Coaxial Laser Wire Deposition

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Abstract. The new coaxial fine wire deposition optic presents reduced weight (~10 kg without fiber and wire feed) and has extended functionality. The optical components are designed for wavelengths of 450 – 550 nm and 890 – 1100 nm. The head is prepared for the processing of even thin wires down to 100 µm in diameter. The new system is equipped with an integrated mini camera, sensors and interfaces to control units and networks. As a result the new head exhibits potential to produce very precise metallic structures as low as 200 - 300 µm. Suitable materials are steel, titanium, nickel and cobalt base alloys as well as materials on the basis of copper.

1. Introduction
Laser cladding has been used for a long time to repair expensive, highly stressed components such as turbine blades or forming tools. However, functional coatings for wear protection and even free-formed structures can also be produced in this way. Up to now, powder-based laser cladding has been mainly used fully automatically in industrial production, but now it is possible to use laser wire processing optics for automatic performance and so they are suitable for industrial production.

The advantages of wire cladding in particular are that wires can be easily direct inserted into the welding zone, so they have a complete material utilization and the characteristic clean processes protect the environment, the machine and the operating personnel.

2. COAXwire
In order to produce precise, high-quality surface coatings, a coaxial laser-wire processing optic called COAXwire was developed (figure 1a), which enables a complete directional independence by using metal wires [1].

For this purpose, the collimated laser beam is first divided symmetrically into three partial beams (figure 1b) and is then focused on a circular focal spot. With a fixed aspect ratio of 1:3, the focus diameter can be changed by selecting the fiber diameter. This optical concept enables the welding wire to be fed precisely into the laser beam axis and thus into the center of the laser-induced weld pool. This ensures that the wire feed and the welding process are completely independent of direction in all technical reasonable welding positions.
Figure 1. Processing optic COAXwire. (a) COAXwire set-up in a robotic cladding system (b) Laser three beam concept. (c) Technical properties: 1 - Safety and collision shutdown, 2 - XYZ-wire supply adjustment, 3 – Crossjet, 4 – Downjet, 5 – Cover glasses.

Depending on the application, fiber, disc or diode lasers up to 4 kW laser power are possible.

The application field of the COAXwire optic includes cladding, repair and additive manufacturing processes. Good examples are wear protective coatings of iron, cobalt, nickel and copper alloys, the repair of cutting and forming tools or components made by titanium and nickel aerospace alloys or the additive manufacturing of functional metal parts.

Further advantages are, on the one hand, the entire material utilization and, on the other hand, the better conditions with regard to occupational safety and health protection compared to powder-based processes.

In addition, the compact design of the processing optic allows easy integration into CNC machines or robotic systems. It is compatible with standard wire feeders from the field of arc welding technology and many more. Commercially available solid or cored wires in fine or standard dimensions can be used with the COAXwire.

A collision and safety shutdown (figure 1c) protects against damage in the case of malfunctions or process irregularities. If necessary the COAXwire laser processing head can be retrofit with a hot wire module. While keeping full directional independence and 3D capability, this option enables a 20 to 40 percent increase in the deposition rate, depending on the material. In addition, the process window for efficient and error-free processing of modern high-performance metallic materials is widening to the same extent.

3. COAXwire mini
The new miniaturized fine wire processing optic was designed in order to explore new wire diameter dimensions and a wider range of wavelengths. The new COAXwire mini processing optic (figure 2) is
basically a miniaturized version for high-precision wire cladding of complex components with fine wires. In particular, it is intended to close the gap for repair and generating high-quality and filigree complex components.

Figure 2. Fine wire optic - COAXwire mini

For the first time, thin wires diameters of 300 to 600 micrometers can be processed in a CNC machine system. For certain alloys, the spectrum can be even extended to small diameters of 100 to 300 µm. This allows a wire cladding of very fine and 3D complex structures as well as using brazing wires for plate frame constructions. Due to utilization of the entire materials, a geometric resolution between 200 and 1200 µm can be reached.

Following new trends in laser source development, the COAXwire mini is designed for relevant wavelengths from 890 to 1100 nm (diode, disc or fiber laser) and finally for 450 to 550 nm (blue and green lasers). This enables materials like copper, brass or gold to be cladde d by fine wire with utilization of always 100%. Further suitable materials are steel, titanium, nickel and cobalt base alloys. The goal is to get almost completely dense metal structures which should always show a fine-grained cast structure.

Beside recording and processing of relevant process data, the new system has the following technical features:
- a mini camera,
- integrated sensors,
- easy precision adjustments,
- fine wire guiding and
- a fume and smoke extraction.

4. Conclusions
The COAXwire mini fine wire optic represents an advanced solution in the age of digital processes and systems. It bridges the gap to high-precision additive laser processes and enables the management and intelligent exploitation of process data. It accommodates the latest developments in diode, fiber and disc laser technology and additionally of blue and green lasers. The laser processing optic opens extended potential of application in cladding, repair and additive manufacturing with fine wires between 0.1 and 0.6 mm.

References
[1] Pajukoski H, Näkki J, Thieme S, Tuominen J, Nowotny S, and Vuoristo P 2016 *J. Las. Appl.* 28 012011-12