

Three-dimensional, multi-factor monitoring and control of laser keyhole welding by inline coherent imaging

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Abstract

Direct measurements of keyhole geometry such as those provided by inline coherent imaging (ICI) are expanding options for process monitoring for industrial laser keyhole welding. ICI has been used to demonstrate real-time closed loop weld depth control. However, practical processing conditions demand a more robust registration of tool-path to workpiece than the position of the process optics alone can provide. Combining ICI with a beam directing system at the camera port of a commercial, fixed-optic laser head, we gain the ability to dynamically steer the ICI beam across the sample surface at millisecond timescales. Here we show how this 3D capability can be used to implement multiple process monitoring and control threads quasi-simultaneously. By sampling data from multiple points in and around the phase change region, we are able to implement autofocus and continuously correct motion error and distortion in the measured keyhole depth. In addition, transverse measurement sweeps of the leading region in common joint configurations enable seam-tracking for closed-loop correction of imperfect part geometry. We present results demonstrating seam-tracking and autofocus update rates on the order of kHz while simultaneously providing weld monitoring for quality control. The combined realization of these capabilities makes ICI a more robust and versatile weld process control and quality control solution.