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OCT – A versatile technology for laser material processing

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Abstract

Optical coherence topography (OCT) is a 3D imaging technique based on low-coherence interferometry. In recent days, it became a key technology in laser material processing. The OCT beam is coupled co-axially to the laser beam into the processing optics and provides surface information of the probe. Additional degree of freedom is obtained when the OCT beam is deflected using a small field scanner attached to the processing optics. This report elucidates the manifold use cases for an OCT-based sensor system in laser processing applications.

Keywords: Optical coherence topography; OCT; low-coherence interferometer; weld depth; seam tracking; image processing; 3D imaging

1. Introduction

Optical coherence topography (OCT) became a key technology in process control for laser material processing. It is a 3D imaging technique based on low-coherence interferometry. A beam splitter splits the OCT beam that originates from a low-coherence light source, into a reference arm and a probe arm (Fig. 1). The light of the probe arm is coupled co-axially to the laser beam into the processing optics. The light of the reference arm is reflected by a fixed mirror, while the light of the probe arm is reflected by the workpiece surface. The interference pattern of both arms is analyzed by a spectrometer providing information about the optical path length difference of the probe arm with respect to the reference arm. When the OCT probe beam is additionally deflected by a small field scanner attached to the processing optics, a depth profile of the workpiece is obtained. OCT-based sensing is applied in manifold laser processing applications and latest results are presented in the following sections.

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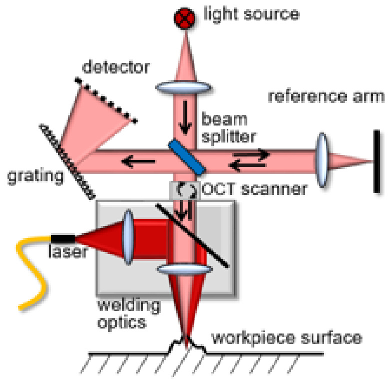

Fig. 1. Scheme of a low-coherence interferometer used in laser processing applications.

2. OCT weld depth monitoring

One possible application is using OCT to monitor the keyhole depth during the laser welding process assuring the weld quality in high mass production. The keyhole depth is a good measure for determining the weld depth in deep penetration laser welding. The depth information is obtained by subtracting the signal from the part surface from the signal from the keyhole bottom. The OCT-based measurement of the weld depth provides continuous information during the entire welding process while cross-section inspections provide snap-shots within the seam. The OCT-based depth information is immediately available and allows to take corrective actions in the production line and automatically discharge rejects. The potential of this technique is massively reducing the necessity for random cross-section inspections which are costly, time consuming and irreversibly destroy the parts.

The technology proves its robustness for many different materials and the measurement error is well below 10% of the weld depth depending on the material and welding situation. Lately, even goods results were shown in copper welding when combining the OCT weld depth measurement with the beam shaping technique BrightLine Weld from TRUMPF. The latter is based on a 2-in-1 fiber with an inner core and a surrounding ring and, in addition, adjustable processing beam power between both. The beam power distribution between core and ring fiber can be adjusted such that the processing beam couples better into the material and the keyhole is stabilized. As shown in Fig. 2, the stable keyhole formation enables the possibility to measure the weld depth using OCT even in copper.

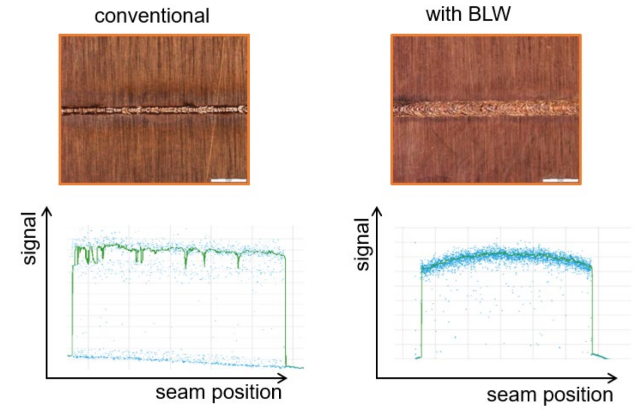

Fig. 2. Welding of copper at 6 kW laser power and 15 m/min feed rate does not allow for a stable OCT-based keyhole signal (left). In contract hereto, a stable keyhole measurement is obtained when using the beam shaping technique BrightLine Weld (right).

3. OCT seam tracking

A second application is using the OCT technology to track fillet seams in remote laser welding applications. This application is often used in car body manufacturing, as for instance welding of doors, A- and B-pillars or battery tanks. Fillet welding requires a high position accuracy of the welding spot in respect to the joint. Due to variances in workpiece dimension, in clamping tools and optics handling systems an active high-precision seam tracking is needed. OCT-based seam tracking fulfills this requirement at a precision of ± 50 µm with respect to the edge. The contact-free method has advantages over tactile methods because the welding speed can be doubled. In addition, it is not bound to any direction. The small field scanner of the OCT sensor system obtains the information by using the direction of the robot's movement and reacts to changes accordingly.

An often-faced challenge is the welding of Aluminum 6000 alloys. Its silicon component is known to lead to hot cracks. This is especially true for flange length shorter than 6 mm due to the thermomechanical stress. Again, the combination of the beam shaping technique BrightLine Weld and the OCT seam tracking is promising. BrightLine Weld allows to selectively control the local energy deposition in the weld seam. This reduces thermal gradients, thus avoiding hot cracks in short flanges, while the OCT seam tracker takes over the exact positioning of the laser beam. Even gaps between upper a lower joining partners can be bridged at highest welding speeds, as shown in Fig 3.

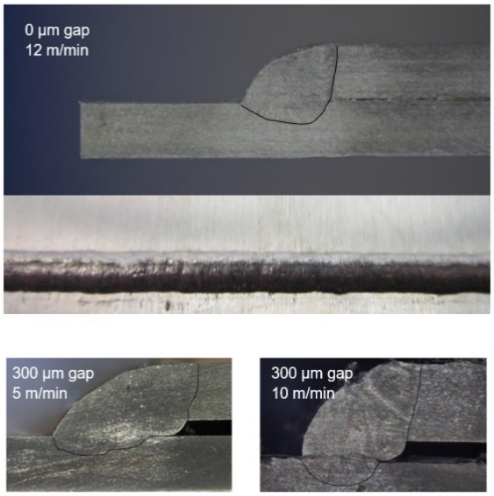

Fig. 3. Fillet welding of AL6082 for an upper sheet thickness of 1mm using the beam shaping technique BrightLine Weld. A gap of 300 µm could be bridged up to welding speeds of 10 m/min.

4. OCT feature detection

A third application is the 3D localization of parts before they are joined by the laser. Examples are pins welding in electrics and electronics or hairpin welding of coils in electric motors. The OCT sensor can sense the three-dimensional profile of the part. This allows precisely localizing a pin pair in space and positioning the processing laser beam accordingly. To take corrective actions prior to the welding process, other pin characteristics can be obtained as well. Examples are a gap, a displacement or a tilt between welding partners. After the welding process, the OCT sensor system can be used for post process quality assurance, for instance sensing the melt ball of a welded pin pair.

References

Dorsch, F. et al., “Capillary depth measurement for process control”, Proc. SPIE 10097, High-Power Laser Materials Processing: Applications, Diagnostics, and Systems VI (February 22, 2017).

Speker, N. et al., “Spatter reduced high speed welding with disk lasers,” Proc. ICALEO paper #408, (2017).

Hesse, T., „ OCT Process Control for Laser Welding “, presentation at 10. Stuttgarter Lasertage (June 5, 2018).

Hesse, T. et al., “Laser welding with beam shaping – latest application results,” Proc. ICALEO paper #702, (October 16, 2018).

Dorsch, F. et al.,”Controlling laser processing via OCT”, Proc. SPIE 10911, High-Power Laser Materials Processing: Applications, Diagnostics, and System VIII (February 7, 2019).