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DVS – DEUTSCHER VERBAND FÜR SCHWEISSEN UND VERWANDTE VERFAHREN E. V.	Laser beam surface welding	Technical Bulletin DVS 3215

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1. Scope

This technical bulletin provides an overview of surface welding with continuous laser beam in the kW range, using CO2, Nd:YAG, fibre, slab and diode lasers. Surface welding with pulsed Nd:YAG lasers is not discussed in this technical bulletin. The applications of the process include a wide range of tasks for surface modification and repair of components and tools. This technical bulletin contains recommendations for professional use and notes on layer properties and potential applications, as well as basic information on the assessment of cost-effectiveness.

2. Definition

From a technological perspective, laser beam surface welding stands alongside plasma-powder and TIG surface welding. It is clearly distinct from thermal spraying, because the filler material is only melted in the area of interaction of the laser beam on the component surface, with the base metal melting slightly at the same time. A valid synonym is laser coating. In the English speaking countries the term „laser cladding" has become established.

3. Features of laser beam surface welding

Laser beam surface welding is used for surface protection of complex stressed components and for repair tasks. The range of applications extends to the processing of functional surfaces of components and tools, the size of which is not limited by the process. In particular, the process is used for coating tasks requiring the highest precision with regard to the layer geometry and component behaviour.

The mechanical and thermal properties of the layer-substrate bond can be set as appropriate within wide limits through the choice of filler material and process parameters.

With laser beam surface welding, final dressing is usually required. This can be done by turning, milling, grinding or eroding.

Characteristic features of laser beam surface welding are listed in Table 1.

Table 1. Features of laser beam surface welding

Characteristic	Limits/rating	Remarks
Laser types	CO_2, Nd:YAG, fibre, slab, diode	Normally at least 1000 W (cw)
Power density	5,000 to 1,000,000 W/cm^2	CO_2 laser due to lower absorption with power densities in the region of 1,000,000 W/cm^2
Exposure duration	0.001 to 2 seconds	Single bead
Track geometry – Track width – Single bead height – Typical layer thicknesses	0.2 to 10 mm 0.1 to 2 mm 0.3 to 3 mm	Greater layer thicknesses possible with multi-pass techniques, 3D contour coatings
Localisability	very good	
Proximity to final contour	medium to high	Final dressing usually necessary
Coverage/deposition rate	100 to 1,200 mm^2/min /0.1 to 2 kg/h*)	Dependent on laser power, material and component geometry
Heat input into the component	low to medium	

*) 6,000 W

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Characteristic	Limits/rating	Remarks
Distortion, form deviations	low to medium	
Layer structure	dense, homogenous	
Bond strength	metallurgical bonding	Bond strength similar to the layer tensile strength
Dilution of layer with base material	2 to 5%	
Environmental conditions	mostly under normal atmospheric conditions	Additional gas shielding possible, typically N_2, Ar or He
Component size	unlimited	Depending on available laser machine
Surface geometry	smaller and/or more complex functional surfaces	Large-area coatings are unfavourable, mainly from an economic perspective
Processing tasks	– Surface protection – Repair coatings – Precision machining	

4. Process principle

In the case of laser beam surface welding, essentially a distinction is made between single-stage and two-stage processes. Whereas in the two-stage process, the previously deposited filler material is melted by the laser beam, with the single-stage process, feeding of the filler material takes place simultaneously with the laser beam.

In the single-stage process, besides the laser parameters, the result is primarily determined by the type and design of the feeding system, its orientation relative to the beam working area, the feed rate of the filler material and the shielding gas supply. In the single-stage process, powders, wires and occasionally pastes are used as fillers.

Melting of the filler material in the two-stage process takes place starting from the layer surface. Energy transfer to the base material is predominantly based on heat conduction. This results in greater sensitivity to overheating and the layer thicknesses achievable in one pass are significantly smaller, by approx. 0.3 to 0.8 mm.

The basic principle of the single-stage process, independent of the type of filler material used, is illustrated in Figure 1 based on the example of laser-powder surface welding.

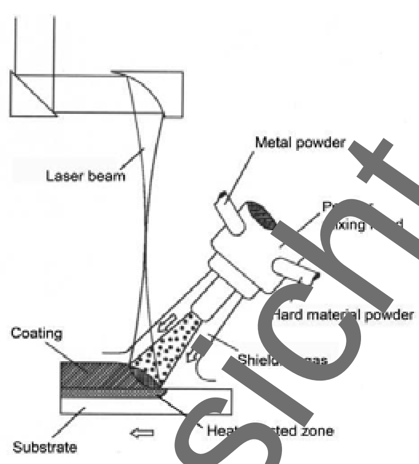

Figure 1. Schematic illustration of laser beam surface welding with powder

Thanks to the laser beam, a strictly localised weld pool is generated on the surface of the workpiece. The fed powder or powder mixture is heated while passing through the laser beam, but only melts in the weld pool.

The slight melting of the base metal required to achieve a metallurgical bond essentially takes place through heat transfer. Through heat dissipation into the cold substrate, the molten filler material hardens very quickly and bead-shaped deposition tracks appear.

The type of filler material is chosen depending on the stressing of the component and the geometry of the processing location. Materials in powder form are the most flexible. The main advantages relate to the shape of the powder jet, which can be variably adjusted to the laser exposure zone and the large number of available metals, alloys and hard materials. In addition to the illustrated variant with lateral powder feed, processing heads with a powder flow arranged coaxially to the laser beam or with quasi-coaxially arranged powder flows (multi-jet nozzles) can be used. The characteristic feature here is that powder input takes place regardless of the feed direction, so that any two-dimensional contours can be welded. The advantages of powder are offset by disadvantages such as incomplete powder use (overspray) and the danger posed to operating personnel by inhalable powder particles. As well as powders, wires have become more prevalent, especially for repair welding of tools and components for the aerospace industry. Metal bands can also be used to produce relatively broad surfacing beads, which should have a rectangular cross-section.

Laser beam surface welding is preferably performed without preheating. For certain crack-sensitive combinations of layer and filler material, however, preheating or the welding of a buffer layer (e.g. of nickel) may be necessary.

Also, cooling of the workpiece may be necessary if there is an unfavourable ratio of layer thickness to base material wall thickness.

With widely differing coefficients of expansion of the parent and filler materials and a tendency to form brittle phases in the dilution area, a metallurgically appropriate intermediate layer can be welded on before the actual, function-defining filler material is applied.

5. Technical components of laser beam surface welding systems

A basic requirement when using a laser for material processing is the integration of the laser in a functional system. Such systems can be divided, regardless of the application, into the four subsystems: laser, beam guidance and shaping, workpiece handling, control and monitoring. The particularly relevant components are highlighted (Figure 2).