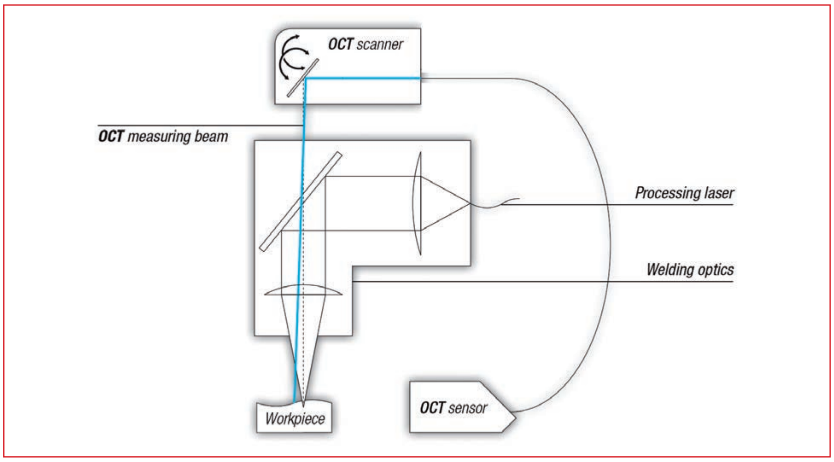
OCT Technology Allows More than Laser Keyhole Depth Monitoring

Simultaneous tracking and quality control by optical coherence tomography for laser processing

The use of laser processing heads implicates the shielding of the human operator from the manufacturing process because of laser protection. Therefore the modern laser processing is fully automated and robot driven. This necessarily requires smart systems for the precise and time efficient guiding the processing laser beam and automatic online quality control.

Among the variety of modern laser processing systems the innovative optical coherence tomography OCT is finally breaking cover and provides trend-setting solutions for simultaneous real-time tracking, monitoring and quality assurance. Optical coherence tomography, as non-destructive, instant and direct examination tool with near-microscopic resolution and with high data acquisition rate, is established as 3D imaging technique in medicine and biology. Since OCT performance is unaffected by the process light, its advantages are beneficial for laser processing that is aimed to be precisely controlled. So far, OCT is mainly used for laser penetration depth measurements, which does not give a complete satisfactory evidence about laser processing success.

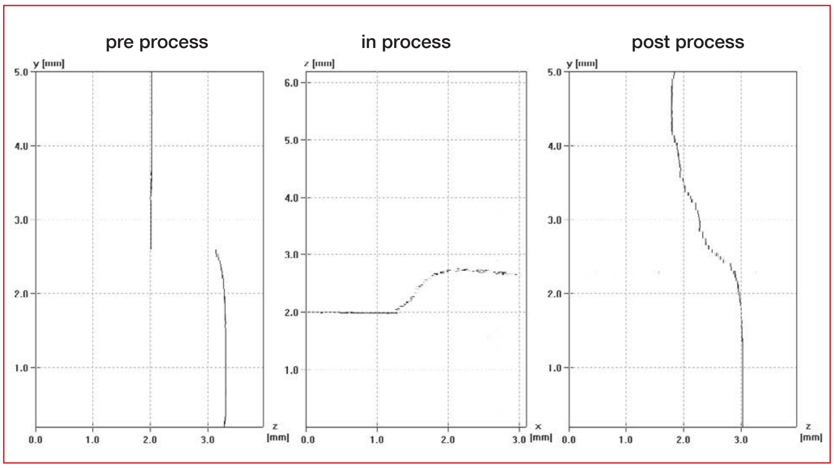
Lessmüller Lasertechnik has developed an OCT system for laser processing applications with emphasis on laser welding that combines seam tracking with simultaneous reliable quality control during both in- and post-processes. With over 400 WeldEye systems installed worldwide, Lessmüller Lasertechnik became a leading provider of online quality control systems for laser welding. WeldEye software adapted to OCT enables quality control assessment by comparing ongoing measured values with absolute or teach-in parameters. The data can be transferred via standard fieldbus interfaces.



Schematic demonstration of OCT operation. Simple integration of the Lessmüller OCT system into the welding optics by connecting the OCT scanner to the laser processing head through a camera port.

Unlike laser triangulation technique, operation coaxially to the process laser through the laser head optics makes OCT advantageous for omnidirectional laser processing application. OCT is also more precise than laser triangulation technique due to µm-accuracy on the one hand and singular point measurement, that gains no impact of unwanted reflections, on the other hand. The OCT measurements are performed regardless of focusing, speckles and interfering factors. Analysis of the interference signal based on the frequency eliminates the influence of the process light and allows to achieve many orders of magnitude higher scanning rates.

The main components of the system are OCT sensor and OCT scanner. The beam from broad bandwidth light source in OCT sensor is split in the interferometer into a reference arm (containing the reflector) and a sample arm (directed to the surface being worked). The sample arm is coaxial to the process beam. The reflection back to the interferometer from the both arms is then analyzed by the OCT sensor and the axial position of every measured point is evaluated.



OCT image obtained under 0° angle of incidence during an active laser welding of a fillet weld: the simultaneous detection of the seam joint position (pre-process seam tracking), the keyhole depth (in-process control) and the surface profile of the solidified seam (post-process quality assurance).

During the active laser processing, OCT scans the work surface with up to 160,000 measurement points per second per scan generating a 3D-profile with µ-resolution. One scan covers the melt pool together with the surrounding area (up to 12 mm) allowing simultaneous tracking and quality control. The integrated in OCT data processing algorithms determine in real-time the position being worked and the distance to the work surface. The OCT output signals are fed back into the processing head, the robot, or another guiding system for a full closed loop operation and the exact positioning and focusing of the laser beam.

Simultaneously, the penetration depth in the deep welding process is precisely evaluated by online depth profiling of the melt pool along the process

Lessmüller OCT sensor measures the axial position of the workpiece surface points with a resolution of 12 µm up to 160,000 times per second.

direction and acquiring the maximum depth value. The so measured laser penetration depth is minor influenced by the production line velocity. This value can be used for quality assessment or for adjusting the power of the processing laser online, if applicable.

The key QA-function of the newly developed OCT system is real-time high resolution topography measurements of the cooled surface directly after the process. Smart, high dynamic data evaluation tool provides online a complete overview of laser processing quality and, in case of failure, NOK message is generated. Thus the processing faults can be detected while processing and auto-corrected before the manufacturing process fails, solving the irregularities faster, thus reducing scrap rate, test costs and rework. Under those conditions efficient and productive laser processing can be attained: time-, material- und energy-saved with high quality achievements.

OCT can be easily adapted through the camera port to all conventional laser processing heads since camera ports of most laser processing optical systems show sufficient transmittance in ~830 nm OCT working wavelength. It can be installed on rigid optical systems, 1D, 2D or 3D remote scanners. Time-consuming process set-up and configuration can be omitted. Being compact and robust OCT system appears to be a simple QA-solution for laser processing technology in high or small volume applications.

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