Laser Speckle Photometry for Inline Monitoring of Additive Manufacturing

Beatrice Bendjus*, Ulana Cikalova

Department of Applied Physics, Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Dresden, Germany

Commentary

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***For Correspondence:**

Beatrice Bendjus, Department of Applied Physics, Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Dresden, Germany

E-mail: **beatrice.bendjus@ikts.fraunhofer.de**

DESCRIPTION

Laser Speckle Photometry (LSP) is an optical and non-contact measurement method that allows to monitor inline fast manufacturing processes. This has already been presented here using the example of Multi Material Jetting technology (CerAM MMJ) to produce ceramic components from various materials. In the field of additive manufacturing of metallic components, Laser Powder Bed Fusion of Metals (LPBF-M) has proven its worth and has been widely introduced with commercial equipment from various manufacturers. However, quality assurance is still a problem. Inline, melt pool monitoring [1] and infrared thermography [2] are used. The former provides data on the stability of the process, but not on the material condition. Thermography measures the surface condition during production, but the local resolution is insufficient. The method also provides very large amounts of data, making further evaluation difficult. As a result of this insufficient monitoring of the surface or component condition, extensive tests are carried out after the manufacturing process using non-destructive methods such as ultrasonic testing, the dye penetrant method or by means of X-ray technology.

The first step was to develop an LSP sensor system to characterize the thermally activated speckle dynamics (LSP signal) generated during the additive laser beam melting process. For this purpose, the sensor system was mounted on the outside of an additive manufacturing system above the build chamber using a viewing window.
LSP data was acquired using 90° angled optics with a high-speed camera. Laser diodes with a power of 1 W were used for illumination. The resolution of the measurement system was between 30 and 49 μm (Figure 1).

Figure 1. Design of the LSP system for connection to the LPBF-M facility in upper area.

The LSP data were recorded during the sample manufacturing process. A total of eight specimen states were investigated. These different states were realized by varying two manufacturing parameters, welding speed and laser power. The sample porosity varied from 0.62% to 19%. For referencing the data generated by the LSP, all samples were subjected to Computed Tomography (CT).

Algorithms evaluating the thermal excitation after a selective melting of the sample area were used to evaluate the sample state. This concerned the area of the thermal zone and the cooling dynamics near the melting area. For this purpose, a special software was developed within the scope of the investigations, which evaluates the results locally and presents them in pictorial or tabular form. In this way, a concept was also developed for the automated evaluation of measurement data. The software recognized the position of the laser beam and automatically determined the parameters relevant for the evaluation of the sample condition. In the investigations, the inline capability of the LSP was proven for the detectability of the local size of the thermal zone, the integral porosity, and the topography. The evaluation of each layer took a few seconds for more than 100 points (Figure 2). Since the porosity is difficult to reference, the investigations focus on the determination of the thermal zone and the relationship to the final properties of the component.

Figure 2. Comparison of CT images of the selected layers with porosity determination and the determined parameters of the size of the thermal zone (as number of pixels, pixel was 16 μm in size).

In parallel, an idea was pursued to miniaturize the LSP sensor technology and attach it to the moving coater for powder application. In this way, the short moment between laser processing and renewed powder application can be used to examine the fresh surface regarding unwanted surface defects. The sensor technology for measuring a track of approx. 1 mm width has been completed (Figure 3). In later steps, the sensor technology is to be further miniaturized so that larger areas of the emerging component can be detected with several LSP sensors in the form of an array.

Figure 3. Design of the LSP system for connection to moving coater of the LPBF-M facility.

A third approach is currently aimed at coaxial integration of the LSP into the laser head of the machine (Figure 4). This requires an adapter for the sensor technology to the existing scanner in the system.

Figure 4. Schematic representation of the LSP sensor module for coaxial connection to the machine.

With this setup, it should be possible to measure the quality of the surface parallel to the machining shortly behind the welding spot. Fraunhofer IKTS has applied for or already received patents for all variants.

REFERENCES

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