# Article 1: Introduction to Laser Cladding Technology

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Some of you are senior technical experts in laser cladding, some have just started to gain their expertise and perhaps some are not familiar with the process. Considering that, I have decided to write my version of the laser cladding technology review. I want to publish a series of short articles related to laser cladding. The idea behind this is to give you my subjective overview of the process and the latest developments in the world of laser cladding.

By that, my intention is not to bother you with deep technical details, but rather to give a summary with simple explanations. I wish that everyone who is not familiar with laser cladding will have a chance to understand the technology and its advantages. If you are more experienced in this technology, I invite you to join me in the discussions, ask your questions and leave your personal opinion. If there will be a related topic that you want me to write an overview of, I will be happy to consider that. I hope it will be interesting to read and I will be happy to get your feedback.

**What is laser cladding about?**
I think it is important to start with the roots, and I am sure that most of you are familiar with the term "welding". Welding technology is used to join two pieces of metal together and is quite commonly used in industry for more than 100 years (according to the literature, the first arc process was patented in 1881). You can find results of the welding process everywhere — almost every metal construction has a welded joint: public transport, cars, ships, bridges, etc. I am sure even at your home you can find examples of welding. In Figure 1 you can see some examples from my home.

How does welding work? To start a welding process you need an energy source. With the help of an energy source, you produce heat on the metal surface, heating it to a liquid phase. In those conditions, two parts can be fused together. That helps not only to connect two metallic parts but also gives freedom to design for metallic constructs.

You can use welding not only for joining two metal parts together, but also for covering the surface of one metal with another material. In that case, you build a layer of filler material on the surface of the substrate. That material usually has better properties and can provide protection against corrosion or/and wear. This process is known as hardfacing or overlaying. In other words, we place a protective coating on the surface of the base material, applying the same principle as in joint welding. Those types of coatings are nowadays widely used in many markets, for example, oil and gas, agriculture, mining, chemical, and steel industries.

The second application where overlay coatings are commonly used is related to 2D/3D dimensional part recovery. Quite often parts subjected to wear can be repaired instead of replaced. This helps to save costs and also decreases long outage times as new components may require substantial time for delivery. For the parts, recovery materials of similar properties to the worn base material are commonly used; however, a better grade material can be selected, that will result in increased lifetime of the repaired components.

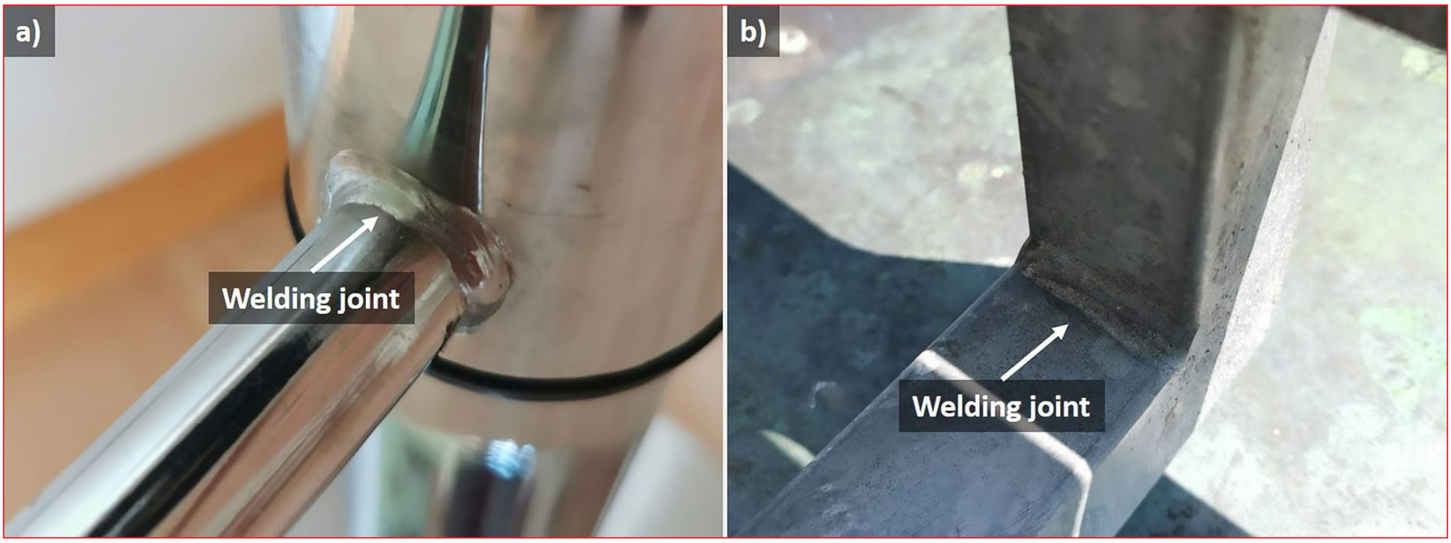


**Figure 1:** Examples of welding joint. a) A welding joint on my bar chair leg. b) A welding joint from my balcony of metallic construction.

What does hardfacing have to do with laser cladding? In my opinion everything! Laser cladding can be even named as a "Queen" among all welding deposition methods. I personally define laser cladding as a coating process by welding where we use the laser beam as an energy source to heat the surface of the substrate. The laser as an energy source offers many benefits in terms of heat control and precision. This allows us to speak about controlled heat input into the base material and offers quality advantages compared to conventional hardface welding processes.

The laser cladding process scheme is shown in Figure 2. With the help of the laser source produced as a beam of energy, it will be transferred to the surface of the substrate. The laser beam builds a spot on the surface, where the heat will be introduced. The main benefit is that with the help of optical components (fibers, lenses, collimators) the geometry and dimensions of a produced spot can be defined and controlled. This helps to achieve the following advantages:

- low HAZ [a] (heat affected zone)
- low dilution [b] with the substrate (around 5%), resulting in better coating properties
- metallurgical bonding, which leads to the highest impact resistance
- low heat input, resulting in negligible distortion
- high process reliability and repeatability.
- high deposition efficiency [c] using powder feedstock materials (80 to 95 %)
- a variety of deposition options

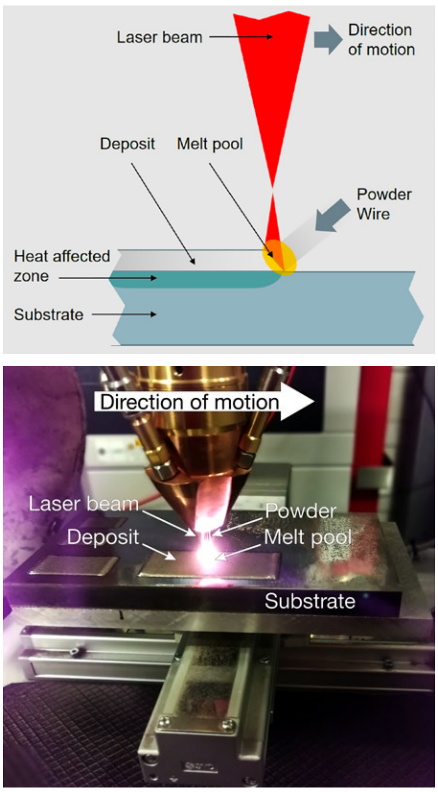


Figure 2: Laser Cladding Process

In the area of the spot, we produce a melt pool on the surface of the substrate. In parallel, filler material in the form of powder or wire is transferred into the melt pool, where the filler material melts and builds a coating on the surface of the base material. As the process happens in the motion of a part or working head we build so-called welding seams of defined size on the surface (the width is typically equal to the spot size of the laser beam). If we need to cover a larger surface, those seams have to be overlapped with the next passes as shown in Figure 2. I have tried to summarize the benefits of laser cladding and also five important takeaways in Figure 3.

**Variety of process possibilities**
Laser cladding has existed on the market for more than 40 years, but is still one of the youngest coating methods. It was not so commonly used in the past due to the expensive costs of lasers and related components compared to other deposition methods. Also, the main applications were in markets with high component costs.

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However, in the last decade, the situation has significantly changed and the technology is now one of the most promising overlay methods, combining price and quality benefits! Laser source prices have dropped down by a factor of ten compared to the beginning of the 21st century.

Another driving factor for the success of this technology is related to the multi-functionality of laser cladding. Below are some examples of the variety of deposition options available with laser cladding and the different methods used to apply the processes.

**Laser cladding of internal surfaces with special heads** (see Figure 4a)
Nowadays with so-called ID heads, you can process parts having internal diameters as small as 25 mm (1 in). The length of ID heads is limited to around 1500 mm (59 in) due to possible vibration at the end of the head during deposition. I have seen 2000 mm (79 in) long heads, but the process stability is not always of the highest level when uysing longer tools. Nevertheless, with 1500 mm (59 in) you can cover part internal surfaces of up to 3000 mm (118 in) depth, simply by turning the component and going in from both ends.

**Wire cladding** (see Figure 4b)
The main benefit here is 100 % deposition efficiency, resulting in full consumption of

**Why Choose Laser Cladding:**

1. Metallurgical bonding with low dilution
2. Low heat input and low distrotion compared to any other welding process
3. High deposition efficiency and various deposition spot combinations
4. High process control and repeatability
5. Multi-functionality in surface technologies — high speed, high power, additive manufacturing, hardening, alloying and treatment of internal surfaces

**Five Key Points About Laser Cladding**

1. A precise process that requires trained and qualified operators with a fundamental knowledge of welding and materials
2. Requires a safety environment — Laser Safety of Class 4
3. The laser is an energy source and any laser supplier can be selected for the laser cladding process
4. Powders and wires of different grades can be used as a filler material.
5. The control process and parameters play a significant role

Figure 3: Key facts about Laser Cladding

[a] HAZ is resulting changes in the properties of base material (microstructure, hardness), suspected by introduced heat during cladding process.
[b] Dilution is a term that describes how much of the base material is mixed with the deposited coating, causing changes in the composition of the overlay. Higher dilution leads to decreased properties of the coating. For example, a classical weld overlaying can have up to 50 % dilution in the first layer, which requires multi-layer deposition to achieve better properties of coating and to compensate for the dilution.
[c] Deposition efficiency (DE) indicates how much percentage of used powder will land in the melt pool to build a coating. Lower DE means less efficient material consumption. For example, for processes like thermal spray a typical DE is below 60%.

the material. Some industries have restrictions using toxic powders, therefore, wire cladding can be a promising alternative. The latest developments in wire cladding have also created new horizons for additive applications. With the help of the coaxial wire-feeding principle, 3D geometries with high precision and excellent process control can be achieved.

**Additive Manufacturing (AM)**
AM of metals has become very popular in the last couple of years. However, not everyone knows, that laser cladding can also produce 3D structures by the process called LMD (laser metal deposition) or DMD (direct metal deposition). With this process we can build structures layer by layer directly on the surface of components thereby changing their design. For this process, wires or powders can be used. Figure 4c shows a typical image of this type of process. In that image, you can see a multi-layer restoration of the turbine blade surface.

**High-speed laser cladding** (Figure 4e)
This is a newly developed method also known as EHLA (Extreme High-speed Laser Application). The unique idea of the process is that you melt the powder before it interacts with the surface, where over 80 % of laser energy goes into melting the powder. This allows for the production of thin coatings with low surface roughness and excellent properties. Due to high deposition velocities for rotating symmetrical bodies and deposition rates already going in the direction over 2 $m^2$/h (21.5 $ft^2$/h), EHLA is in competition with processes like thermal spraying and hard chromium plating. Another advantage of EHLA is its deposition efficiency of 90 %.

**High power laser cladding** (Figure 4d)
I know many companies who already operate with laser powers of 10 to 20 kW. In most cases, they use a rectangular spot to cover a large surface in one pass and to produce thick coatings. The main benefit here is a high surface coverage rate for massive components. You can work with spot dimensions over 10 mm (0.39 in) in diameter or with a rectangular spot of 20 mm (0.79 in) width. For massive parts, that offers extremely high productivity.

**Laser surface engineering** (Figure 4f)
It is not directly related to coating technology, but still can be realized using the same components as laser cladding. Laser hardening allows you to selectively increase the hardness of the base material simply by focusing the laser beam on the required surface. Just as in laser cladding, you create a spot on the surface, but by controlling the spot temperature, it is possible to heat selective areas of the part. Controlling the temperature helps to stay below the meting point of the base material, and avoids any changes in surface structure and roughness. Selective heat input, combined with rapid cooling, causes martensitic transformation of the steel surfaces and increases the hardness of the material at depths up to 2 mm (0.079 in). Another advantage of this process is the elimination of post hea treatment (mechanical of heat-treatment) requirements. ■■■

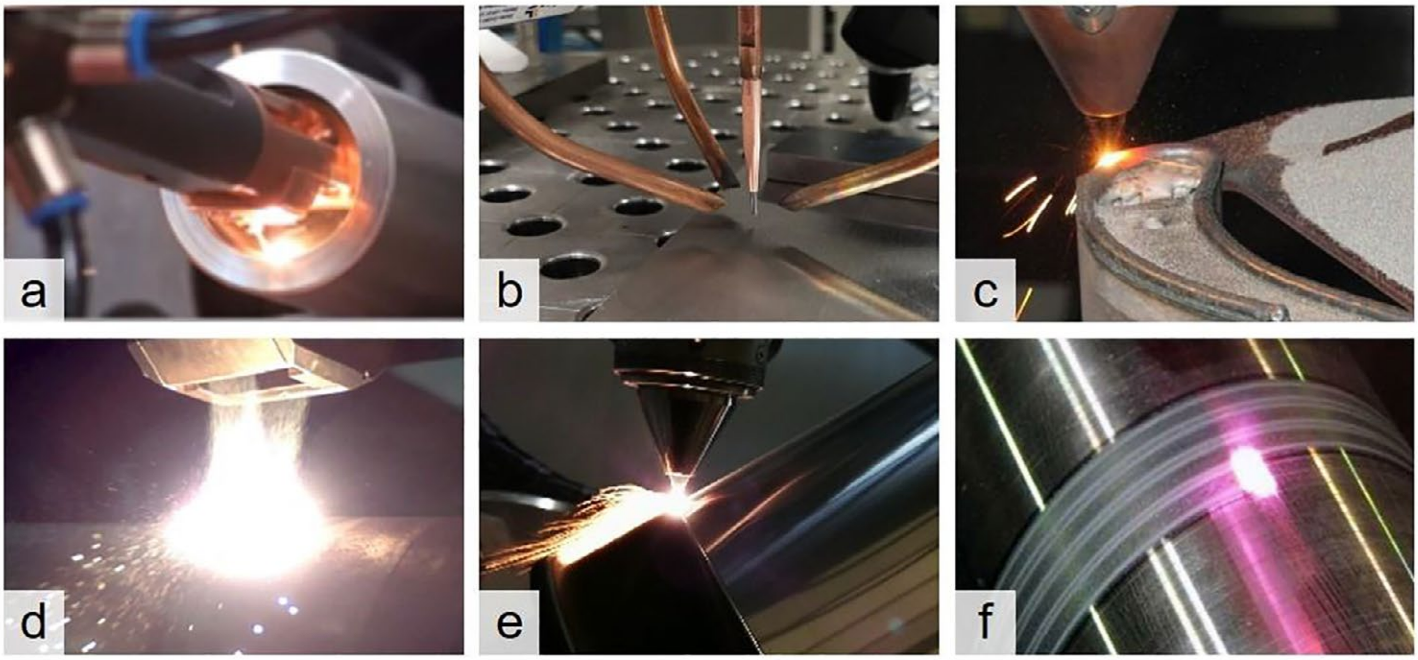


**Figure 4**: Laser Cladding sub-groups

**Acknowledgment**

I want to thank my team for their great work, motivation and a high level of professionalism by making our laser center a great place to work. Thank you Jörg Spatzier and Kemal Coskun. I want also to thank my colleague Dr. James Vecchio for his help and support. A special thank you goes to my manager Dr. Alexander Schwenk for his trust.

**Postscript**

In July 2019 we have started restructuring our laser cladding R&D capabilities and it was decided to open a Laser Center of Competence. Here we work as a team on providing new solutions for the protection of parts by laser surface engineering.

**Our main goals are:**

- to provide engineering, industrialization and service support for our customers
- to support all ongoing projects in materials development
- to be involved in the latest developments in laser cladding technology
- to provide high-level technical expertise by having a highly experienced technical team on board



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