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AUTOMATED LASER BEAM WELDING OF TUBE/TUBE SHEET JOINTS

THE TASK

Heat exchangers cool liquids in various industrial machines. Spatial separation of primary and secondary media makes it possible to make use of the waste heat, which contributes to the efficient utilization of energy resources. However, manufacturing heat exchangers is a time and energy consuming process.

Welding of tube/tube sheet joints can be performed with a special TIG weld head centered in the tube by a pin. The head then welds with a rotating electrode. Over the years this technology has proved to be very reliable. The process is stable and not likely to be disturbed by outside influences due to the solid connection between weld head and workpiece. However, the process is also characterized by high heat input and slow speed yielding to thermal warpage and long process times.

The task is therefore to reduce time and energy consumption during the manufacturing of tube/tube sheet joints. Furthermore, an automated processing is desired for which laser beam welding is principally suitable.

OUR SOLUTION

The laser welding of tube/tube sheet joints was already successfully demonstrated. However, the industrial implementation has so far failed due to insufficient process robustness under actual production conditions.

An international consortium with project partners AIMEN Technology Center, Labor, CMF, ENSA, Fraunhofer IWS, Integasa, Precigal, Precitec and Sill Optics have now successfully implemented a laser welding process based on the TIG welder concept. An industrial robot now automatically moves the weld head from one welding location to the next, which was previously done by hand.

Development and testing of the laser weld head for tube/tube sheet joints was funded by the European Union under the program "Orbital" (FP7 262455). Fraunhofer IWS engineers developed the opto-mechanical concept, which determines the required welding path with respect to the axially located centering pin. The system was tested and validated.

Weld head parameters

Laser type	fiber coupled solid-state laser
Wavelength	1030 - 1090 nm
Fiber coupler	QBH, D-connector
Maximum laser power	2000 W
Maximum welding speed	5 m min^{-1}
Industrial robot	KUKA, ABB, other models upon request

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RESULTS

The welds should be fabricated in a fully automated manner (Fig. 2). The geometry of the tube sheet is given in form of CAD data. A post processor creates the motion program for the robot. Measurement routines are provided for each robot to define the coordinate system.

Cross sections of welded joints made from different materials

Inconel Ni-30Cr-9Fe
welding speed $v_s = 2$ m min^{-1}

Steel 1.4301
$v_s = 1$ m min^{-1}

Titanium SB265Gr.1
$v_s = 2$ m min^{-1}

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The software user interface allows the adjustment of individual laser welding parameters or to select already established parameter sets.

An automatic mode can be activated, which will perform a fully automated welding of the tube sheet. A manual mode is available for testing purposes and to evaluate the effect of weld parameters. A laser protection class 1 certification has been applied for.

Compared to the conventional TIG process, the laser welding process requires one tenth of the time. The automated laser process also decreases auxiliary process times, which reduces the total fabrication time even further. Only a fraction of the time is needed compared to the conventional process. From a materials point of view, tube/tube sheet joints were made from Inconel, stainless steel and titanium (Fig. 3). Complying with customer requests, the weld seam geometries correspond precisely to those of TIG seams.

1 *Titanium welding process of a tube/tube sheet joint*

2 *Laser weld head for tube/tube sheet joints*

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