Article 3: Trends in the Technology; Part 1

By Dr. Arkadi Zikin - Head of Laser Center of Competence, Wohlen, Switzerland
Email: arkadi.zikin@oerlikon.com; LinkedIn: https://www.linkedin.com/in/arkadi-zikin/

My intention is to help you to decide for yourself whether EHLA, high-power laser cladding or any other type of process is the right choice for you. It is important to mention that I try to focus on what is already available on the industrial scale, rather than scientific laboratory scale, as in my eyes those two worlds are not the same and the latest trends do not always mean a stable process under industrial conditions. I will be happy to receive your feedback if the information you read doesn't give a full picture and want to learn more.

Note: All the images in this document are by permission of content providers or are taken from open access internet sources and are linked to the reference. My intention is not to advertise any of the companies, it is more to show the trends in the world of laser cladding.

Where will technology development lead us?

Nowadays more and more companies show interest in laser cladding. Some of them want to purchase a system for their applications, some might be interested in service or cooperation and some just want to understand how competitive this technology is compared to existing solutions like thermal spraying, hardfacing or, for example, hard chromium plating. With this article, I want to give you a short overview of the latest developments within the technology, which might help you get an idea of the possibilities and answers to questions like:

- What are the latest trends in the laser cladding world?
- What are the main developments in terms of productivity?
- What possibilities do we have and what might be important to consider if you decide to work with laser cladding?
- Should I work with a circular or rectangular spot?
- Is EHLA the right choice for me?

Let's try to answer those questions together. Probably the best would be to start from the roots. Laser cladding has been used for over twenty years to salvage high-cost components in markets such as aerospace and energy. Then lasers were quite expensive, and an energy source of 2 to 3 kW power was considered high-tech — enough to repair turbine blades, but way too expensive for many other applications. In those twenty years, many things have changed — prices for lasers have dropped almost by a factor of ten and also the high power lasers (let's say 10+ kW) became convenient to use in industrial conditions. I think that was one of the main factors explaining why the technology is finally of high industrial interest — it became price competitive to alternative surface treatment solutions for a wider scale of applications. Furthermore, the technology has also developed and now offers a variety of deposition options, which I have tried to summarize in Figure 1.

For starters, let us focus on three main groups:

High-speed Laser Cladding

Let's keep the name of EHLA, as it relates to the principle of melting most of the powder before it interacts with the surface. This process has been grabbing attention in the market in the last couple of years. It is phenomenal how rapidly it has developed. Imagine that the first R&D system was installed by Hornet at Fraunhofer ILT back in 2013 and there are over 50 systems operating worldwide in research and production activities. My personal view on the EHLA development curve is presented in Figure 2. Please let me know if I have missed some of the facts. What makes EHLA so exciting? Imagine you can use it for rotationally symmetrical bodies and deposition velocities, in the range of 100 to 200 m/min (328 to 656 ft/min) or greater. With that, we can produce coatings that are thin, dense and metallurgically bonded to the substrate with excellent properties. On average per pass, it is possible to get a thickness between 50 to 300 µm (0.002 to 0.012 in). A surface roughness after deposition of Rz < 50 µm can be achieved . Additionally, it is possible to remelt the surface by the interaction of the laser spot with the deposited coating. It

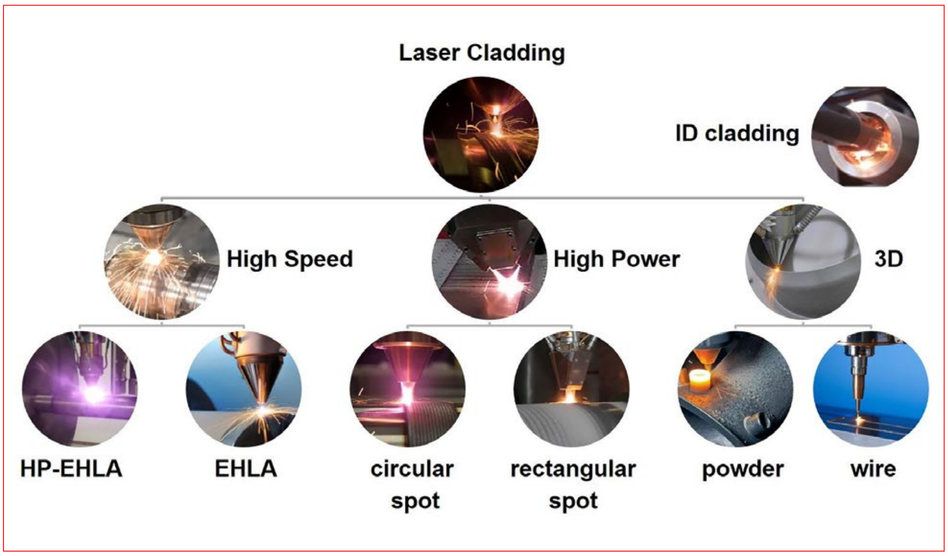

Figure 1: Classification of Laser Cladding

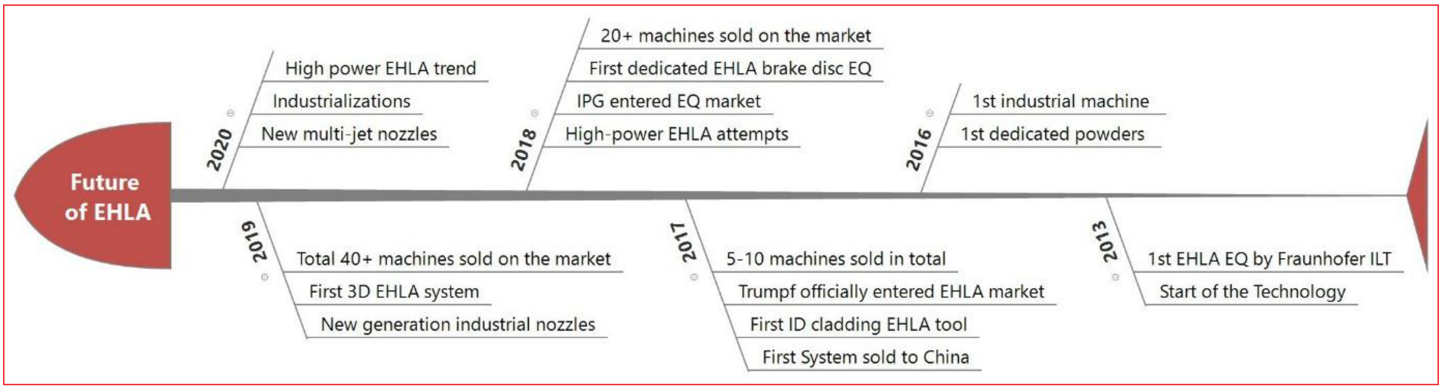

Figure 2: EHLA development status June 2020

does remove some of the asperities and smooth the coating, dropping Rz values below 20 µm. Some examples of EHLA surface quality and cross-sectional images are shown in Figure 3. You can see, that EHLA can be applied directly on the surface of cast iron, or the propagation of cracks on hard materials like Metco 15E (hardness over 800 HV), can be significantly reduced or avoided (for example by pre-heating the components).

The above-mentioned benefits make EHLA an attractive technology and push further developments. Nowadays in 2021 (August) everyone talk about deposition rates exceeding 4 m²/h with high-power EHLA. Those values put EHLA in competition with thermal spraying, spray and fuse and even hard chromium plating. High-speed laser cladding is also getting more and more attention from the application side, in particular for discussions and advertising about hydraulic rods and brake discs, show us just the tip of the iceberg for the potential technological direction.

When considering technological challenges, I see two main directions for high-speed laser cladding:

- **Materials.** I strongly believe, that due to the rapid cooling and application of fine-grade powder particles (-53 + 20 µm) the development of new generation materials are of high importance and interest. At Oerlikon, we put a lot of attention on that topic. One of the examples is shown in Figure 3, as a modern coating solution on complex substrates. Utilizing our unique Scoperta™ Rapid Alloy Development (RAD) technology, Oerlikon Metco has developed breakthrough material solutions (Metco 1020 and Metco 1720) for protecting hydraulic cylinder rods from wear and corrosion that can be applied using standard laser cladding or EHLA processes.
- **Industrialization**, and by that I primarily mean the reliability of the process and new-generation nozzles, which can ensure stable operation for series production. There is a lot of work done in that direction and in 2020 we have a couple of new generation nozzles already available on the market. I don't want to compare the nozzle suppliers, as I intend to show what is available, and let you decide which of the ways you would prefer. The overview of the latest nozzles is shown in Figure 4. There are mainly two working principles: coaxial powder supply and multi-jet powder supply. Both new-generation nozzles can currently work with powder volumes over 100 g/min (13 lb/h) and with energy power over 10 kW.

High Power Laser Cladding

Laser power exceeding 10 kW can be divided into two main fields:

- **Working with circular spot geometry.** Here the latest development is the spot size which can be cladded up to 12 mm (0.47 in) in diameter, with depositions velocities over 1.5 m/min (4.9 ft/min). The logic behind this is very simple — a bigger spot and higher velocity are compensated for by the power of the energy source.
- **Working with rectangular spot geometry.** Nowadays there are flat-jet powder nozzles available with rectangular geometries up to 45 mm (1.77 in) in width (Figure 6). The powder consumption, however, also increases accordingly and can go upwards of over 300 g/min (40 lb/h). Also due to the large area of interaction between the laser spot and the substrate surface, high power laser is required.

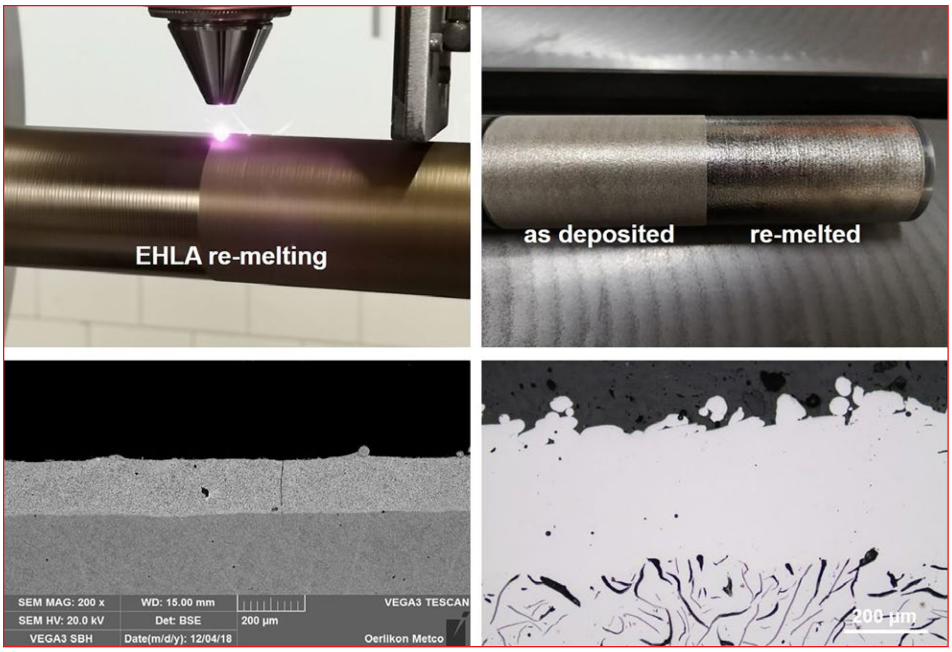

Figure 3: Surface quality after EHLA and re-melting; Cross-section of microstructure for Metco 15E (on the left side) and new generation Metco Fe-based alloy, deposited directly on cast-iron.

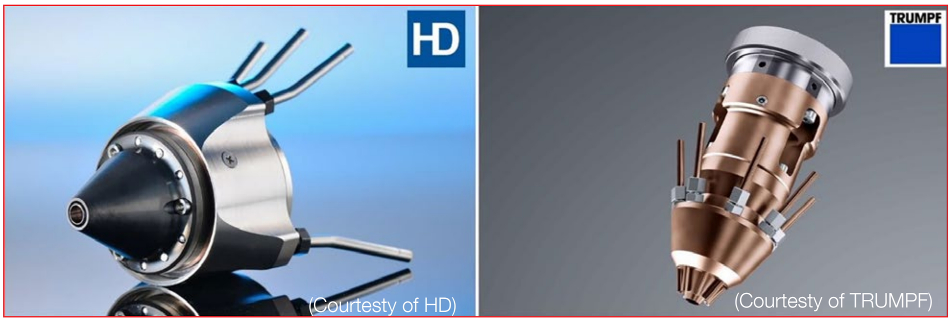

Figure 4: Highno EHLA nozzle by HD http://hd-sonderoptiken.de/en/; Multi-jet EHLA nozzle by Trumpf https://www.trumpf.com/en_INT/applications/additive-manufacturing/laser-metal-deposition-lmd/

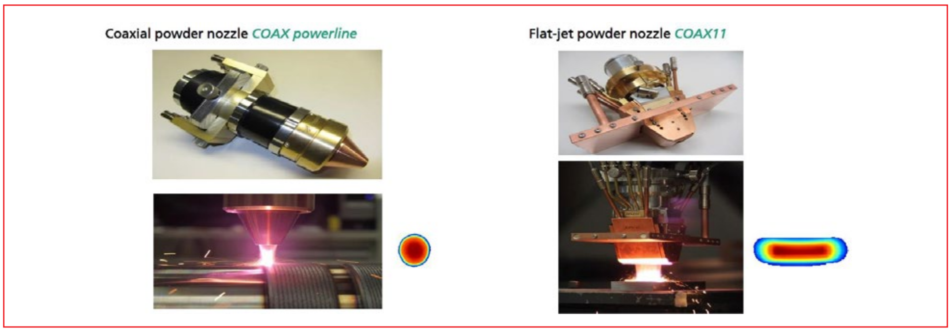

Figure 5: Examples of high power nozzles with circular and rectangular spots (Courtesty of Fraunhofer IWS)

Historically this direction was always in the focus of Fraunhofer IWS in Dresden. No wonder that their products like COAX powerline and COAX11 are well-established in the market. Both types of processing heads are shown in Figure 7. Both of these principles have their advantages and disadvantages. Working with high power laser of over 10 kW, in general, requires more care for optical components due to back-reflections and heating effects. Also, the lifetime of processing heads under industrial conditions might strongly depend on the number of hours of operation.

3D Laser Cladding or LMD (or any other convenient acronym)

In this process, we primarily speak about 3D structures, the building of components or multi-layer repair of complex geometries. This part of the technology became popular in parallel to the developments happening right now in the additive manufacturing world. It is a very promising direction that has proven to be very productive and is already widely used in many industrial segments. The main questions experts commonly ask related to this technology are:

- How to minimize and prevent overheating the parts due to multi-layer deposition? Overheating can have a strong influence on the microstructural features of the produced component and as a result, lead to decreased mechanical and/or wear behavior properties.
- How to increase productivity and get faster? The production time is always a question customers ask.
- How to increase deposition efficiency and ensure almost no overspray? The topic of material consumption and toxicity of overspray particles for example.

In Figure 7, the main trends of the technology are presented and should give an idea about possible solutions to the above-mentioned questions. One of the promising trends is related to wire-feed laser cladding. Wire as a filler material has one significant benefit versus powder — 100 % consumption of the deposited material. With the development of coaxial wire feeding principles, the issues of constant wire feeding were mostly solved. Additional improvement was also achieved by changing the cladding trajectory at constant deposition velocities — in the past that could lead to the defects in “corners”. A short video on Laserlines's web site (https://www.laserline.com/en-int/laser-additive-manufacturing/) gives a good idea about coax-wire cladding features.

Another promising direction of technology development is related to a combination of two processes within one system — cladding and milling. This helps to address multiple topics and produce parts of very complex geometries in the same system. In my opinion, that is a very interesting approach that is nicely described by DMG Mori (https://en.dmgmori.com/products/machines/additive-manufacturing/powder-nozzle/lasertec-65-3d-hybrid). DMG Mori is one of the pioneers in providing such systems to the market. I think this solution is great for the production of prototypes, repair/production of single individual components or small series of parts. On the other hand, there are also a couple of challenges for such a complex, and for sure, an expensive hybrid system for medium and high volume production. It is a matter of simple calculations to find out what is more effective — one hybrid system or two machines (one cladding, another milling), working in parallel on the same product. In general, the main benefits here are related to the development of CAD/CAM chains for the technology itself. It has given a push to the digitalization of laser cladding. Offline programming combined with process monitoring options during the

- Wide, defect-free single tracks with 45 mm width and 20 kW laser power
- Fine-grained solidification structure
- Low degree of overlap between single tracks
  - Increased cladding rate
- Metallurgical bonding to the substrate
- Low dilution (iron mixing):3 to 5%
- High productivity at moderte cladding speed
- Deposition rate up e.g., 14 kg/h and 1.2 m^2/h @ 1 mm layer thickness

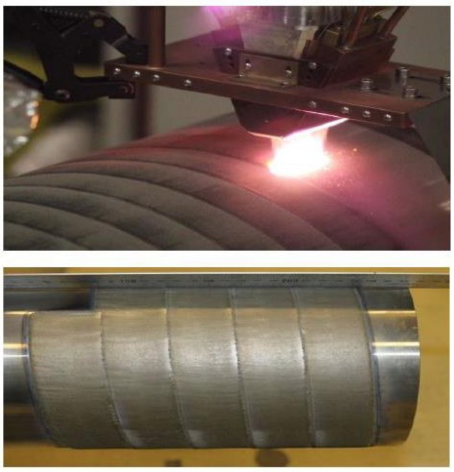

Figure 6: 45 mm spot with 20 kW laser power (image courtesy Fraunhofer IWS)

deposition process ensures excellent reliability and high quality of products.

3D EHLA is one of the latest trends recently presented to the market. It combines high-speed laser cladding and LMD. The latest developments are still ongoing and the progress can be monitored in the project, futureAM – Next Generation Additive Manufacturing (https://www.futuream.fraunhofer.de/en/news_and_media.html), which is lead by my colleagues at Fraunhofer ILT. It is really impressive to see this method taken to new heights and the incredible benefits it can offer in the future. For now, it is still an R&D process and it sure is exciting to see how this will develop. ■■■

Figure 7: 3D laser cladding development directions

Acknowledgment

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www.oerlikon.com/metco
info.metco@oerlikon.com