Application Note

Improving Additive Manufacturing with the Help of Infrared

Additive manufacturing (AM), also known as 3D printing, is revolutionizing manufacturing. In contrast with subtractive manufacturing methods such as machining, AM technologies create components directly from a computer model, adding material only where needed. Heat is often an integral part of this process – one that needs to be monitored closely in order to see consistent results. This paper discusses how infrared (IR) cameras can help manufacturers find systematic problems and determine what changes are needed to maintain product quality.

Growing numbers of high-tech organizations are pioneering additive manufacturing (AM) technologies to use in applications ranging from product development to specialized manufacturing in fields such as architectural design, aerospace components, and medical implants. NASA has even sent two different 3D printers designed to operate in zero-G to the International Space Station.

The advantage of AM is it allows for far greater design flexibility, decreased energy consumption, and a faster time to market. But AM parts can be subject to quality issues, thermal stresses, and distortions that can be difficult to diagnose. Studying the process and its thermal properties with an IR camera can help manufacturers make quick corrections with minimal production delays.

FLIR SC8202 MWIR camera monitors a stage of the AM process.

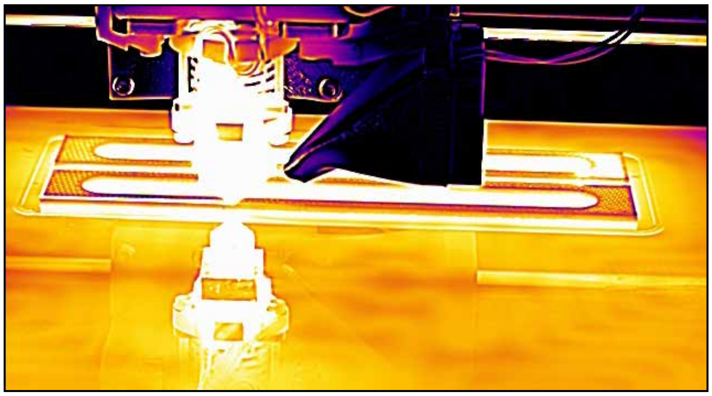
Taking Control of the Process

While researchers are experimenting with a variety of base materials – from carbon-fiber reinforced thermoplastics to living cells – the majority of additive manufacturers use metal- or polymer-deposition technology. These materials are proving tricky in their own right, as researchers are still working to improve the AM processes and to understand the reasons for process failures.

Additively manufactured parts are subject to a variety of quality issues, most often due to unknown cause-and-effect relationships between the manufacturing process parameter settings and the process characteristics. Too often, process parameters are set using trial and error techniques, which are time-consuming, costly, highly subjective, and machine- and material-specific.

The ability to monitor processing equipment, materials, and in-process part temperatures quickly and accurately is crucial to additive manufacturing research. Typical contact forms of temperature measurement, such as thermocouples, RTDs, and thermistors, would be difficult or impossible to use effectively.

The solution for many researchers is to use infrared science cameras: high speed, noncontact temperature measurement tools that can provide the data accuracy necessary to correlate in-process temperature data with measures of finished part quality. IR cameras can monitor the effect of changes to printer settings or to the materials used. These cameras can



Thermal image of an AM extruder laying material at high temperatures.

also help identify the source of quality issues such as part porosity, delamination of layers, shrinkage, poor surface finish, and dimensional and form errors, as well as thermal stresses and distortion.

Tools for Temperature Monitoring

IR cameras have the features needed to monitor temperature changes in a variety of materials. Ralph Dinwiddie, an AM researcher at Oak Ridge National Laboratory in Knoxville, Tennessee, says his lab uses IR cameras to measure temperature over several locations and stages of the production process. “We need the ability to record temperatures at high speeds and to calibrate these cameras with our own black-body source,” Dinwiddie explains.

Common tools for AM researchers can include high speed, midwave infrared (MWIR) cooled cameras, such as the FLIR X6900sc, and lower resolution, longwave infrared (LWIR) uncooled cameras, such as the FLIR A65sc. The differing capabilities of these cameras make each particularly suitable for specific sets of tasks. For example, the uncooled A65sc is compact and can be mounted easily on a polymer 3D printer to monitor the temperature of the extruder tip and/or the extruded material. Its thermal sensitivity of less than 50 mK allows A65sc cameras to distinguish between minor variations in temperature. For tasks for which high speed temperature measurements are crucial, the cooled X6900sc’s windowing capability allows for the faster frame rates necessary.

Oversized AM printers can create objects as large as a small car.

Dinwiddie says it’s vital to his research to have a camera with windowing capabilities. This means the camera reads out a smaller subgroup of pixels on the IR detector, reducing the number of pixels per frame. This allows the camera to send out more frames per second, achieving faster frame rates.

Accessories can be important, too, says Dinwiddie. “My work also demands a lot of flexibility in terms of lenses. For example, I’ve used telephoto lenses, wide angle lenses, standard 50-millimeter lenses, as well as microscope lenses, and a macro lens. I’ve also used extension rings so I can focus much closer than I’d normally be able to do.”

Although each new AM system or material presents its own set of characterization challenges, some common tasks include real-time detection of porosity while the parts are being printed with the e-beam systems. A pore typically appears on a thermal image as a dark spot. The cameras have also proven especially useful for “dialing-in” the correct processing parameters needed to prevent the formation of pores when working with new metal powder formulations.

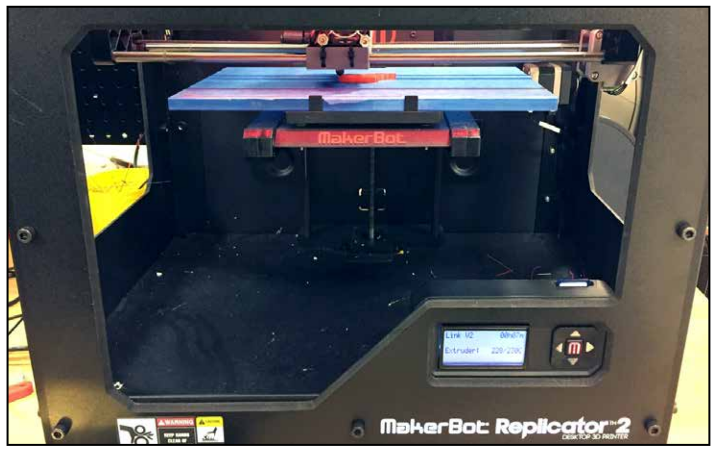


Table-top AM printer builds layers from polylactic acid (PLA).

IR cameras can help researchers better understand the role of temperature in the construction of polymer 3D systems. They can use the camera to measure the temperature of each layer of a part as it is applied and study how the temperature of lower layers affects the bond strength between layers. The cameras are also used to measure the temperature of the build chamber and monitor the thermal gradients in the part itself as it cools. With many polymer materials, uniform cooling helps reduce distortion in the finished part, which is why some 3D printers have a heated build chamber to slow the cooling of a part’s outside edges.

Conclusion

IR cameras have proven their value in advancing a wide range of emerging AM technologies by giving materials scientists the accurate results they need to fine-tune materials, equipment, and process parameters. This refining of the AM process will help the industry meet its expected rapid growth in the coming years.

For more information about thermal imaging cameras or about this application, please visit:

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