Characterizing Motion Errors in Metal Additive Manufacturing Machines

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Introduction

Laser powder bed fusion (LPBF) is a metal additive manufacturing method where part quality depends on controlling motion-related process errors. The machine is featured in Figure 1.

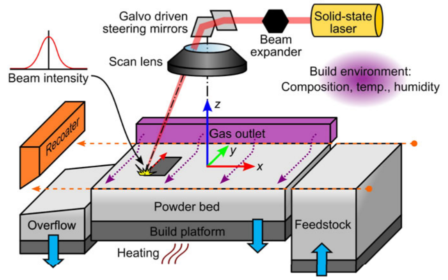

Figure 1. Diagram of a laser powder bed fusion machine [1]

Errors such as deviations from straight paths, vibrations, or collisions, can lead to failed prints and increased costs. This research develops methods to measure motion errors in the recoater arm of an LPBF system. A laser displacement measuring interferometer (DMI) and an accelerometer mounted on the arm will be able to measure straightness, roll, and vibrations, allowing the assessment their impact on powder bed flatness and layer thickness. Detailed in prior studies, Berez and Saldaña [2] studied recoater blade errors and their effect on powder bed flatness. Lu et al. [3] used a DMI to measure errors in the movement of the powder bed as it traveled along the z-axis. Redford et al. [4] observed the vibration and dynamics of the recoater arm by using an accelerometer and gyroscope.

Objectives

Research Goals:

- Utilize a DMI to measure the straightness and rotational errors
- Observe the recoater's high frequency vibrations and dynamic response of the recoater arm by using triaxial accelerometer
- Compile data into plots describing the recoater's kinematic behavior

Method

To measure kinematics of the recoater arm, a DMI was mounted onto the LPBF machine. The three DMI components, as shown in Figure 2, that were used as follows:

- Laser emitter
- Steering mirror
- Target

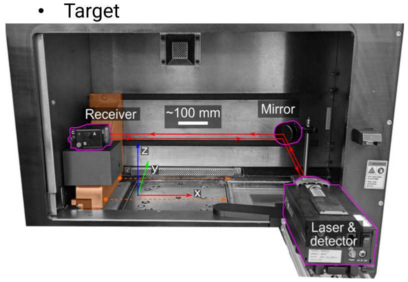

Figure 2. DMI components used

To measure the dynamic response of the recoater, a triaxial accelerometer was secured onto the recoater with mounting wax.

Collected Data

When implemented, the laser interferometer shows that there were multiple types of motions errors. This is shown in Figure 3 for the straightness errors and in Figure 4 for the rotational errors.

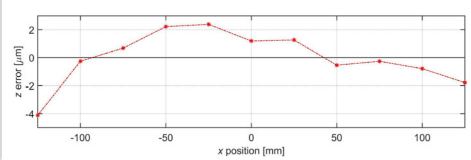

Figure 3. Straightness motion error plot

Figure 4. Rotation motion error plot

Results

The straightness error contributes about 6.5 µm deviation from the ideal path suggesting the guide rails are misaligned and imperfect, causing irregular peaks and valleys. The rotational error leads to 46.2 µm of vertical displacement at the arm's tip, likely due to the rails being offset or warped, which allows for roll and other inaccuracies. When compounded, this is shown in a plot detailing the total motion error of the recoater arm shown in Figure 5.

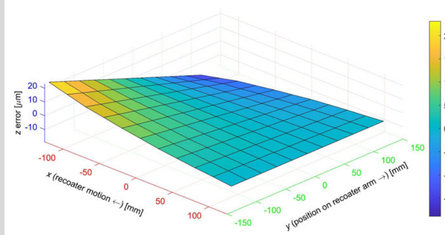

Figure 5. Total motion error plot

The initial accelerometry data shows a detectable amount of vibration in the when the recoater is in motion as shown in Figures 6 and 7.

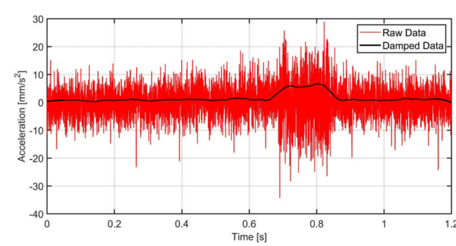

Figure 6. Acceleration in the x-direction programmed to move to 10 mm at 75 mm/s

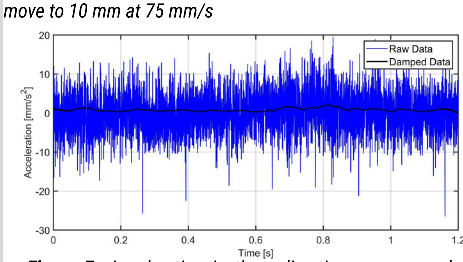

Figure 7. Acceleration in the z-direction programmed to move to 10 mm at 75 mm/s

It is expected that a large amount of acceleration will be measured in the x and z directions during collisions with objects.

These results indicates that the recoater arm does not move in a perfect path and can impart irregularities into the surface of the powder bed which will reflect these errors as well. These errors is significant since this would affect the machine's performance in a critically detrimental ways.

Conclusions

In conclusion, significant errors in the recoater arm's motion can impact the end product's quality. An interferometry and accelerometry system was used to observe these errors. Future research should study the repeatability of these errors. Determining the repeatability will allow for the potential correction of the printing process since repeatable errors can be adjusted for, while random errors cannot. Using the principles of AM machine tool qualification proposed by Berez and Dushaj [1], improving quality control during manufacturing and construction, AM machines can be monitored for off-nominal performance and defective processes and parts can be avoided.

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References

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