PROCESS MONITORING FOR ADDITIVE MANUFACTURING

A Summary

June 2015

AUTHENTISE

www.authentise.com | info@authentise.com
Wide industrial adoption of Additive Manufacturing (AM) depends on the ability to accurately repeat a process within known tolerances. The exact advantages of 3D printing become liabilities in manufacturing. Without proper controls a process designed to allow for maximum flexibility and individual customization leads to deformation of the model and microscopic variances in material properties. The complex geometries made possible by 3D printing make standard post-process inspection useless. New techniques and process are required to make 3D printing viable for industrial uses.

Authentise is addressing this challenge with Authentise Monitor, which uses machine learning and computer vision to deliver real time analysis for print beds and melt pools. To read more about Authentise Monitor, see here.

Background

There are a few fundamental issues with current metal AM methods.

1. Micro-porosity
2. Lack of fusion between neighbouring layers
3. General anisotropicity of prints in the z direction

There are many causes for these issues, but a few are:

1. Complex thermal history/heat transfer due to heating, cooling, and subsequent re-heating of small sections of the material (due to layer to layer printing)
2. Non-uniformity in metal powder deposition for a printing layer (re-coating)
3. Non-uniformity in the weld bead, caused by a variety of factors generally related the machine state, such as variations in laser power, chamber temperature, chamber gas concentrations
4. Local geometry of the part being printed. Parts with complex geometry will have an equally complex thermal condition, which can cause unexpected heating/cooling patterns.
5. Machine printing settings such as speed and hatch spacing.

Because of the variety of issues and causes, there is not one good solution for fixing issues in metal AM. Instead, the general consensus is that creating a feedback loop of closely monitoring the process variables and machine state and adjusting them in-process is the best way to reduce part to part variation and increase general build quality.

Current Solutions

There are currently a few solutions aimed at fixing the issues inherent with AM, though they are all in infancy. A few of these solutions are: machine and environment state monitoring, powder bed uniformity, melt pool analysis, and finer control of print conditions by using print simulation.
Machine and Environment State Monitoring

Many current systems for repeatability focus on machine and environment state such as measuring O$_2$ concentration, machine temperature and laser power levels. More sophisticated monitoring involves controlling the location of the beam waist or caustic as it interacts with the powder surface. This may be done by splitting off some of the light emitting on-axis. These systems have a tolerance range and simply shut down the machine when tolerances are exceeded.

Powder Bed Uniformity

Some work in repeatability focuses on the powder bed and ensuring that the bed is uniform. Images are captured for each layer of printing which then are manually inspected by a technician after applying simple filters to highlight abnormalities. In the case of multiple concurrent prints the images can be automatically compared against each other to provide some simple automatic irregularity detection.

Melt Pool Analysis

Development is being made in active melt pool analysis to generate a heatmap of a part as it is constructed. This involves an enormous quantity of data and complex signal processing. Two approaches are being actively developed by various organizations: collection of emitted light and melt-pool imaging. Collection of emitted light is used to infer the thermal energy at each point in the produced part and suffers in accuracy because it is not a direct measurement. Melt-pool imaging requires extremely high frame-rate information capture due to the speed at which the laser operates.

Print Simulation

Work is also being done to simulate the the melt-pool accurately in an attempt to pro-actively control characteristics of a part by manipulating the melt-pool through laser control. This may produce parts with interesting physical characteristics but does not help in repeatability because it takes into account no measurement of the actual physical process while it is occurring.

Most organizations that are using AM are doing so without sophisticated monitoring or simulation. They instead rely on deep domain experience from their technicians to diagnose and resolve variances in production. These variances manifest from machine-to-machine or from day-to-day on the same machine requiring constant vigilance from well-experienced staff to avoid high failure rates.

To read more about how Authentise is addressing these challenges with Authentise Monitor, please follow this link: [www.authentise.com/tech/monitor.pdf](http://www.authentise.com/tech/monitor.pdf)