BUSINESS UNIT
THERMAL SURFACE TECHNOLOGY

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MINIATURE LASER PROCESSING OPTICS FOR HARD METAL INTERNAL CLADDINGS

THE TASK

Wear resistant hard metal coatings are an excellent choice for cladding. A potential application is the coating of cylinders in extruder tools, which are used in the fabrication of plastic raw materials. Plastic raw materials are poured through a funnel into a heated cylinder with an internal extruder screw. Movement and pressure mix the plastics and the melt is ejected through a narrow exit port. The cylinders are up to 8 m long and experience strong wear due the external heat and high friction. The aim of an EU project (EU-DEBACOAT, FP-7, FZK: 315417) was to clad the inner diameter surfaces of the cylinder with a wear resistant hard material coating. The surface to be coated is deep inside the cylinder with small diameter and hard to reach.

The Fraunhofer IWS research task aimed at developing an inner diameter laser cladding head, which could clad especially hard materials. The following requirements had to be fulfilled:

- internal cladding of long cylinders, which could also be conical or double-performed,
- a maximum immersion depth of 1800 mm at minimum inner diameters of 58 mm,
- maximum possible laser power of 1000 W while being capable of long-term stable processing of at least one hour,
- the integration of a process camera and temperature monitoring.

OUR SOLUTION

The new "Mini-ID" optics (Fig. 1) is capable of immersion depths of up to 3000 mm at a minimum inner tube diameter of 50 mm. The optical fiber is completely integrated into the center of the head. All media delivery channels for powder, inert gas and cooling water, run along the outside of the optical fiber like a magazine. Behind the fiber connector there is a connecting element for the powder gas mixture, the inert gas, cooling water input and output flows, a thermocouple running to the farthest optical component and also an integrated endoscope camera, which is mounted very close to the melt pool. After the laser beam exits the fiber it is collimated by optical lenses and focused using long focal lengths. Then it is diverted by 90 ° and again focused to the substrate. The final optical element is integrated into a cassette so that it can be quickly exchanged.

The powder delivery feed is connected from the side and is suitable to be used for dragging as well as pushing welding directions inside the tube (Fig. 2). The melt pool is shielded with inert gas, which runs along the laser beam to the exit port. The inner diameter cladding head is completely water cooled, all the way from the connecting element to the laser beam exit port. The head offers to adjust the collimated laser beam to the exit port and to align the powder nozzle with respect to the melt pool. A ball pressure screw can be used to support the inner diameter coating head inside the tube that is cladded. The head is modular and can be expanded with 500 mm long extension modules.

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RESULTS

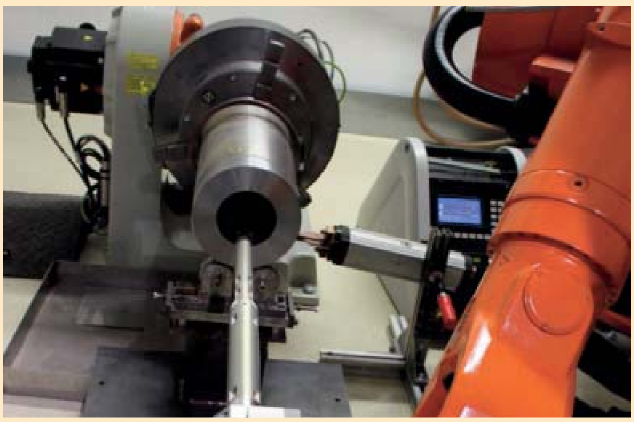
The inner diameter laser cladding optics Mini-ID can handle up to 1.5 kW laser power. A thermocouple for temperature measurements of the final optical component and an endoscope camera for process monitoring are integrated into the head.

Prior to performing long-term process stability tests with deep tubes, the optics had to be thoroughly tested to demonstrate its process technology and welding quality. Welding tests of 15 min were successfully performed on flat samples with Ni base alloys and a typical laser beam diameter of 1.8 mm, a working distance of 6.5 mm and 500 W laser power.

The long-term stability tests were performed through cladding real parts for the plastics manufacturing industry. The cylinders had an outer diameter of 200 mm, an inner diameter of 110 mm and a length of 500 mm. The parts were inductively pre- and post heated so that hard metal alloys could be internally coated while avoiding crack formation. Figure 4 shows the welding setup with induction support.

Long-term internal cladding runs were performed for up to 2 hours. The tubes were preheated to 300 °C, with a laser power of 700 W and a laser beam diameter of about 2 mm, the feed rates of the head inside the tube were 500 mm min^{-1} (Fig. 3). The Ni base alloy was coated on the inside surface of the cylinder to a thickness of 0.5 mm. At the end of the process the cylinder temperature was 370 °C. All optical components of the constantly cooled internal diameter cladding head survived the test without damage despite the heat load inside the heated tube and being surrounded with a flow of residual powder.

Welding setup for inductively assisted inner diameter cladding



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1 *Internal diameter cladding optics Mini-ID mounted to KUKA robot*

2 *Lateral powder gas flow at the cladding head*

4 *Long-term coating of a cylinder with laser powder cladding*

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