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Industrial Paper

Novel working head for laser-assisted surface treatment and additive manufacturing

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Abstract

ERLAS Erlanger Lasertechnik GmbH is developing the next generation of a laser working head for surface treatment as well as additive manufacturing. Its main advantage in comparison to existing models will be the possibility of a quick switching between beam shapes and processes. Also, the head will possess a wobble function. Designers concentrated on a compact, reduced-size version. At LANE 2018, **ER**LAS will present the working head as well as first results of application.

Keywords: laser beam hardening; laser beam cladding; laser system technology; process parameters; applications

1. Historical Review

The advantages of using laser technology for surface treatment in tool making and mould construction have principally been known since the mid- 1980s. Amende (1985) presented the first laser beam hardening applications on materials and components for machine construction. Bergmann and a group of junior scientists worked out a basic understanding of both, the laser hardening process (Bach, 1991; Messer, 1997) and the material specific requirements for successful heat treatment (Müller, 1999). The energy of a laser is used for a quick heating up of the material. The desired hardness results from self-quenching of the material into a martensitic grain structure. In order to avoid melting of material and so-called high temperature brittleness, it is necessary to run the process temperature controlled (Müller, 1999). For a prolonged period of time the industrial application was hindered by high investment costs, limited acceptance by toolmakers and due to non-available system technology on an industrial level. The key to cost-effective and more efficient system technology was the use of solid state lasers (Stiele, 1999) as well as high power diode lasers (Dierken, 2000; Hoffmann, 2007) instead of CO_2 lasers.

Today it is state of the art to use laser hardening technology whenever wear resistance of selected tool areas shall be improved. These areas are edges of cutting tools, pinch edges, contact surfaces of hemming nests, closing areas of injection moulds and radii of deep drawing tools.

Laser beam cladding, a deposit welding with additional powder (Gasser, 1997; Schneider, 1998) came up in the late 90´s as a second surface treatment of tools with laser technology. Typical applications of laser beam cladding are the modification of dies and moulds, the production of hard and wear resistant layers on soft base materials, repairing of sealing edges of plastic moulds and the near net shape manufacturing of cutting edges. Laser beam cladding is a more complicated process with many parameters, in particular due to the feeding of additional material.

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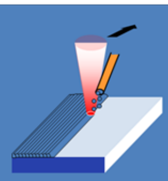

PROCESS PARAMETER	LASER BEAM HARDENING	LASER BEAM CLADDING
Laser Power	2…6 kW	2…6 kW
Laser Intensity	$10^3…10^4$ W/cm^2	$10^4…10^5$ W/cm^2
Spot Geometry	Rectangle	Round
Track Width	5…60 mm	0.5…5 mm
Velocity	approx. 0.3m/min	approx. 0.5…2.5 m/min
Process Gas	Optional	Ar or He, < 5l/min
Filler Material	None	Powder, Wire
Process Temperature	Below Melting Point (±20 K)	Above Melting Point

Fig. 1 Typical process parameters of laser beam hardening in comparison to laser beam cladding.

As can be seen in Fig.1, the only common parameter in laser beam hardening and laser beam cladding is maximum laser power. While the laser hardening process requires a rectangle spot geometry which is up to 60 mm wide, the laser cladding process needs a spot diameter of only 5 mm. For laser beam hardening a process gas is dispensable, whereas shielding gas is almost essential for high quality laser beam cladding especially when using powder filler material while feeding.

2. State of the art

As for economic reasons both technologies, laser beam hardening as well as laser beam cladding, should be feasible with one and the same laser system. Therefore, **ER**LAS Erlanger Lasertechnik GmbH invented **ER**LASER® Hard+Clad systems in 2005 and presented them to the public in 2006. According to customer's application, different strategies for realizing these systems are available. It is either huge gantry systems that may operate as guiding machines for the multi-function working head or just common standard articulated robots. The feeding of parts can be automated or manual, depending on production requirements. Today, almost all the world's leading automotive manufacturers utilize these innovative systems made by **ER**LAS.

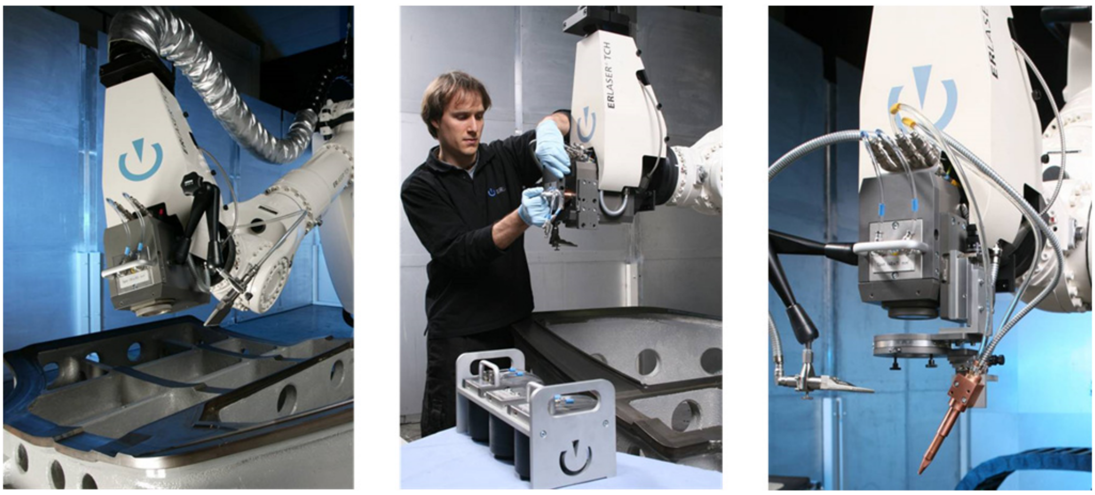

Fig. 2-4 show the conversion from laser hardening set up to laser cladding set up. An exchange of the focusing mirror and an installation of the powder feeding nozzle is necessary.

Although there are no more advanced systems available to this day, some disadvantages should be mentioned. Setting up like changing mirrors is to be done manually. That means, the process is being interrupted, a person needs to handle costly optics, setup errors may occur, and the system cannot produce for some time. All in all: auxiliary process time is increasing.

3. Upgrading laser surface treatment with new ERLASER® Hard+Clad working head

The Erlangen specialists recognized the above mentioned limitations. They started developing the next generation of a working head to be even more efficient than today. The latest innovation of an **ER**LASER® Hard+Clad working head was realizable due to improved beam quality of high performance diode lasers. Therefore, it is more compact and owns an internal mirror revolver for an automatic change of the beam imaging optics. Even technology-specific auxiliary equipment such as feeding devices for powder or wobbling appliances are automatically exchangeable.

Fig. 5 Novel working head for laser-assisted surface treatment and additive manufacturing.

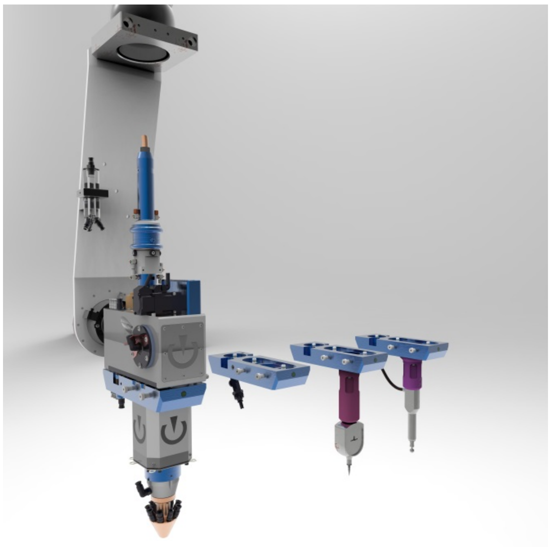

Fig. 6 Working head – one tool, various applications.

The presence of an appropriate pyrometer is essential for receiving excellent results in laser surface treatment, especially for laser beam cladding of regular and even multi layered structures. The latest **ER**LASER® Hard + Clad working head has a two colour digital high speed pyrometer with an extended temperature range from 600°C to 2300°C (standard is 350°C to 1300°C). The pyrometer is used for a temperature measurement in the interaction zone of laser beam and workpiece. Via closed loop control of the laser power laser processing is performed in optimum temperature ranges, dependent on processed materials at different pre-set values.

While laser beam hardening, typical temperatures of 1000°C to 1300°C are needed, but more importantly, during cladding processes temperatures of even 1800°C to 1900°C are common. Why is the measurement of temperature and therefore control of proper energy input indispensable for good results? Heat treatment of relatively small workpieces as well as different types of materials may heat them up very fast and in different velocities, this leads to a danger of gas emission, overheating and finally to failures like pores and cracks.

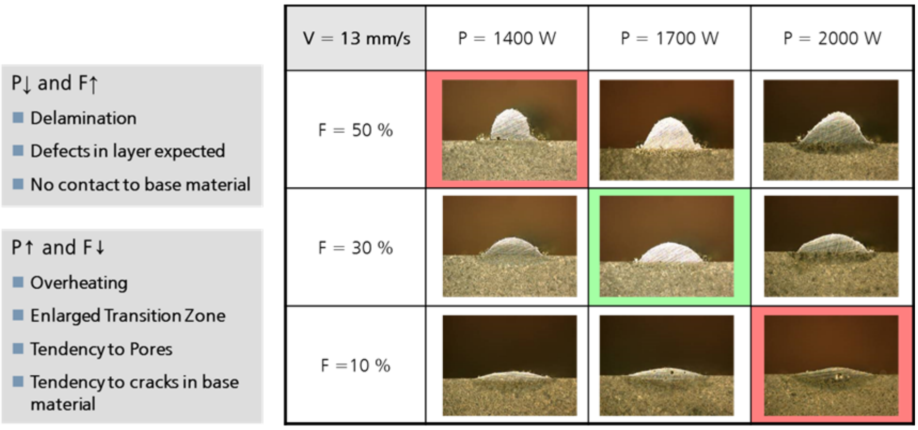

Fig. 7 Cross section depending on laser power and powder feeding rate.

The illustration shows cross sections of tracks all produced with a speed of 13 mm/s. From the left to the right the laser power was increased. From top to bottom the powder feeding rate decreases. It is obvious that the track geometry is determined by the powder feeding rate. Laser power is not decisive in this case.

4. Application – First results

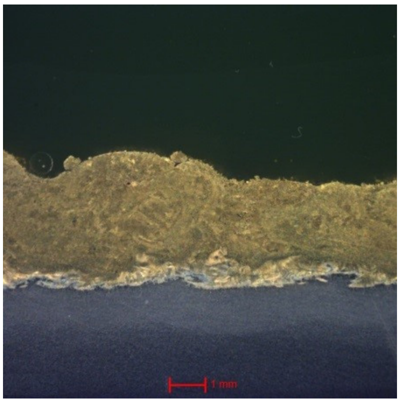

Fig. 8 Multi-layered structure resulting from a non-temperature-controlled process.

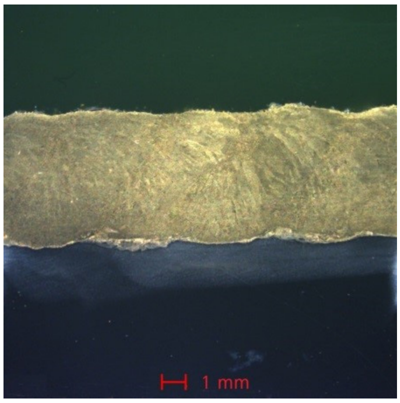

Fig. 9 Multi-layered structure resulting from a temperature-controlled process.

Fig. 8 shows that in a non-temperature controlled process significant differences in the heights of layers are already found after the third layer. Without temperature control, process limits are reached at 3 mm built structure, whereas in a temperature-controlled process creating coatings up to 6 mm is absolutely trouble-free (see Fig. 9). In cladding processes with different materials, e.g. aluminium bronze on steel, different thermal conductivities as well as different melting points create a rather small process window. Here, working with a high-speed pyrometer is essential.

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