Measurement of Gas Flow in Laser Powder Bed Fusion Machines

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Introduction

Laser Powder Bed Fusion (LPBF) is an additive manufacturing process, where a high-powered laser melts thin layers of metal powder together to build a part. While printing, the laser's melt pool can eject partially melted powder up into the air, creating spatter and a plume of metal condensate. These byproducts can cause problems in the manufacturing process, obscuring the laser or depositing spatter particles in the printing path. [1] To clear the spatter and condensate from the build area, and to prevent oxidation during printing, an inert gas is blown across print bed. Current efforts to understand the quality and efficacy of gas flow have taken measurements of gas flow speed over the print bed, but flow direction and conditions of turbulence have not been reported. Understanding these characteristics of the gas flow is important, as the flow direction of the gas or its recirculation could impact how spatter and condensate are cleared away.

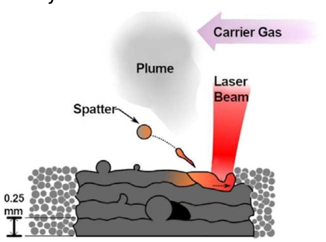

Figure 1: LPBF Printing process and byproducts [2]

Objectives

This research works to develop two methods of characterizing gas flow inside of LPBF printers.

1. Hot Wire Anemometry (HWA)
2. Tuft Testing

With these methods, both speed and direction of the carrier gas at any point above the build area can be found.

Methods

One commonly used method of measuring gas flow over the build area utilizes HWAs to take measurements at different points in an area. As shown in Figure 2 below, this method has been developed and automated for use in an EOSM280 LPBF printer. This automation is done using a gantry built to move around in the printer, being controlled by an Arduino Nano ESP32. The gantry can be used to either automatically take measurements over the entire span of the frame or be manually controlled over Bluetooth to take measurements at specified locations.

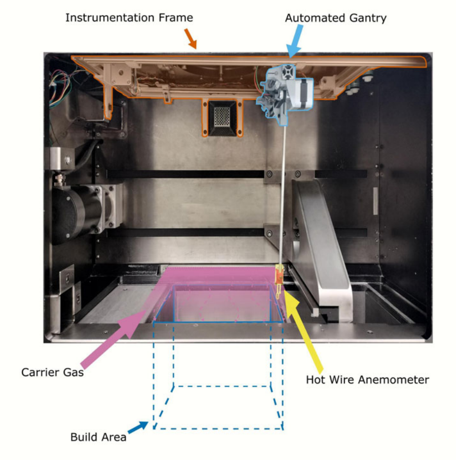

Figure 2: Hot Wire Anemometer setup inside of an LPBF printer

Figure 3 shows the tuft test experimental setup, pictured from the side. Tuft testing is commonly used in the automotive industry to characterize gas flow, but has not yet been brought into the context of LPBF machines. [3] Strands of polyester yarn are placed on the end of steel rods, which can be moved up and down in the print area. By filming the reaction of the yarn to the gas flow from above, a qualitative overview of the flow field can be obtained. With machine learning and computer vision techniques, these videos can be analyzed to get quantitative data on the speed and direction of flow at different points over the print bed.

Expected Results

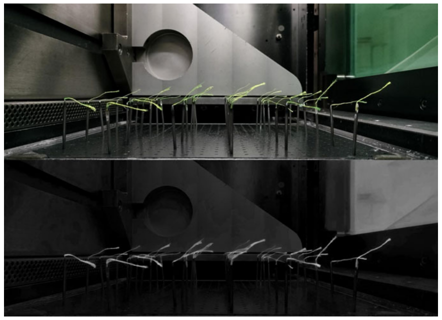

Figure 3: Tuft test setup inside of LPBF printer, with and without filtering for green light

Figure 3 above displays the way the tufts are expected to react to the gas flow. As the gas flows into the build chamber from left to right, the tufts should move with the path of the carrier gas. After a green light filter is applied, an algorithm could be used to extract directional and velocity data from the movement of the tufts.

Figure 4 below shows the expected results from the HWA test setup. Once data is collected in in relation to the build area, it can be analyzed using MATLAB. It is expected that the variation in speeds and direction of gas flow over the print bed is significant.

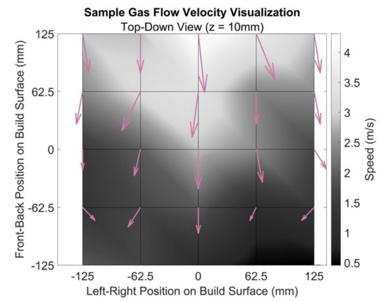

Figure 4: Expected Velocity Vector Field

Conclusions and Further Work

As the carrier gas flow across the powder bed is an important component of the LPBF process, it needs to be well understood and standardized between machines. As it stands now, the gas flow between different machines is variable enough to impact the quality of parts produced. The methods developed through this project will assist in the effort to characterize the gas flow in LPBF machines.

As data has not yet been collected, more work is needed to complete this research project. The HWA needs to be calibrated to the inert gasses used during printing. Once the EOSM280 has been restored to working order, measurements will be taken. The data from the HWA setup will be analyzed in MATLAB.

Finally, the hardware for the HWA gantry can be improved further. For more accuracy, it can be more precisely located in the build chamber. Additionally, the setup made more rigid and slim for further improvements.

Acknowledgements

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References

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