REVIEW

The Third Laser Colloquium Hydrogen LKH_2: Pioneer for the Fraunhofer Project H2GO

The third edition of the Laser Colloquium Hydrogen LKH_2 attracted 70 production professionals to Aachen with a special feature. After two virtual meetings, the third LKH_2 took place as a face-to-face event for the first time, which the Fraunhofer Institute for Laser Technology ILT used for live demonstrations at the institute's new hydrogen laboratory, which maps the entire process chain. At the two-day insider meeting of the hydrogen community, the LKH_2 guests also learned how the Aachen-based company intends to give wings to the "H2GO - National Fuel Cell Production Action Plan" with its research activities.

"Tomorrow's energy is water that has been decomposed by electric current. The elements of water thus decomposed, hydrogen and oxygen, will secure the earth's energy supply for an unforeseeable period of time." This is how Jules Verne raved about the fuel cell, the working principle of which the Swabian chemistry professor Christian Friedrich Schönbein discovered in 1838 during an experiment by serendipity. But the time was not yet ripe for Schönbein's gas battery, as he called it.

Is the breakthrough coming with the heavy-duty truck?

Jules Verne's vision may now become reality – but in road transport: More than 180 years later, Transport Minister Dr. Volker Wissing is counting on the major breakthrough of the fuel cell in mobile use, with 80 million euros in funding for truck fuel-cell production, which a consortium of 19 Fraunhofer institutes is to put into practice in the project "H2GO - National Fuel Cell Production Action Plan." Coordinated by the Chemnitz-based Fraunhofer Institute for Machine Tools and Forming Technology IWU, the ambitious project is expected to help reduce the cost of hydrogen vehicles in heavy-duty transport significantly, according to Wissing.

The third LKH_2 demonstrated how intensively research and industry are already working on this in Aachen. The colloquium focused on the series production of electrolyzers and fuel cells. Each of these so-called stacks requires around 300 to 400 bipolar plates (BPP) in addition to the membrane electrode unit. Production is still not only too slow, but also too expensive: Currently, the production of the so-called stacks costs a total of around 300 to 400 euros per kilowatt. The H2GO project is intended to help reduce costs to around 30 euros per kilowatt.

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The basic research carried out by the experts at Fraunhofer ILT in their new 300 square-meter hydrogen laboratory can contribute to improving production. Although there are similar facilities throughout Germany, Fraunhofer's lab has a special unique selling point according to Dr. Alexander Olowinsky, initiator of the LKH_2 and head of the Joining and Cutting department at Fraunhofer ILT: "Since we offer a wide variety of practical applications, our new hydrogen lab is unique." Guests at the LKH_2, who experienced live demonstrations at the experimental facilities in September, were able to see for themselves how, for example, ultra-thin metal plates 70 to 100 micrometers thick can be precisely cut and reliably welded into gas-tight stacks with the laser.

The intensive demonstrations also focused on how typical problems can be prevented not only in the laboratory but also under series production conditions. Here, artificial intelligence (AI) has already proven itself many times over in Aachen. Fraunhofer ILT scientists presented two examples among many: the first by Dr. Frank Schneider, of the Macro Joining and Cutting group at Fraunhofer ILT, who presented the digital process online optimizer for intelligent laser machines (DIPOOL). Here, the Aachen researchers combine the temporal and spatial programmability and controllability of laser tools with machine learning for the first time. As part of the BMBF project DIPOOL, the institute is working closely with a completely new type of multispectral sensor technology from 4D Photonics GmbH in Isernhagen, which Managing Director Christoph Franz also uses as a "WeldWatcher®" for welding bipolar plates.

Take two: Siamese neural network compares sections

The second example was provided by Christian Knaak of the Process Sensors and Systems Technology Group at Fraunhofer ILT. Knaak relies on a so-called Siamese neural sensor network for the rapid detection of splashes in BPP laser micro welding, which does not analyze the entire image but only compares characteristic sections. Looking ahead to further research, Knaak suggested that not only should the actual laser process be monitored with AI assistance, but also upstream and downstream process steps should be targeted.

Metallic 3D printing is also suitable for use in plate production. Electrolysers for hydrogen production, for example, require components that often consist of special material pairings. Dr. Andreas Weisheit, head of the Coating LMD and Heat Treatment group at Fraunhofer ILT, described how the institute produces such plates using laser material deposition (LMD). During laboratory tours at the institute, the LKH_2 guests saw how an LMD system coated a structural steel plate with a thin porous nickel-aluminum alloy.

Laser double beam prevents humping effect

It wasn't the first time at an LKH_2 event that the word humping effect was mentioned, which commonly occurs during laser welding: At high welding speeds, the molten pool lifts and beads; the seam becomes leaky. As a countermeasure, Dr.-Ing. Jan Weberpals, Subject Specialist Laser Beam Processes for Car Body Construction and Electromobility at Audi AG in Neckarsulm, recommended the ARM process from laser manufacturer Coherent. ARM stands for "adjustable ring modulation": the modulated interaction of the central beam with a laser ring. By selectively changing the intensity of the two laser beams, Weberpals was able to weld wafer-thin bipolar plates gas-tight and spatter-free at a rate of one meter per second. He is now targeting 1.2 meters/second, which seems to be reasonable maximum speed to him.

TRUMPF Lasertechnik GmbH, Ditzingen, also relies on targeted beam shaping. According to Ralf Kimmel, Director of Strategic Account Management, distributing the single beam of a single-mode laser over several beams has proven effective in taming the dynamics of the melt pool. In this way, the laser welding speed can be increased by more than 11 percent by selectively combining the central and ring beams with a variation in the respective laser power, without the humping effect occurring.

Always welding 20 percent below the limit

Weil Technology GmbH from Müllheim, Germany, which builds scalable systems for the production of up to 12 million BPPs per year, takes a different approach. In its prototype plant, the machine builder uses a "dual field scanner" with two lasers, each with a welding speed of 500 millimeters per second, which, in conjunction with fully automated clamping technology developed in-house, reliably welds bipolar plates every second. According to Arthur Schellenberg, Product Manager for Development and Innovation, process reliability is the top priority: Weil would therefore always remain at least 20 percent below the possible maximum speed during laser welding.

Laser welding under vacuum is a specialty of LaVa-X GmbH from Herzogenrath, Germany, which laser welds 50 to 150 micrometer-thin BPPs made of steel and titanium on a fully automated system using the method at a negative pressure of 1 millibar. According to Dr. Benjamin Gerhards, head of research and development, the advantages of the method are that it can be used to weld chrome-nickel steel without oxidation and titanium without embrittlement and subsequent cleaning. In addition, an extra welding pass can be eliminated since the process is far more reliable. In addition, the process, which has already proven itself in space projects such as MERLIN, can even be used to weld coated BPPs.

Special machine builder Graebener Maschinentechnik GmbH & Co. KG from Netphen-Werthenbach has around 20 years of experience in BPP production, developing complete, scalable systems for the production of several million plates per year. Managing director Fabian Kapp explained that the company chose laser fusion cutting to cut 50-micrometer-thin hydroformed titanium BPPs for quality reasons. Compared to waterjet-guided laser or abrasive waterjet cutting, the more precise edges created with high repeatability speak in favor of the process – a prerequisite for stacking the BPP.

Addressing the entire process chain with suppliers

Extremely thin sheet is also a specialty of Dutch special machine builder AWL-Techniek B. V. of Harderwijk, which offers complete scalable systems in modular design from 750,000 to 10 million BPPs per year. AWL Technology Manager Woute Zweers described cleanliness in laser welding as a key to high-quality production. To obtain tight and accurate seams, the Dutch company cleans the sheets before cutting. A special tip: AWL uses optical cameras for the final high-speed check of the seams, like many other manufacturers. Zweers, however, pointed out a sometimes neglected detail: optimal lighting during the quality check.

The complete process chain is offered by Andritz Soutec AG from Neftenbach (Switzerland) together with press manufacturer Schuler and Thyssenkrupp Automation Engineering: The chain is designed for the annual production of 50,000 stacks with 15 to 20 million BPPs. In shift operation, this can only be achieved if a plate is produced approximately every second. However, a laser welding speed of 500 millimeters per second is sufficient for this. Daniel Wenk, Vice President Business & Development, gave details: “We proceed conservatively by welding plates slowly with eight lasers at a speed of 30 meters per minute.” The cooperation is primarily concerned with safety, as they are entering new territory here. In Aachen, Wenk had one wish for the Fraunhofer consortium and the entire H_2 community: the formation of working groups to develop and standardize the production of BPPs – especially when it comes to leak testing.

Invitation to participate in the DPP research campus

In this way, the Swiss speaker addressed an important aspect that Prof. Arnold Gillner, Head of “Research Markets” at Fraunhofer ILT, also picked up on: “I also don't yet know how in-situ process control of leak tightness is supposed to work every second. There are still a lot of questions to be discussed next time. We can tackle these issues together here in Aachen at the Digital Photonic Production DPP research campus at our test facilities to get a hydrogen platform up and running.”

Interested parties can learn about the results of the work on the hydrogen future in the H2GO project and at the DPP research campus in Aachen, along with other topics such as battery technology, as early as January 2023 at the LSE'23 Laser Symposium on Electromobility. The fourth LKH_2 in September 2023 will once again offer an all-round event on hydrogen technology.

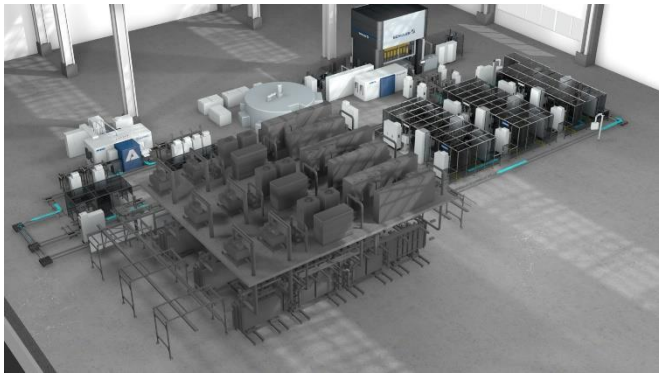

Image 1:
Turnkey to the stack: Schuler, Thyssenkrupp Automation Engineering, and Andritz Soutec supply the complete turnkey process chain (the picture shows the layout of a typical line) for the annual production of up to 50,000 fuel cells.
© Andritz Soutec AG, Neftenbach, Switzerland.

Image 2:
For the first time live: After two virtual events, 70 experts met in Aachen for the third LKH_2 Laser Colloquium Hydrogen of Fraunhofer ILT to jointly explore new paths into the future of hydrogen. The picture shows the new hydrogen laboratory.
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Image 3:
Many guests of Fraunhofer ILT took the opportunity of the laboratory tour to ask questions about the production of bipolar plates.
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Image 4:
Dr. Alexander Olowinsky, initiator of the LKH$_2$ Laser Colloquium Hydrogen and head of the Joining and Cutting department at Fraunhofer ILT: "Since we offer a wide variety of practical applications, our new hydrogen laboratory is unique."
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Image 5:
Daniel Wenk, Vice President Business & Development Andritz Soutec AG, Neftenbach (Switzerland): "We proceed conservatively by welding plates slowly with eight lasers at a speed of 30 meters per minute."
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Image 6:
Prof. Arnold Gillner, Head of "Research Markets" at Fraunhofer ILT: "We can tackle many topics together at our test facilities at the Digital Photonic Production DPP research campus in Aachen to get a hydrogen platform up and running."
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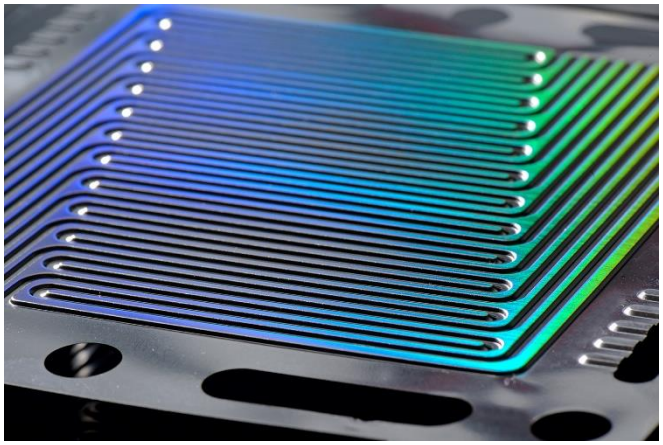

Image 7:
By means of UKP laser microstructuring functionalized bipolar plate (design of the bipolar plate: Dana Victor Reinz).
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