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Evaluating Acoustic Emission Signals as an in situ process monitoring technique for Selective Laser Melting (SLM)

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FY Plan: FY16 Only

Introduction

In situ real-time monitoring of the Selective Laser Melting (SLM) process has significant implications for the AM community. The ability to adjust the SLM process parameters during a build (in real-time) can save time, money and eliminate expensive material waste. Having a feedback loop in the process would allow the system to potentially 'fix' problem regions before a next powder layer is added. In this study we have investigated acoustic emission (AE) phenomena generated during the SLM process, and evaluated the results in terms of a single process parameter, of an *in situ* process monitoring technique.

Scope of Completed Work

This Tech Base has successfully completed a preliminary investigation of the efficacy of detecting, recording and processing of acoustic signals during a single powder layer SLM experiment. The goal was to evaluate this acoustic modality as a possible method of in-situ process monitoring. Initial measurements were based on attaching a high frequency piezoelectric sensor to the build plate and record AE data for a variety of process parameters (laser power, scan velocity, etc.) during a short build. Time-frequency analysis, power spectra, and identification-classification algorithms were applied to the acoustic data to determine possible process related signatures that indicate characteristics of the build process.

LLNL's experimental SLM platform

In-situ acoustic signatures were recorded on LLNL's SLM single layer test bed. The SLM test bed provides a unique platform to conduct observations and measurements on the physical mechanisms during the melting-solidification process. The test bed is an 'open' system with direct access to the build environment and control of parameters. With this system, different build parameters are isolated and the corresponding acoustic spectra are compared with processing conditions.

Results

A small 10MHz piezoelectric transducer was attached to the bottom of the test bed build plate (OD 25 mm x 3.1-mm thick) and the system was programmed to weld two sets of 50-individual traces, 12-mm long, spaced 0.2-mm apart. Each scan set was symmetrically positioned on either side of the circular build plate. A single layer of steel powder (ASME318) 50-um thick was leveled onto the upper surface of the build plate. The optical power for the first scan set was 150 (W), and 600 (W) for the second set. The laser velocity was held constant at 250 mm/s for both sets. The total scan time for a data set (50 traces) was approximately 20 seconds, with each individual trace taking 50 us and then a 400-ms delay while the laser is positioned to the next scan line. The scan sets were completed sequentially with a short pause between the first and second runs to change the power. The build plate was then removed from the test bed, the traces were filed off, fresh powder added and the scan sets were repeated.

The recorded signals were pre-processed. This included removal of a dc bias and non-acoustic electrical noise. The post-process data was organized into two sets based on incident optical power; low (150W) and high (600W). Each data set was comprised of 50 -individual traces, 50 μs in duration. Several different spectral estimation algorithms were applied to the two data sets yielding similar results. Figure 1.0 shows a comparison of the measured acoustic spectra, for the two optical power settings using the MUSIC spectral estimation algorithm. The data clearly shows that resonance peaks are shifted or in some cases completely missing depending on the optical power setting. Note that these spectral estimates represent an average of the 50 scanned traces. Each of which occupies a different geometrical location relative to the acoustic emission sensor. Geometric and propagation losses are averaged into these comparisons. However, because of the symmetrical location of the scan lines, relative to the sensor, these losses are the same for both the high and low power data sets and thus will not introduce geometrical differences between the two scan sets. Micrographs for the high and low optical power SLM regions were taken for comparison and, these are shown in Figure 2.0.

Conclusions/Further Work

This Tech Base project has shown that there are measureable and repeatable differences in the acoustic signatures of a SLM processes as a function of incident optical power. Future work should involve quantifying the physical mechanisms that are generating the sound as it relates to melt quality and process improvement. Possible approaches might include image processing and segmentation techniques to correlate periodic features and weld speed to recorded audio spectra. Recent modeling efforts developed at LLNL of the complex physics associated with the melt pool may also benefit from this new diagnostic modality. Ultimately these efforts can lead to fewer fabrication flaws and improved components.

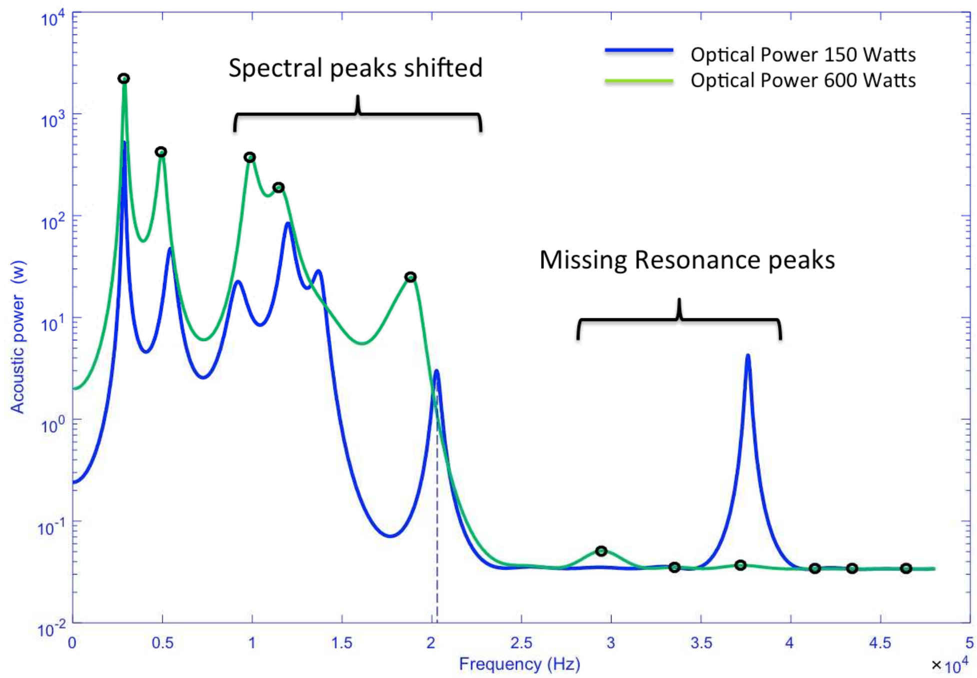

Figure 1.0. The graph compares the average acoustic spectra from 50 scans signal for each of the two optical power settings. The data clearly shows that resonance peaks are shifted, or in some cases, completely missing depending on the incident optical power. This measurement represents an encouraging first step towards further application of acoustic signals as a diagnostic parameter for SLM process monitoring.

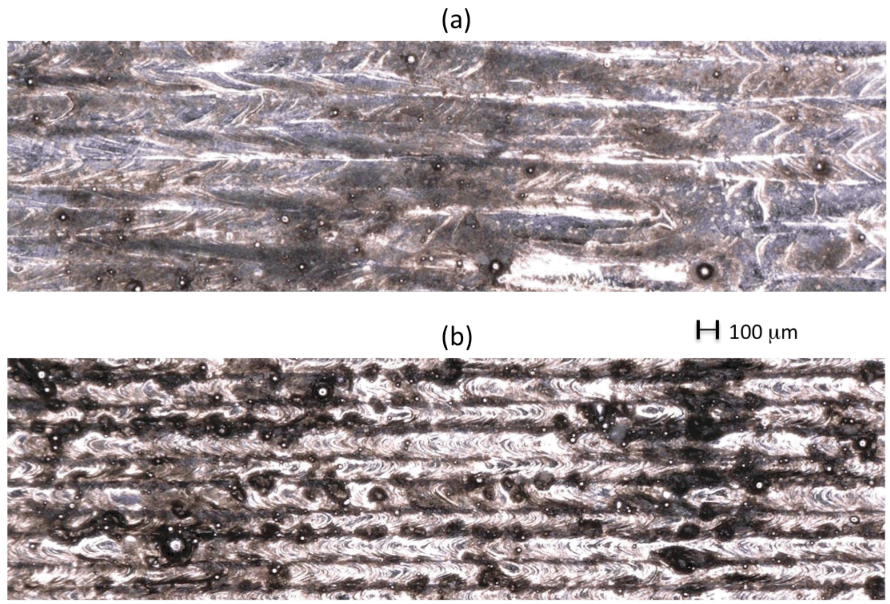

Figure 2.0. Microscope image showing the SLM traces on the surface of the build plate for the two incident optical powers; (a) 600 Watts, and (b) 150 Watts. The laser scan velocity was constant at 250 mm/sec for both sets of traces.