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Improved continuous tube welding due to unique process sensor system and process control

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Abstract

A unique camera-based triple sensor system increases productivity, yield and quality of continuous welding of tubes and profiles. It combines high-precision seam tracking and beam positioning with weld spot visualization and characterization, and seam geometry measurement. The higher overall precision allows operating the process closer to its limits, online quality monitoring detects faults immediately. The process setup time is greatly reduced, and also the waste during startup is reduced. Finally, full documentation sets the basis for data traceability.

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Keywords: laser beam welding; process control; sensor system; seam tracking; keyhole diagnostics; roll forming process

1. Motivation / State of the Art

Laser beam welding of tubes and profiles from sheet metal stripes that are spooled from a coil is widely used, in particular for material like stainless steel where extrusion does not work. At the high welding speed of up to 20 m/min. (sometimes even more) CO_2-lasers are commonly used because they show a better weld seam quality and the tendency to form spatters or humping is much lower than with solid state lasers.

Using sheet metal from a coil – typically of some hundred meters length – requires continuous endless welding. Key to success is a good process control, in particular a precise positioning of the laser spot in respect to the joint, typically a butt joint. Presently, external seam tracking sensors that detect the joint with some centimeters forerun are state of the art.

The length of the forerun limits the feed rate for a given positioning accuracy and thus the productivity. A short forerun, in combination with a high detection speed is required.

After the welding, the seam quality needs to be checked almost immediately, because in many cases the welded tube is sawn and boxed or spooled to a coil again in one manufacturing flow. Therefore commonly, a

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test station for seam qualification is added directly in the production line.

With our integrated sensor we address all control and test issues of a tube mill or profile welding machine at once: We measure the joint position at very small forerun, we monitor the weld spot, and we measure the seam geometry immediately after solidification.

TRUMPF has introduced the SeamLine Pro sensor system previously for solid state laser applications [1]. Now, its unique features have been adapted and optimized to CO_2-laser tube and profile welding.

2. Experimental

Our **SeamLine Pro** is a unique system that is virtually an integrated triple sensor. It monitors three zones of the weld spot and its surrounding simultaneously, online and in real-time. It uses a fast CMOS-camera in quasi on-axis configuration (fig. 1). The sensor measures and controls the joint position for precise seam tracking ("*pre-process*"), the weld spot for process visualization and characterization ("*in-process*"), and the solidified seam geometry ("*post-process*") is measured. Integrated appropriate illumination modules, impinging lighting as well as laser line projectors, assure robust and reliable process observation.

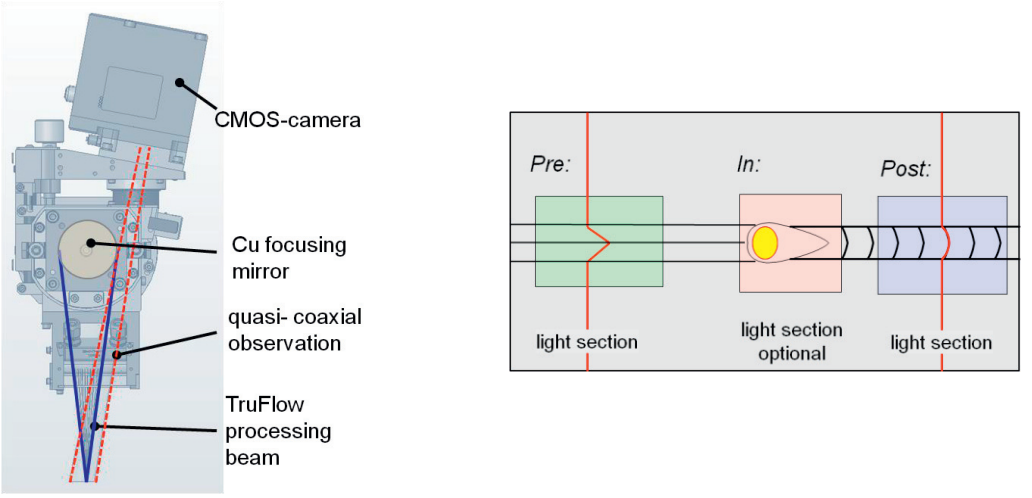

Fig. 1. Scheme of a CO2-welding optics with quasi-coaxial process observation with a CMOS-camera (left). Right hand side shows schematically the three sensors zones

All three sensor zones – *pre, in*, and *post* – are observed quasi-simultaneously with the same CMOS-camera through the same optics at a high frame rate. The camera images are recorded and evaluated in real-time by a high speed image processing system. The joint position (*pre*-process) is measured just a few millimeters in front of the weld spot (fig. 2) and in respect to the actual weld spot (*in*-process) (fig. 3). In combination both features together ensure an unparalleled positioning accuracy and allow high welding speed with low waste rate.

Weld spot observation (*in*-process zone) also allows process characterization e.g. by keyhole analysis.

The *post*-process sensor measures the seam geometry instantaneously and e.g. seam width, overfill or undercut are determined.

All data are evaluated online and cross-checked for plausibility and error tolerances for immediate fault detection and possible correction. Also, all data are stored for full traceability.

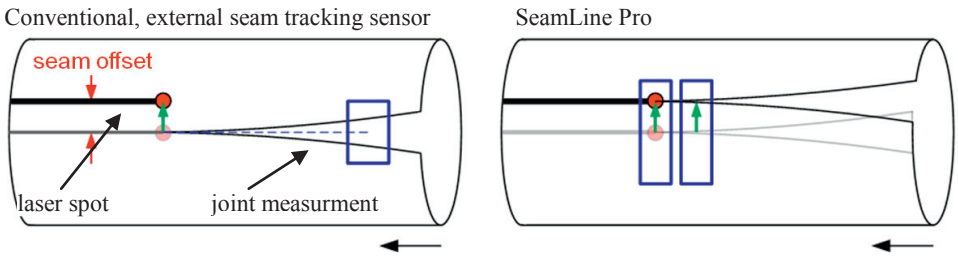

Fig. 2. Conventional (left) and integrated (right) seam tracking. Integrated seam tracking allows much shorter forerun which results in higher positioning accuracy. (The arrows indicate feed direction.)Results and Discussion

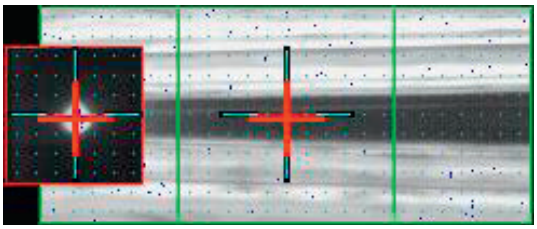

Fig. 3. Simultaneous observation of laser spot (left hand side) and butt joint. Illumination of *pre*-process zone with impinging light.

TRUMPF's SeamLine Pro sensor has been implemented in a roll forming system of a tube mill and is running in a real industrial environment for many months without problems. The enhanced positioning accuracy allows operating the welding process closer to the process limits. The integrated process visualization allows a simple and safe process monitoring for the machine operator. Together with the high and fast beam positioning, the process setup e.g. after change of an ingoing coil, is much faster and with less waste. Also, any affect due to a change of the processing beam path, which may be caused by a change or cleaning of a beam guiding mirror, is immediately corrected by SeamLine Pro, because the actual laser spot position is used as reference for the seam positioning.

The seam is measured and inspected e.g. regarding holes immediately after the welding process. As in many tube mills the seam is grinded inside the machine, a later seam measurement is not possible any more. Full quality control and data traceability is frequently demanded.

Finally, the weld spot is evaluated regarding specific characteristics which are determined by the details of the respective process. Because of the high flexibility of the advanced image processing, the evaluation can easily be adapted to a large variety of welding processes.

In summary, SeamLine Pro is the key to higher productivity of continuous laser beam welding processes. It also provides process visualization, quality control and full process documentation.

References

[1] Friedhelm Dorsch, Holger Braun, Steffen Kessler, Winfied Magg, Dieter Pfitzner, Sven Plasswich: Process Sensor Systems for Laser Beam Welding. *Laser Technik Journal*, June 2012, No. 3, pp. 24 (2012)