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Laser cladding of forming tools for bipolar plates for wear protection and repair

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Abstract

The development of advanced coating techniques for forming tools of bipolar plates is crucial for the advancement of fuel cell production to improve service life and enable a fast and robust repair. The aim of this work is to develop a coating process and a digital process chain for protecting and repairing forming tools to enable cost reduction and scaling in fuel cell production. Different high alloyed Fe-based coating materials (e.g., tool steel M2) were tested concerning layer quality and hardness. In the context of the digitized process chain, scanning of the tool surface before and after the cladding process was investigated regarding accuracy and generation of geometry data of the surface for path planning of both cladding and post-processing.

Keywords: Hydrogen technology; forming tool; bipolar plate; additive manufacturing; laser metal depostion; extreme high-speed laser material deposition (EHLA); laser cladding; LMD; coating; wear resistance, corrosion protection; repair

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1. Introduction

The goal of the H2GO initiative (National Fuel Cell Production Action Plan) is the economic production of fuel cells used in cargo mobility. The research presented here was carried out within the R2HP network (roll to half-plate). Within the R2HP network advanced coating processes and a digital process chain for the coating and repair of forming tools is to be developed to enable cost reduction and scaling of fuel cell production. The coating and repair of the forming tools to produce the bipolar plates will be realized with the help of the advanced extreme

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high-speed laser material deposition (EHLA). The acquisition of the bipolar plate geometry data is a prerequisite for the utilization of the EHLA process for coating of the forming tools, in addition to the qualification of the process for the given task (combination of coating and base material).

2. Process principle and system technology

2.1 Process principle

At the Fraunhofer Institute for Laser Technology, the EHLA process was developed as a high-speed variant of laser material deposition (LMD). In Figure 1 the EHLA process principle is compared with the conventional laser material deposition.

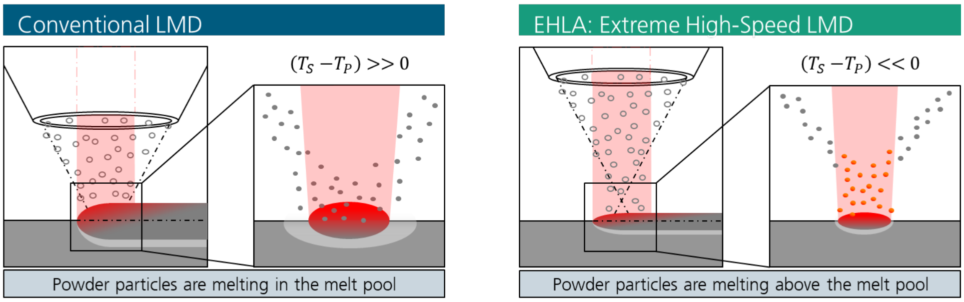


Fig. 1. Extreme high-speed laser metal deposition (EHLA) versus conventional laser material deposition (LMD)

In laser material deposition, the powder gas jet is focused on the interaction zone between laser beam and workpiece. The melting of the powder takes place in the melt pool. With the EHLA process the powder jet focus is located above the surface. This allows the particles to be molten above the melt pool, thereby greatly increasing the achievable process speed. With EHLA, feed rates of over 500 m/min are feasible, while also reducing the heat-affected zone to 20-100 µm. EHLA coatings consist of one or more layers, which typically have a thickness between 25 and 400 µm each. Alongside the very high coating rates exceeding 5 m²/h, EHLA coatings exhibit remarkably low surface roughness. Despite the high process speeds and the low heat impact on the substrate, a fusion-metallurgical bond is created between the coating and the base material.

2.2 System technology

Commercially available disk, diode, and fiber laser systems in the multi-kilowatt range can be used as beam sources for the EHLA process. The workpiece handling must be capable of achieving the required process speeds with sufficient accuracy. The metal powder is conveyed with commercially available powder feeders. A HighNo 5.0 EHLA nozzle was used to focus the powder jet within the scope of the presented investigations. The HighNo 5.0 is a joint development between Fraunhofer ILT and HD Sonderoptiken, specifically designed for use in the EHLA process. The versatility of EHLA coating technology provides application for small components with diameters of a few millimetres as well as for large components with dimensions in the range of several metres. The initial investigations of the process were related to rotationally symmetrical components.

Schaible et al. initiated the transfer of the rotational symmetric EHLA process to an additive manufacturing and freeform caoting process by validating the EHLA technology on both, a gantry-type and a dedicated

EHLA3D tripod system. So far stainless steel (316L) as well as several Ni-based and Al-based alloys have been developed and validated for EHLA3D.

3. EHLA process for coating of wear layers on mild steel

For the results shown below, 1.3343 was used as the coating material. The hardness of this material depends to a large extent on the manufacturing process and the heat treatment condition. 1.3343 is often used in milling and cutting tools as well as die applications. The chemical composition of 1.3343 is given in Table 1.

Table 1: Chemical composition of 1.3343

Elements	C	Si	Mn	P	S	Cr	Mo	V	W
Min.	0.86					3.80	4.70	1.70	5.90
Max.	0.94	0.45	0.40	0.0300	0.0300	4.50	5.20	2.10	6.70

Due to its high achievable hardness, this material is predestined for use in wear protection. However, the deposition of this material by laser is challenging due to its brittleness associated with the high hardness. Figure 2 shows a 1.3343 EHLA coating applied on St14. St14 is a structural steel and is often used for forming tools. The final coating layer thickness is approximately 140 µm and is thus in the lower thickness range of typical wear protection coatings. The coating that was applied at a feed rate of 30 m/min is free of cracks and exhibits a low porosity.

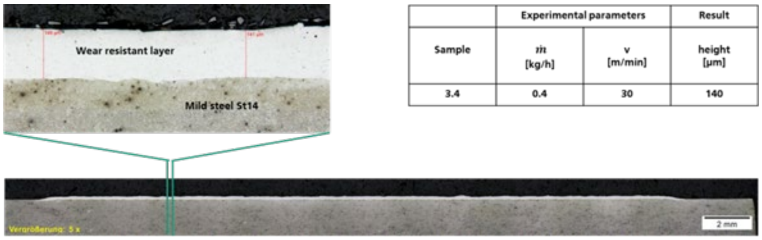
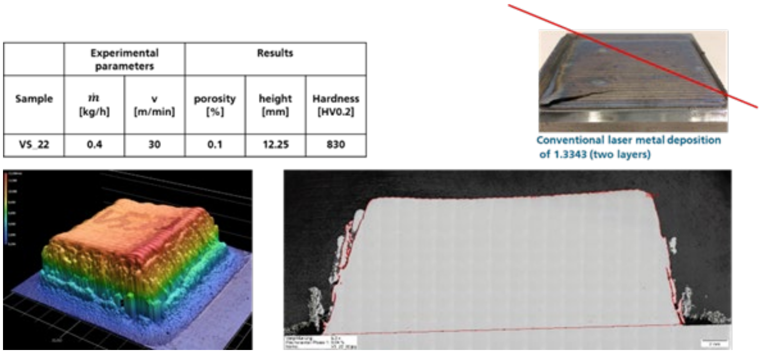


Fig. 2. Application of a 1.1334 EHLA coating on an St14 substrate

The layer thickness that can be achieved with the EHLA process is not limited to the range of few micrometers. Figure 3 shows the application of 1.3343 on a 1.3343 substrate. A crack-free coating with low porosity with a total thickness of above 12 mm could be produced. The EHLA process not only enables productive coating through high feed rates but also the multi-layer application of extremely brittle materials that cannot be applied in multiple layers using conventional laser material deposition. The shorter temperature-time cycles achieved in EHLA give the material less time to form precipitates, potentially reducing the susceptibility to crack formation.



	Experimental parameters		Results		
Sample	$\dot{m}$ [kg/h]	v [m/min]	porosity [%]	height [mm]	Hardness [HV0.2]
VS_22	0.4	30	0.1	12.25	830

Fig. 3. Application of 1.3343 to a base material which is made of 1.3343

4. Acquisition of bipolar plates geometry data

For the coating of forming tools, the geometry data of the forming tool must be generated. The data is required to enable path planning for the coating process. In combination with computer-assisted path planning, the EHLA process allows a near shape coating application. The finishing of the wear protection layer is performed by milling or electrical discharge machining (EDM). The process chain for repair of forming tool parts is identical, except that here a local coating and finishing is performed based on the inverse geometry data of the bipolar plate (see Figure 4).

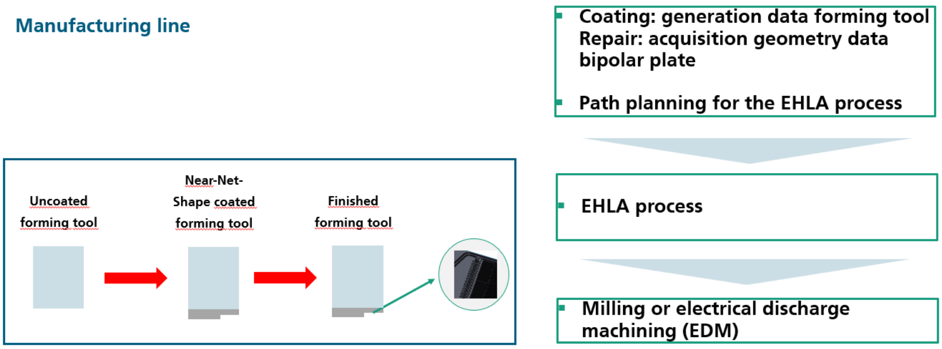


Fig. 4. Manufacturing line for coating and repairing of forming tools for the production of bipolar plates

Figure 5 shows the acquisition process for the inverse geometry data of the bipolar plates. By merging the scans in x and y direction, hidden corners and undercuts can be made visible. Existing artefacts due to reflections are cleaned up.

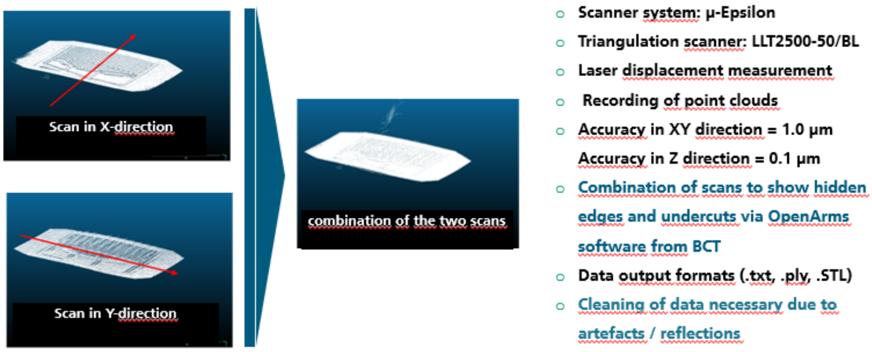


Fig. 5. Acquisition of the bipolar plate geometry data

5. Summary and next steps

The material 1.3343 can be applied to St15 without cracks and with low porosity using the EHLA process. A coating hardness of 830 HV [0.2] was measured on the produced samples. In contrast to conventional laser material deposition, crack-free 1.3343 multi-layer coatings can be applied with the EHLA process, which is presumably attributable to the high feed rate of 30 m/min. Coating thicknesses of more than 12 mm can be achieved with the same type of processing. When determining the geometric data for coating or repairing a forming tool, merging the scans in x- and y-direction allows the detection of hidden corners and undercuts.

In the next steps, further wear protection materials such as Ferro 55 are to be qualified for the EHLA process. Comparative sliding friction, wear and corrosion tests are to be carried out for different coating thicknesses. Finally, laser-coated forming tools will be produced and tested under real conditions.

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