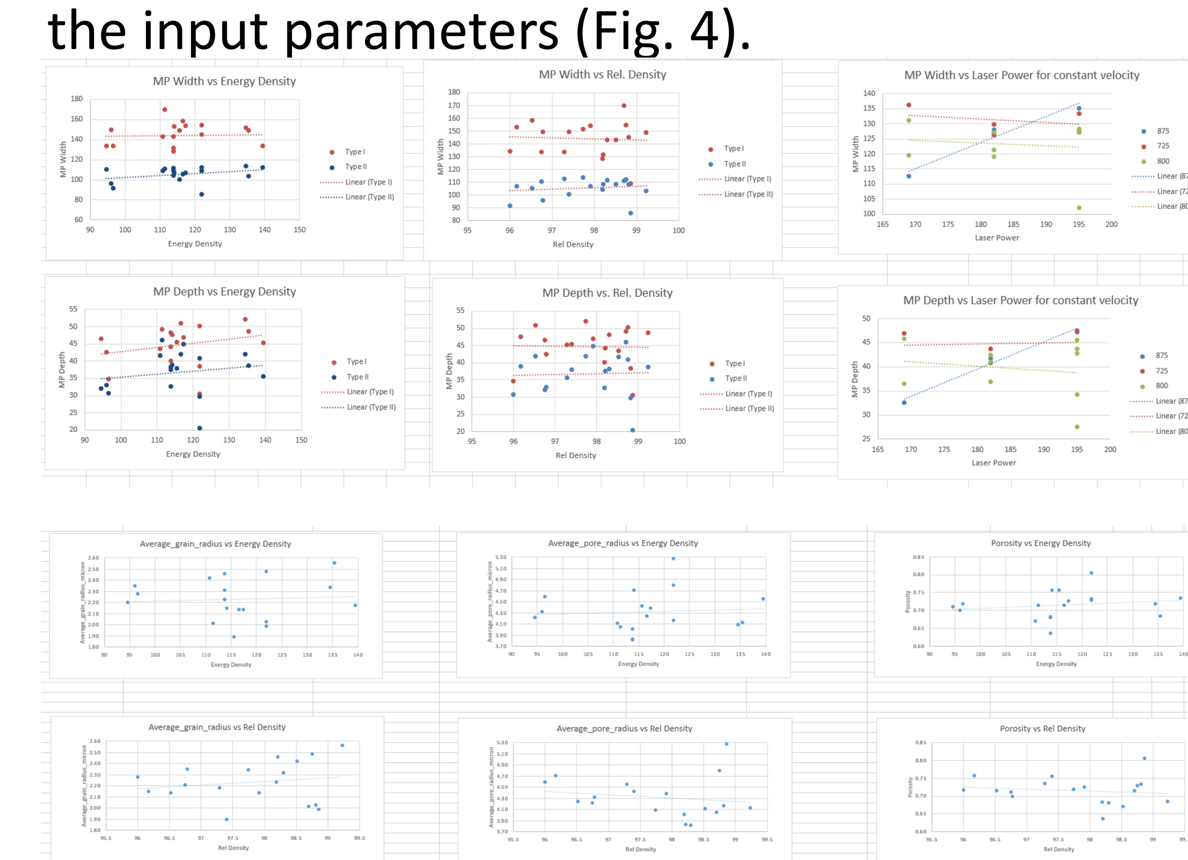

Figure 4: Measured data shown by points and trendlines.

Challenges and Future Direction

Additional research work will be performed in following areas:

1. Use of machine learning techniques to run algorithms automatically while the product is being additively fabricated.

2. In-line measurement of process signatures occurring during the process and alerting the user to reconfigure and change process parameters of the L-PBF machine to get product without any defects.

3. Big data stream management to study large measurement data formats with higher resolution at a time rather than splitting them into smaller data files possibly using high speed parallel-computing techniques and capabilities.

References

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