

High-performance welding for safety-relevant applications

Deposition welding with reproducible, predictable quality for safety-relevant applications

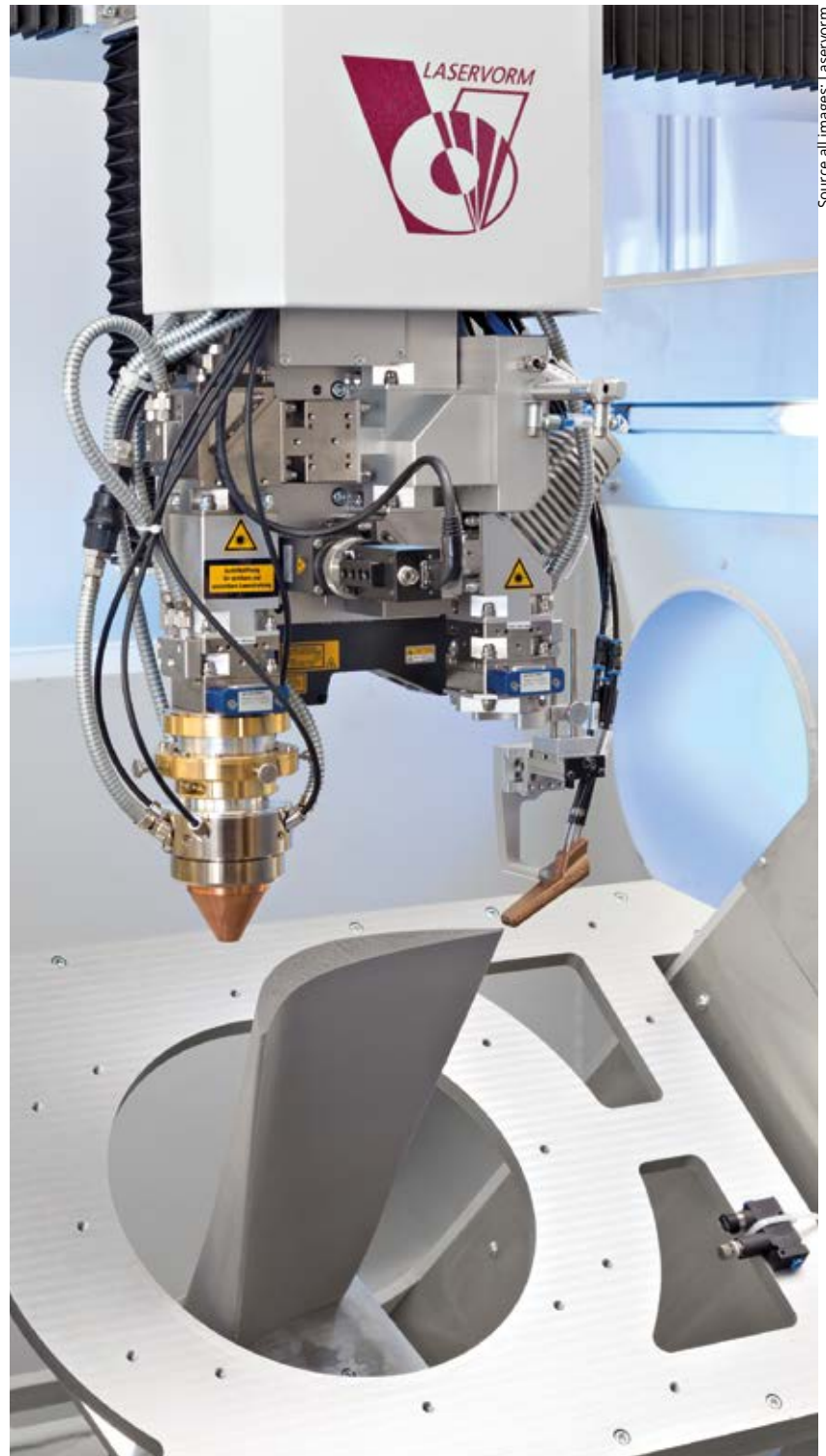
Laser deposition welding helps to speed up the repair process and reduces costs. An important component for this is the new tracing technology from Laservorm, which records at exactly which point of the component which parameters have had what effect.

Turbines are among the most powerful machines: they operate as gas turbines in engines, as steam and hydroelectric turbines in power generation, or in aircraft engines. Gas turbines have an output of up to 600 MW mech, in contrast to steam turbines generating almost 1.8 gigawatts in the largest nuclear power plants, such as the Olkiluoto nuclear power plant in Finland. Several individual steam turbines often operate here at high output in parallel. Hydroelectric turbines can reach over 700 MW, and jet engines in aircraft create up to 510 kN of thrust power.

The blades rotating in the turbines are subjected to enormous forces and are correspondingly susceptible to wear. In order to operate efficiently, turbine blades must be optimally shaped to ensure the best flow and are therefore built to very strict manufacturing tolerances. Even the smallest deviation from the optimum shape will reduce power or engine performance and increase fuel consumption.

Wear damage to aircraft turbines is caused by vibration, friction, or erosion due to sand and dust particles, hard landings or when birds are drawn into the engine. Each type of damage is different and has to be repaired appropriately. The process therefore requires accurate recording of the process data and its analysis.

A single new turbine blade can cost several thousand euros, depending on its stage within the compressor and the engine size. Repairing a blade costs significantly less than purchasing a new



Source all images: Laservorm

Fig.1 Tracing of the parameters is important for safety-relevant applications like turbine blade repair to control the cladding process.

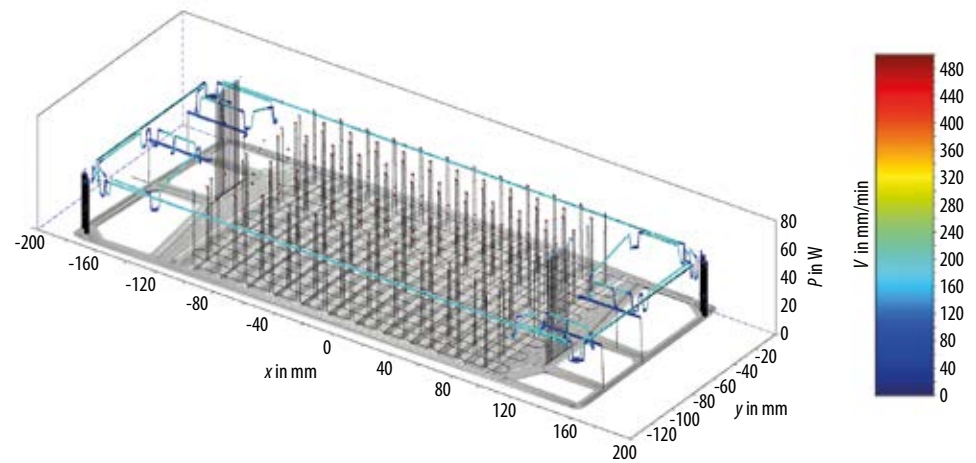


Fig. 2 When welding bipolar plates, 50 μm thick foils must be reproducibly tight and precisely welded, with a positioning accuracy of less than 100 μm for plate sizes of about 340 mm \times 130 mm.

part, although repairing is not yet the automatic choice. For this reason, such repairs can take from several hours to a few days, and, in the case of aircraft turbines due to strict quality assurance, up to three weeks. Since practically every damaged item is unique, the aim is to develop an adaptive and, if possible, self-learning process chain to make the repair process cost-efficient.

Laser cladding is the preferred technique for repairing turbine blades whereby the monitoring of basic characteristic data is now carried out as standard. The geometry of turbine blades is particularly challenging: a laser beam cannot be guided over the component at a constant speed due to the tapered shape and tight curve. Likewise, the material thickness varies, which leads to different run-out zones and, in the worst case, causes the molten pool to run away. Tracing is essential in order to avoid skewed components, as it can be used to determine exactly when the process no longer meets the desired parameters and corrective action must be taken.

Here, the joint project called “Transformation of complex product development processes into knowledge-based services for generative manufacturing – TWIN” aims to automate the repair process. TWIN documents the process variables and component properties that are important in production. This ultimately reduces personnel and material costs by avoiding failed attempts, and provides deeper insights into the manufacturing processes and its problems. Automation solutions can be designed in this way, and the first systems are already running largely autonomously.

Monitoring the basic characteristics of a 3D printer, such as oxygen content,

temperature, laser power and powder quality, is already standard. Other possible sources of error in laser melting are, for example, non-optimal scan speeds, or too much or too little energy input in the powder bed. The latter leads to powder that is not melted, which shows up in the form of irregularly shaped pores. A too high energy input causes the melt to boil and gas bubbles to form.

Project participant Thomas Kimme, CEO of Laservorm: “With the NC-integrated tracing function, our company has created a tool for real-time data logging in time slices of 800 μs (standard) and 10 μs (optional). This allows fast laser processes, such as welding with a feed rate of 1 m/s, to be recorded with sufficient accuracy and in relation to workpiece coordinates.” The convenient thing is that the user can now individually define which parameters are recorded in which time slices and windows. This means that tracing can be effectively adapted to the application purpose and help to better understand and control processes.

Parallel to the TWIN project, high-performance tracing and data transfer in real time was successfully carried out and tested with the welding of bipolar plates. This fast transfer of data provides the basis for AI-supported analysis of the data, enabling a real-time reaction to fluctuations in production and early prevention of errors. For this, the entire transmission chain must work and react fast enough, often in the range of milliseconds.

The data libraries generated by the data make it possible to draw conclusions about the processing of new materials and structural shapes, and to anticipate the actual assembly-build process by simulation, thanks to ‘digital twin’.

Reproducible high-performance welding of bipolar plates

In a sub-project of TWIN, Laservorm has developed its new tracing technology. The background is that heavy-duty traffic generates about 25 percent of the CO₂ emissions of the transport sector, which must be drastically reduced according to EU regulations. The fuel cell, which generates electrical energy and heat from hydrogen and oxygen, and thereby allows CO₂-free driving with a long range and fast refueling, is therefore becoming increasingly interesting for buses and heavy-duty transport.

A fuel cell stack consisting of 350 to 500 cells is required for an output of 100 to 150 kW. Between these units are bipolar plates that supply the necessary reaction gases and remove the resulting water. The bipolar plates account for up to 45 % of the production costs.

In addition, the manufacturing of the bipolar plates with their complex flow technology, tight tolerances during forming and high demands on the welding of the half-shells is problematic. The 50 μm -thick foils must be reproducibly

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Fig. 3 With tracing, the user can define which parameters are recorded at which time, and that these parameters are documented based on location.

tight and precisely welded. The required positioning accuracy of less than 100 μm for plate sizes of about 340 \times 130 mm is another challenge. In addition, bipolar plates must not warp after they have been welded.

“It is now time to research manufacturing processes suitable for large-scale production so that fuel cells can be put on the road in significant numbers,” says Dr Ludwig Jörissen, head of fuel cell research at the ZSW in Ulm. According to his estimate, it would be possible to produce about 10,000 units/year/standard of fuel cells. And he laments the poor availability of fast inline measurement and testing methods for robust and defect-free large-scale manufacturing. An essential step on this path is the new tracing technology.

Tracing technology ensures quality

The parameters must be just right for a laser system to weld fine structures, as required for bipolar plates at up to 1 m/s (Fig. 2). The new tool provides the data for this by closely monitoring the process and determining how changed

parameters affect the welding result. A special feature of the system is that the associated workpiece coordinates are also recorded.

“What is new about this tracing is that the user can define which parameters are recorded at which time and that these parameters are documented in relation to the location. Previously, this was only possible through our machine setter and could not simply be redefined on site,” Kimme says, pleased.

The technology is directly integrated into the control system and eliminates the need for an external data logger. The new method reliably collects and stores all process data from the laser process at time intervals of up to 800 μs . Among other things, the system records laser power, feed rate and position of the laser head, plus the exact coordinates of the spot where the laser beam hit the part. In this way, defects can be precisely determined in the case of quality problems, and the data obtained forms the basis for future AI-based process control.

The tracing technology consists of two software components. The TracingClient is integrated directly into

the controller and allows the values of all components connected to the controller to be read out. The TraceServer records the tracing data. This system can be integrated into the plant or operate externally. “This tracing technology is a development of our company and therefore best adapted to our systems. This guarantees high performance, and the correspondingly high data throughput allows tracing data to be recorded without delay, even for very complex, fast laser processes,” Kimme says.

The tracing data is provided independently of the respective system, e.g. in a csv file, for further processing with tools such as KNIME, MATLAB or Scilab, or via cloud-based KAnalysis platforms.

Documentation of control interventions

In adaptive processes such as laser cladding, the different measured values can be used to individually adjust the processing of each component. Thanks to coordinate-related recording of the data, possible trends and creeping errors and their causes can be detected at an early stage (Fig. 3). This means that during quality control, it is still possible days later to find out how each component was processed as well as why and where quality problems occurred. For AI to be able to guide the control processes, it needs the data in sufficient quantity in real time. This provides a solid basis for reacting directly to fluctuations in production in the future and counteracting the occurrence of errors at an early stage, not only for bipolar plates or turbine blades, but for all laser processes.

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