PRESS RELEASE

Hours needed to mill forming tools? A thing of the past!

Bipolar plates for fuel cells are mass produced every second. The forming tools used to manufacture them are milled from high-quality metal alloys that provide them with high wear resistance. In the National Action Plan for Fuel Cell Production (H2GO), the Fraunhofer Institute for Laser Technology ILT in Aachen is breaking new ground: Instead of milling the tools from an expensive solid block, the institute is using extreme high-speed laser material deposition (EHLA) to apply wear-resistant functional layers to low-cost structural steel close to the final contour. This reduces costs, construction time and tool wear. The EHLA process can also be used to repair damaged and worn tools, thus making a significant contribution to the circular economy.

"We are taking a completely new approach," reports Dora Maischner, project manager at Fraunhofer ILT. "Until now, forming tools for bipolar plates have been milled from high-quality tool steel in processes that take hours. We apply a wear-resistant functional layer close to the final contour on low-cost material." The researcher is working on a sub-project of R2HP (Ready to Hydrogen Production). This sub-project is part of the large-scale research project H2GO - National Action Plan for Fuel Cell Production, in which 18 institutes of the Fraunhofer-Gesellschaft are involved throughout Germany. Fraunhofer ILT is working with the neighboring Fraunhofer Institute for Production Technology IPT and the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz to develop the new process for manufacturing bipolar half plates. They aim to increase the service life of the highly stressed and precisely structured forming tools, while at the same time reducing their costs and construction times, and also to establish an efficient repair process for damaged or worn tools. The key to this is the extreme high-speed laser material deposition (EHLA) developed at Fraunhofer ILT.

Revolutionary approach to tool production

Modern ELHA 3D systems achieve speeds of more than 30 meters per minute. Thanks to digital process chains, the wear-resistant functional layers can be applied quickly and efficiently using the additive process. In addition, the three-dimensional material structure can be controlled so precisely that the highly wear-resistant layer welded onto low-cost structural steel comes very close to the intended final contour. Previously, it was milled from a solid block in an hour-long process that is very demanding on the milling tool; now it only needs to be finished in a targeted manner. The new EHLA-

Press contact
Petra Nolis M.A. | Head of the Communications Group | Telephone +49 241 8906-662 | petra.nolis@ilt.fraunhofer.de
Fraunhofer Institute for Laser Technology ILT | Steinbachstraße 15 | 52074 Aachen, Germany | www.ilt.fraunhofer.de

based process chain also minimizes costs because only a thin functional layer of high-quality material needs to be applied. At the same time, since the material is applied to near-net-shape and the mechanical processing is minimized, the construction time and tool costs for the milling heads, subject to enormous stresses from the high-strength material, can be reduced considerably.

What makes the EHLA process so special? The powder melts above the workpiece in the laser beam – in other words, it is deposited on its surface already in liquid form. "In the EHLA process, it is not the component but the powder that absorbs a large part of the laser energy before it hits the workpiece," explains Viktor Glushych, group manager Coating LMD and Heat Treatment at Fraunhofer ILT. The patented process significantly accelerates the deposition process compared to conventional laser cladding processes, minimizes the thermal load on the components and creates more homogeneous microstructures in the metal layers. This, in turn, improves wear resistance.

Increased wear resistance

The coating materials used in the ongoing research project are the high-speed steel 1.3343 and the martensitic stainless steel alloy Ferro55, both of which are characterized by high hardness and wear resistance. Maischner explains: "1.3343 has a hardness of around 830 HV0.5 and Ferro55 around 820 HV0.5. This puts them in the range of the standard tool steel 1.2379, which is used in both hardened and unhardened states." The wear protection can be applied at a coating speed of 30 meters per minute; a coating thickness of approx. 1.2 millimeters is achieved per layer. The required coating thickness can be set by applying several layers, a coating thickness of one millimeter in this case. The digital control system ensures that the material forms precisely and selectively, an advantage that makes it possible to produce robust wear protection coatings. According to the team's findings, the coating structure is even more important for wear protection than the hardness of the material. "This is because wear resistance depends to a very high degree on the microstructure of the material," says Glushych."EHLA produces extremely fine-grained microstructures, which improve the mechanical properties and, thus, significantly reduce abrasion. The fine-grained structure gives the coatings high resistance to wear, even under heavy loads."

The moment of truth comes with the sliding friction wear test

In order to precisely evaluate wear resistance, Fraunhofer ILT uses a sliding friction wear test from the Clausthal University of Technology, which simulates realistic wear scenarios for the application. The system presses a pin onto a counter plate with a defined force and moves it back and forth. The amount of material removed can then be measured very precisely. The results to date indicate significant advantages of the test specimens coated using EHLA compared to those manufactured with conventional materials.

To demonstrate the new EHLA-based process chain in practice, the team has set up a demonstrator on which it has used EHLA to coat simple structural steel (St37) with the high-speed steel 1.3343 close to the final contour. Both conventional milling and structuring with ultrashort pulse lasers are used for finishing at Fraunhofer ILT. Since mechanically processing materials with high hardness causes significant tool wear, the non-contact laser process is of great industrial interest. “Our aim in the project is to prove that the entire process chain from coating to structuring the biopolar plates is already covered by near-series processes,“ explains Maischner. The researchers want to test the resilience and wear resistance of different forming tools on a test stand at Fraunhofer IPT by the end of this year. They are focusing on forming processes close to series use, in which a bipolar plate has to be stamped every second, as required for efficient industrial production.“The method allows us to realistically test the service life of tools coated with EHLA,“ explains Maischner.

Re-use: tools with multiple lives

The team is also focusing on the efficient production and reuse of tools. “We are already in contact with companies that manufacture tools for bipolar plates and have received very positive feedback,“ explains Glushych. What is attracting interest, in particular, is the possibility of building up functional layers close to the final contour at the typical EHLA process speeds and, thus, significantly shortening the time-consuming machining ablative steps. The option of reconditioning worn tools using the same EHLA process has also met with positive feedback. This is because instead of having to melt down tools at the end of their service life, the industry can rebuild the defective or worn contours and mechanically finish them using EHLA in accordance with the digitally stored construction plan.

The new process chain can thus pave the way for repeated re-use of tools; such closed-loop processes are in demand because they prevent the downgrading of high-quality alloys and also eliminate the need to melt down worn tools and to transport the parts, both of which consume a great deal of energy. As soon as the tool wears out, users can mill the layer back to a defined, digitally stored contour on site and coat it again using EHLA. “This procedure conserves resources and allows tools to be used for the long-term,“ emphasize the Fraunhofer researchers.

EHLA coating reduces fine dust pollution

Successes in the passenger car sector may encourage other potential users to enter this new form of toolmaking. EHLA has proven to be an effective process for wear protection coating: In the case of brake discs, the thin, firmly adhering EHLA protective coatings have been able to significantly minimize abrasion. The advantage not only benefits car owners, but also can significantly reduce the amount of particulate matter in the environment. This know-how forms the ideal basis for advancing the mass production of ultra-thin bipolar plates for commercial vehicles.

H2GO - National Action Plan for Fuel Cell Production

The H2GO project started in May 2022 and will run until November 2025. The Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz is coordinating the joint project, which is funded by the Federal Ministry of Digital and Transport (BMDV) with 80 million euros. Eighteen Fraunhofer Institutes are developing cost-effective production methods for fuel cells in order to convert heavy duty vehicles to emission-free drivetrains. "With our funding, we want to help generate marketable products from research on an industrial scale," explained Transport Minister Dr. Volker Wissing at the project launch.

EHLA process - an innovation from Fraunhofer ILT

The Fraunhofer Institute for Laser Technology ILT has continued to develop the patented Extreme High-Speed Laser Material Deposition (EHLA) process for new applications since 2012. This allows surfaces to be protected against wear and corrosion in an efficient and environmentally friendly manner. In the EHLA process, the powder is melted directly in the laser beam before it hits the component. As a result, the powder absorbs the majority of the laser energy, which significantly reduces the thermal load on the base material. Coating speeds reach several hundred meters per minute and layers with a thickness of 30 to 400 micrometers can be produced.

The process is also cost-effective, as up to 90 percent or more of the material used is actually applied to the component. Applications can be found in the automotive and aviation industries as well as in offshore facilities, where resistance to wear and corrosion is required.

The process has become more versatile with the extension to EHLA3D: Fraunhofer ILT has transferred the process to high-speed kinematics in collaboration with the machine manufacturers Ponticon and Makino. Now EHLA3D not only enables fast coating, but also the precise additive manufacturing of complex, three-dimensional geometries with various high-strength materials such as tool steels, titanium and aluminum.

EHLA has received several awards, including the Joseph von Fraunhofer Prize in 2017 and second place in the Steel Innovation Award in the "Steel in Research and Development" category in 2018, as well as the first Berthold Leibinger Innovation Award.

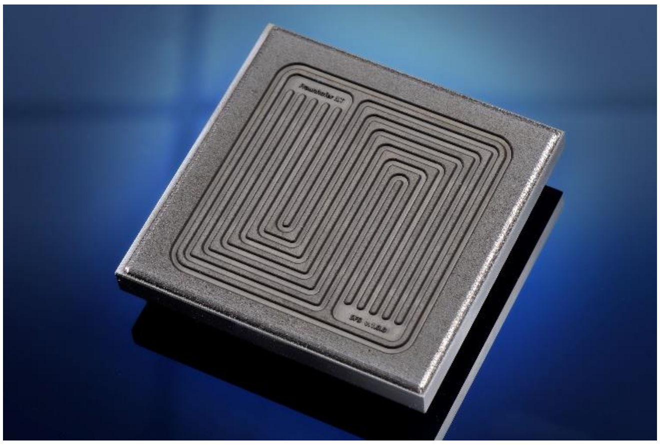

Image 1:
Demonstrator for EHLA technology: 3D printing and finishing by conventional milling are what make this tool stand out; it can be used to produce which bipolar plates economically, quickly and sustainably in seconds in the future.

Image 2:
Test facility in the H2GO project: Fraunhofer ILT coats components for fuel cells quickly and precisely with wear-resistant coatings on an EHLA system in preparation for large-scale production.

Image 3:
"EHLA creates extremely fine-grained microstructures that improve the mechanical properties and thus significantly reduce abrasion." Viktor Glushych, Group Manager Coating LMD and Heat Treatment at Fraunhofer ILT.
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Professional contact

Viktor Glushych M. Sc
Head of Coating LMD and Heat Treatment Group
Telephone +49 241 8906-152
viktor.glushych@ilt.fraunhofer.de

Dipl.-Ing. Dora Maischner
Group Coating LMD and Heat Treatment
Telephone +49 241 8906-8017
dora.maischner@ilt.fraunhofer.de

Fraunhofer Institute for Laser Technology ILT
Steinbachstraße 15
52074 Aachen, Germany
www.ilt.fraunhofer.de