AMSENSE®

TOMOTHERM™ THERMAL TOMOGRAPHY SENSOR

The AMSENSE thermal tomography sensor system is an add-on module featuring a 12 MP silicon-based CMOS camera filtered for sensitivity in the NIR spectrum. The camera is configured to run at nominal 4 Hz and exposure time of 250 ms, enabling integration of sensor data over time steps with continuous data acquisition. The camera is mounted in one of the sensor viewports above the build chamber, providing a field of view to capture the entire build plate. The resulting temporal and spatial registration of thermal emissions provides a powerful foundation for process monitoring and control, as such emissions are generally sensitive to a wide range of critical and non-critical process anomalies.

WHAT DOES IT DO?

The thermal tomography sensor is controlled through the AMSENSE user interface to collect continuous imagery data and process into tomographic composite images each layer. The tomographic composite images provide a map of emission intensities for each layer by overlaying the intensities from each frame collected during the layer. A false color representation of the data (converting grayscale intensities to a blue-through-red color scheme) thereby provides an intuitive "heat map" for each layer of the build, which can be used to detect a wide range of key process features that often lead to build failure or part defects. Types of processing anomalies which generally show up in the thermal emissions signature include (1) layer defects due to uneven powder spreading, (2) inclusions formed during melting and resolidification, (3) delaminations and overhangs, and (4) unexpected process temperature variation (e.g., laser striking spatter, laser performance degradation, etc.).

The fidelity of the resulting tomographic data in *x*-*y* space for each layer also makes it possible to develop automated detection algorithms using the composite images as source data. Ultimately, this data may be correlated with NDE and destructive characterization data to provide confidence in defect detection algorithms, upon which process control and part certification strategies may be developed. In addition to the layer-wise composite images, the data can also be sliced at other angles through the part (for example, perpendicular to the build plate). Further, the raw image frames and numerical data are also available to the user for individual analysis or use in custom image processing techniques.

EXAMPLE DATA

Figure 1 shows thermal tomography data (in both grayscale and false color) for a set of cylinders processed with different laser parameters for each cylinder. The hatching patterns are clearly visible in the imagery, as well as the different signatures resulting from different parameters. Used as such, tomography can aid the development of optimum process parameters.

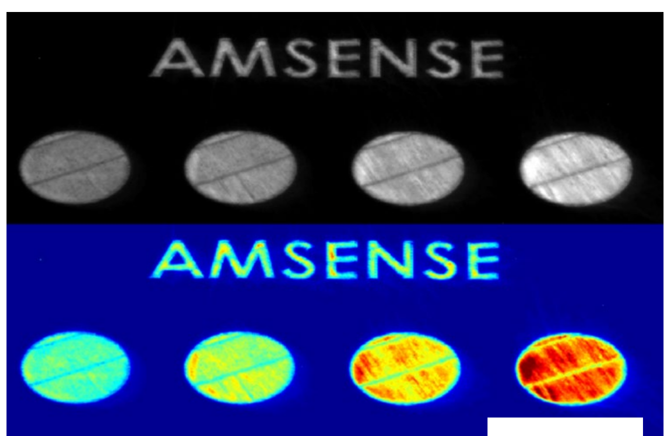

Figure 1

In Figure 2, the process parameters remain constant, but geometry is varied. The resulting tomography data is plotted in both *x-y* (horizontal) and *x-z* (vertical) to see how the signature varies in each direction. Tomography may thus be useful in applications development (parts design) as hot and cool spots may indicate different microstructures, and thus require varying the parameters or design to achieve desired properties.

A final example is shown in Figure 3, where a part was built with a highly inclined wall. The build eventually failed due to a critical delamination. The tomography sensor was able to see the delamination develop over the course of approximately 100 layers. Using this data real-time, the build could have been stopped to prevent wasted resources.

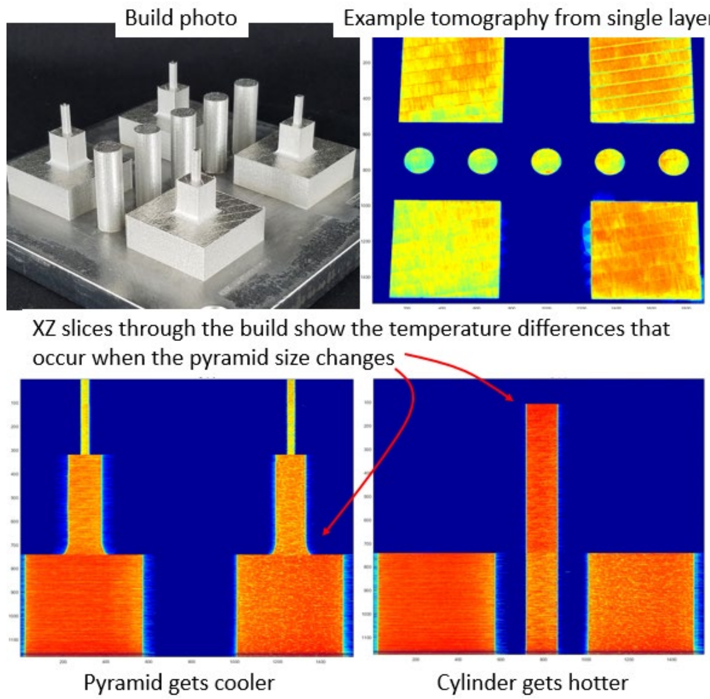

Figure 2

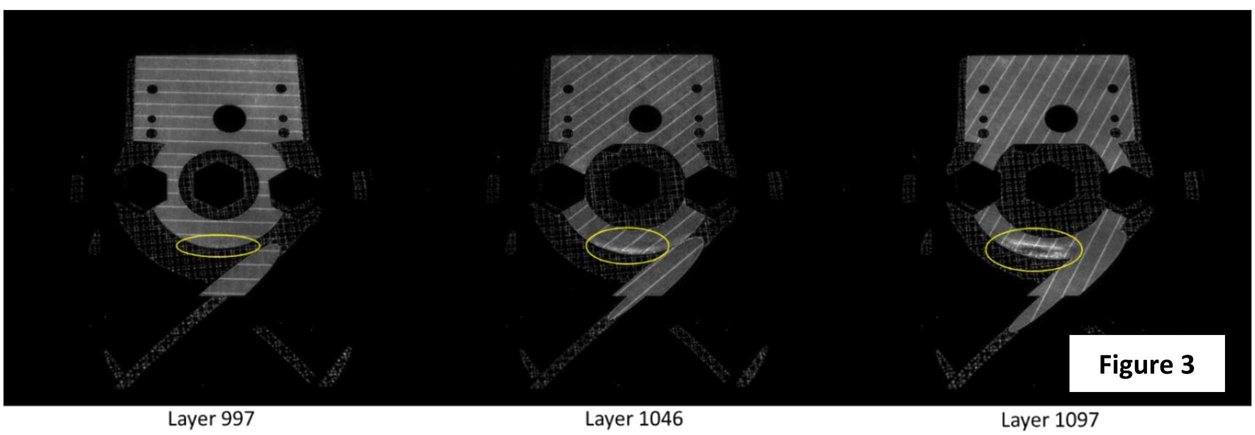

Figure 3

FUTURE OUTLOOK

Like other AMSENSE sensor modalities, there is a rich landscape of research and development that can be enabled through the collection and analysis of thermal tomography data. Research is ongoing through several AMSENSE users and development partners to create and demonstrate more advanced analytics around this data. With its detailed and intuitive visualizations, along with access to raw data, the sensor can also be of immediate use in process development, applications development, and production monitoring, even without more advanced analytics. The AMSENSE thermal tomography sensor thus provides a potential key element of an AM part's "digital thread".