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ERHEAD® Variospot 25 – Innovative laser processing head

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Abstract

The laser is becoming increasingly important as a tool in the field of materials processing. Various processing methods can be realized across industries with lasers and a corresponding processing head. These includes well-known processes such as welding as well as emerging processes such as laser hardening and cladding. The previous bottleneck was that a separate processing head was required for each individual process. This is now a thing of the past with the introduction of the ERHEAD® VARIOSPOT 25. The new modularly designed processing head from **ER**LAS manages the balancing act between cost-effectiveness and flexibility. For the use of a single technology, the variant with a plug-in module can be implemented; if different optical images are required, the rotor module is used. The modular design of the head allows subsequent upgrading with the rotor module. Four mirrors with different images can be mounted on the rotor. The mirrors selected by the user are mounted via a maintenance opening, so that the setup status of the head can be adapted to new applications at any time.

Keywords: Laser cladding; Modular processing head; Laser hardening; Laser welding; Wobbing spot

1. Review/State of the Art

The laser hardening process has its origins in the 1980s. First applications have been made scientifically in the field of mechanical engineering in the mid to late 80s e.g. by Amende (1985) and Amende (1988). The understanding of both, the laser hardening process presented by Bach et al. (1991) or Messer and Bergmann (1997) and the material specific requirements for successful heat treatment shown by Müller (1999) followed in short time. The basis for laser hardening is the phase transformation by heating up steels with sufficient carbon as well as cast alloys quickly and self-quenching them afterwards by their own mass. In this transformation process, the dissolved carbon is transformed as martensite in the crystal lattice. Compared to other hardening processes, the transformation process occurs only locally at the required point, i.e. the application of the temperature is locally limited, which in turn leads to low distortions and stresses.

Another process for the surface treatment of metallic workpieces is laser cladding. Liu and Mazumder (1994), Gasser (1997) as well as Schneider (1998) contributed fundamentals to the understanding of this process. In laser cladding, the surface properties of metallic base materials are locally modified. A filler material, usually in powder form, is fed onto the substrate using a nozzle under an inert gas atmosphere, where it interacts with the radiation of the laser. The filler material is melted, whereby the dilution of filler material to base material should be as low as possible so that the properties of the functional layer are not affected. This process allows the use of low-cost steels whose surface properties can be modified as required. The microstructure produced can show superior properties compared to conventional processes if the heat treatment is properly controlled (see Ahn (2021) and Ya (2015)).

Erlanger Lasertechnik GmbH from Erlangen, Germany has over 20 years of experience in the use of laser technology for surface treatment and processing of metallic surfaces. The range of workpieces includes serial parts (e.g. hand tools) as well as single parts in large dimensions (tool making in the automotive industry). Specially developed and built systems are used both at ERLAS at two locations and worldwide, among others, at leading companies in the automotive industry and their suppliers. Customer requirements, the further development of beam sources with regard to design, performance and beam quality together with many years of process experience have inspired new and further developments time and time again. However, it was recognized early on that laser-based additive manufacturing is also highly interesting, particularly in toolmaking, and will be used increasingly. With the realization of a processing head that has the option of manually changing the focusing mirror, the prerequisites were created to be able to display different rectangular images for varying track widths during hardening and to also generate round spot geometries for cladding if required. For many customers who have applications for both surface technologies namely laser hardening and cladding, the time-consuming setup change of the processing head on the guiding machine is no longer necessary.

2. Novel processing head for multiple laser technologies

ERLAS now presents a processing head with outstanding technical features that impresses with its modular design and is thus ideally suited for a wide variety of tasks in the field of laser material processing. Hardening with varying track widths, joint welding (also with gap), cladding with adaptable track width.

The small size, with a compact design of 250 x 150 x 200 mm^2 and a weight of 20 kg, was made possible by an optical configuration of the mirrors designed for common solid-state lasers with a wavelength in the infrared range. A prerequisite for the application of the compact processing head is that the collimated laser beam which has a diameter smaller than 20 millimeters. The focal length of the lenses currently in use is typically 300 mm – 350 mm.

The inexpensive entry into the new technology is offered by the basic head, which is shown on the left side in figure 1 and has manually pluggable mirrors. The working head is a multi-talent that can be adapted to the technologies of hardening, cladding and joint welding within a very short time. Moreover, temperature measurement technology, which reliably measures in the range 600°C to 2300 °C, and laser power control for process monitoring guarantee high and reproducible production quality in laser beam hardening and cladding.

The modular design of the head allows subsequent upgrading the basic module with a rotor module. Figure 1 (right side) shows the ERHEAD® VARIOSPOT 25 with rotor module. Four mirrors with different spot geometries can be mounted on the rotor. The mirrors selected by the user are mounted via a maintenance opening so that the head's set-up status can be adapted to new applications at any time. With the help of the rotor, processes with four different imaging proportions can now be run without the system operator having to intervene manually. This increases the availability of the machine and its productivity, as setup times are reduced. For many applications in the field, the four laser spot geometries are sufficient. If there are additional imaging requirements, these can be accommodated on a further rotor module, which can be changed with just a few screws. For unmanned changing of the hardening, cladding and joint welding technologies, the head also has coupling systems, which pick up the adapter matching the required technology from a station. The lines for the powder supply are led through the housing, so that the head appears very tidy and these are not exposed to damage by heat and/or collision.

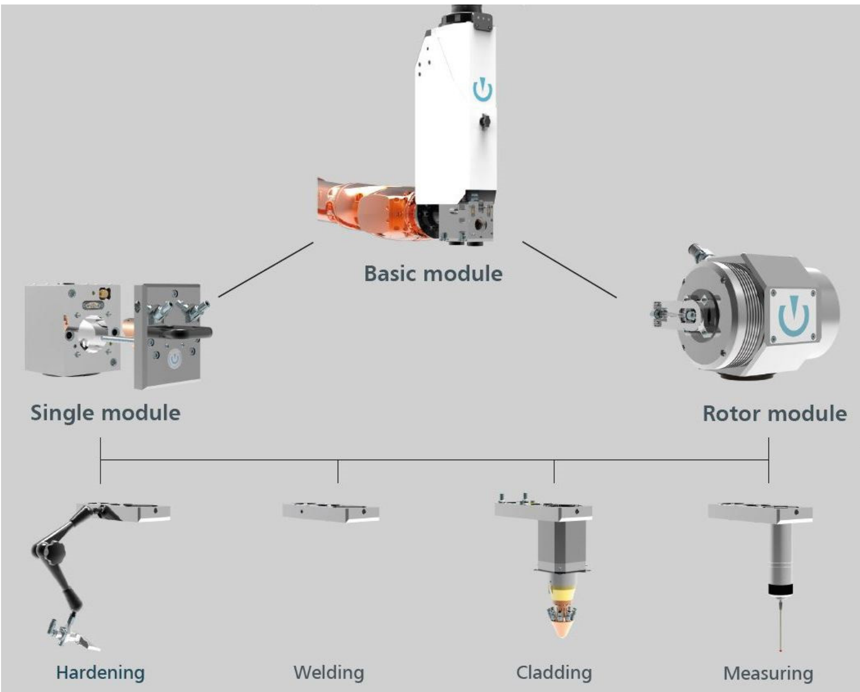

Fig. 1: ERHEAD® VARIOSPOT 25. The version with pluggable mirrors is shown on the left. The version with rotor module is on the right side. On the bottom the different tools for hardening, welding, cladding and measuring can be seen.

If required, it is possible to equip the processing head with a large number of sensors in the spirit of industry 4.0, so that potential thermal changes of the system, that may occur during several hours of running the process, can be detected. Furthermore, powder flow and the status of the protective glass in terms of contamination or damage can be conveniently checked on the operator interface without interrupting the running operation.

Figure 2 shows in detail the different technologies that can be implemented with the new processing head. In addition to the already proven combination of laser hardening and cladding, it is now also possible to perform deep welding processes. This is achieved by the optimized optical setup in combination with the appropriate fiber and laser.

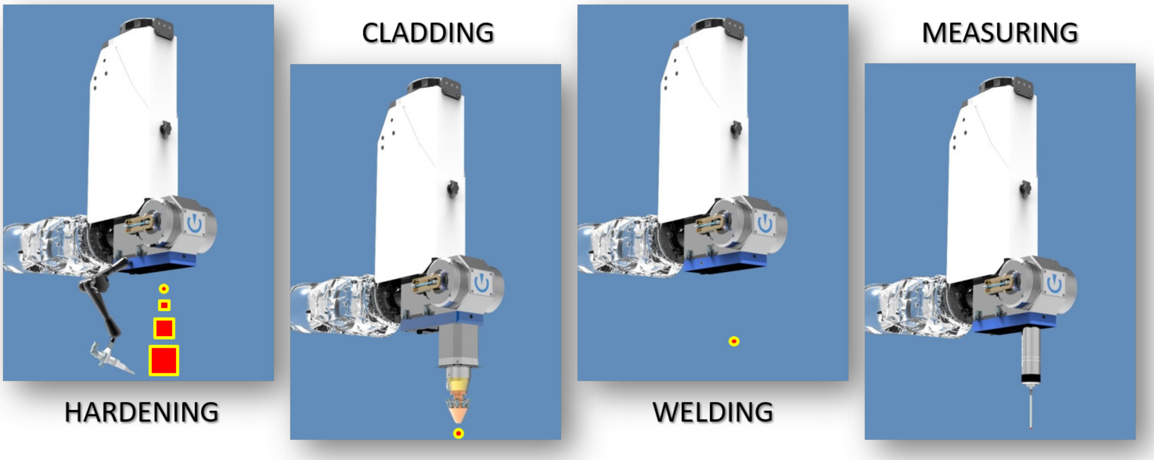

Fig. 2: The new processing head is capable of four different technologies, respectively laser hardening, cladding, deep penetration welding and tactile measuring.

In addition to the four technologies shown above, the new setup also allows the process-reliable oscillation of the imaging mirrors. Therefore, the mirror adjustment system is designed to be so highly dynamic and powerful that the focal spot can oscillate at a frequency of up to 200 Hz over 20 mm, which corresponds to a deflection of the mirror by 1.7 degrees. For higher amplitudes, the frequency is appropriately limited to ensure stable continuous operation of the head. The processing head is temperature controlled and is actively cooled. The clever integration of cooling channels and flushing of the head with purified air eliminates contamination of the optics. The possibility of "wobbling" results in additional fields of application which can otherwise only be served by scanner systems or special optics, e.g. with double focus or designs as zoom optics.

In welding, well-known applications are gap bridging or aluminum welding. In hardening and cladding, track widths can be varied dynamically at high feed rates. A prerequisite for cladding is specially designed powder feed systems, which control the powder flow according to the geometry of the component, in order to keep material consumption as low as possible by minimizing overspray. **ER**LAS has developed concepts for this, which must be consistently developed further in order to be able to offer industrially suitable processes.

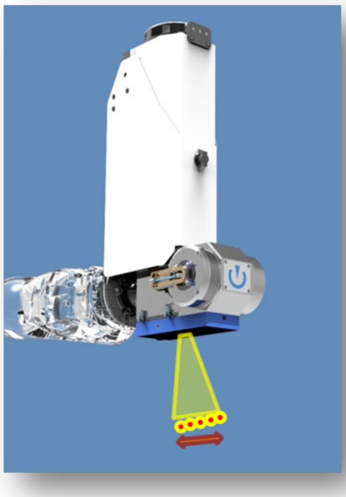

Fig. 3: ERHEAD® VARIOSPOT 25 with wobbling laser spot.

3. First results

The measurement of the optics has shown that the focus shift is negative and has a value of -0.023. When using transmissive optics, the focus shift is always positive (the focus moves closer to the optics with increasing power). For the ERHEAD® VARIOSPOT 25, which is equipped with mirrors and not lenses, the focus shift is very small, regardless of the sign. A value of -0.023 means that the focus changes by 2.3% of the Rayleigh length per kW of laser power. Most beam parameters hardly change (M^2 is almost identical, the deviation is negligible at less than

0.2%). Laser power measurements have shown a loss of about 2% in the optical path. This result is consistent with the general assumption of about 1% loss per optical element. Furthermore, temperature measurements on the focusing copper mirror have shown no heating.

The following figures show the first tests of the wobble function of the rotor module for the cladding process. With a fixed deflection of the mirror, the frequency is changed in defined steps. The track width during process control without oscillation is approx. 4.5 mm. For the experiments, an ordinary stainless-steel powder (316L) was used, which is applied e.g., as a buffer layer.

Figure 3 shows the results of the first single track cladding experiments. Section “a)” is a track with a width of 4.5 mm where no oscillation was performed. Section “b)” shows the single track at 10 Hz. It can be seen that no homogeneous wide track was generated at this frequency. The laser spot oscillates and creates curved tracks, but they are not homogeneous in width.

In area “c)” the frequency was increased to 30 Hz. Here the melt pool is already more dynamic and shows a wider front. Only when the frequency is increased to 50 Hz, as seen in section “d)”, a homogeneous wide track is produced. Taking into account the possible exit angle from the powder nozzle, the track width could be increased to 5.4 mm and thus by almost 1 mm compared to the initial shape.

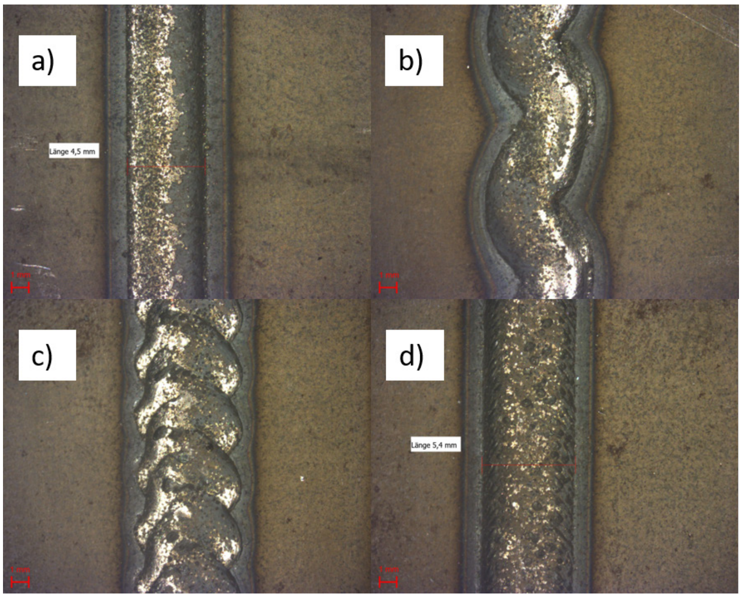

Fig. 4: Four single cladding tracks. a) track without oscillation; b) track with wobble frequency of 10 Hz; c) track with wobble frequency of 30 Hz; d) track with wobble frequency of 50 Hz

The variation of track width during cladding enables the creation of a wide variety of structures, which can be smaller or larger as required, with one processing head without changing optics or tools
Experiments on process control for the other technologies are being scheduled and their results are expected in the course of 2022.

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