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3D-capable Coaxial Laser Brazing Head

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ABSTRACT

Laser processing heads for brazing applications still operate with lateral wire feed suffering from two major disadvantages: the reorientation and the low joint strength. The head's reorientation becomes very complex if small radii are to be processed. Moreover, the joint strength is limited due to shadowing effects of the laser beam by the filler wire. Thus, the preheating of the wire and the base material are inhomogeneous and lead to a reduced wetting ability and thus to reduced strength of the joint.

In order to overcome these limitations, the optical system design, which is developed for diode and solid-state laser applications, enables the generation of a donut shaped laser intensity distribution with a concentric and obscuration-free wire feed. Thus, it provides a full-3D-processing capability without lateral interference contours. Despite of the current design still operating with an external seam tracking system, the optical design is already prepared for an internal, coaxial tracking.

Despite of the design aiming on the brazing industry, applications in the area of aluminum welding or cladding are also conceivable and currently under investigation. Particularly cladding is of great interest, since the 3D-capability is of major value.

Keywords: laser brazing, cladding, coaxial wire support, 3D-capability

1. INTRODUCTION

The industrial breakthrough of laser beam brazing goes back to 1998, when the Audi TT Coupé and the VW Bora successfully implemented this process into their production lines. In the past two decades, laser beam brazing increasingly found its way into the automotive industry and established as a key process in the car body construction.

Laser processing heads for brazing applications usually operate with lateral wire feed, resulting in two major disadvantages (Kogel-Hollacher, 2012): First, the reorientation of the head is very complex if small radii are to be processed. Second, due to shadowing of the laser beam by the filler wire, the preheating of the base material is not homogeneous and leads to a reduced wetting ability and thus to reduced strength of the joint.

In order to overcome these limitations, the developed optical system design for diode and solid-state lasers (Diettrich, 2011) enables the generation of a ring-shaped laser intensity distribution with a concentric and obscuration-free wire feed. Thus, it provides a full-3D-processing capability without lateral interference contours (Pütsch et al., 2012). Although, the current design still operates with an external seam tracking system, the optical design is already prepared for an internal, coaxial tracking (Fig. 1).

Fig. 1: CoaxBrazer design with attached sensor technology

While current state of the art systems operate at processing speeds of 3 to 4 m/min and provide moderate seam cross sections, the new design provides a significant benefit in the wetting behavior at comparable speed levels. Thus, higher processing speeds of up to 10 m/min can be achieved, still ensuring large wetting and superior tensile strength.

Despite of the design aiming on the brazing industry, applications such as aluminum welding and laser cladding are also conceivable and of major interest.

2. DESIGN OF THE COAXIAL BRAZING HEAD

In order to understand the benefits of the coaxial laser brazing head, a fundamental knowledge on the optical design is mandatory. The principle of the laser beam forming is depicted in Fig. 2.

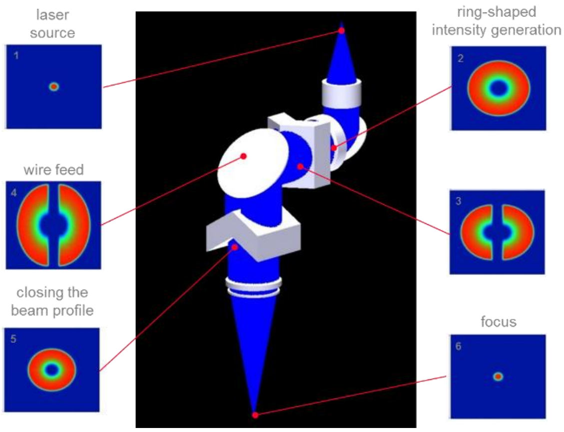

Fig. 2: Principle of the laser beam forming (Gatej, 2015)

The optical design enables the use of every fiber-guided laser source, including diode lasers, fiber lasers and disk lasers. The homogeneous or Gaussian beam intensity distribution is collimated and transformed into a ring-shaped intensity distribution providing a hollow space in the center. Using a prism element, the beam is separated into two segments. This allows the introduction of a wire feeding tube into the center of the optical components without any laser beam obscuration at this point. Therefore, starting at the beam bending mirror, each single component afterwards is to be drilled. The second prism element closes the beam profile and delivers a rotationally symmetric intensity distribution. After the focusing optics, the beam keeps its ring-shaped intensity distribution almost until the focal area, where it becomes an almost Gaussian beam profile.

3. APPLICATION RESULTS

The processing quality is analyzed in different applications, encompassing typical joint designs in car body manufacturing. Usually a CuSi3 brazing wire with diameters of 1.0 – 1.6 mm are applied for brazing zinccoated steel plates with flanged seams. Fig. 3 depicts the processing of such a seam at 3.5 m/min using a 4 kW fiber laser (NA of 0.1 and a fiber core diameter of 200 µm) with the head mounted on an industrial robot. Moreover, the seam is tracked by an external optical seam tracking system and the position is corrected by two linear drives, mounted perpendicular to the processing direction.

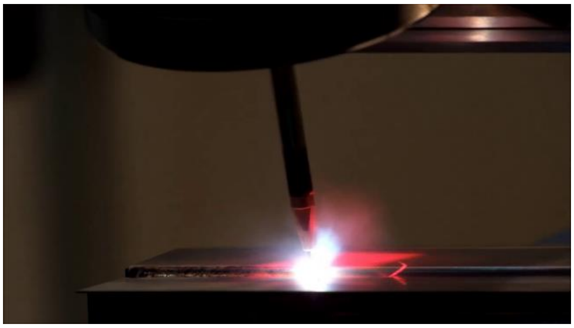

Fig. 3: Coaxial laser brazing of a flanged seam using a CuSi3 wire

Laser brazing in the automotive industry partly requires complex robot programming due to small radii and reorientations to be processed in combination with the usually used lateral wire feed providing an interfering contour. The coaxial principle with the ring-shaped laser intensity distribution simplifies this task and enables the design and processing of more complex 3D-seam-geometries.

An application area where complex 3D-geometries are already produced today, is the area of laser cladding. Particularly powder-based processes with coaxial nozzles allow flexible processes in all directions. However, powder-based laser cladding has one major disadvantage: the powder consumption is very high, since material, which was not melted, cannot be used for further processing. Moreover, adhered and not melted particles reduce the surface quality and have partly to be removed for improving the processing of multiple layers. The wire-based coaxial laser cladding (Fig. 4) overcomes these limitations and provides a smooth and economical processing.

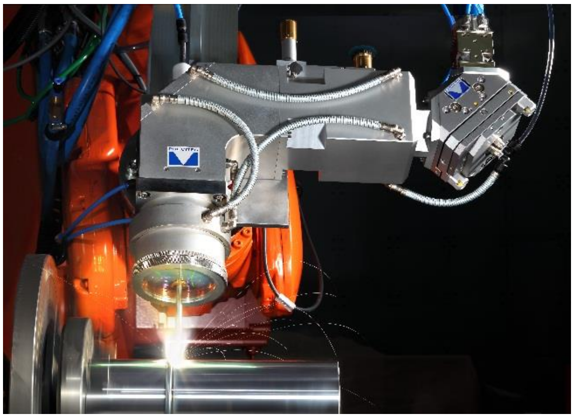

Fig. 4: Wire-based coaxial laser cladding on a rotating cylinder

Finally, the 3D-capability is demonstrated in terms of laser cladding by generating a circle of a steel alloy consisting of multiple layers on a planar substrate plate (Fig. 5).

Fig. 5: Wire-based coaxial laser cladding of a circle after one layer (left) and twelve layers (right)

4. CONCLUSION AND OUTLOOK

The wire-based CoaxBrazer, a brazing and cladding head with a coaxial wire feed providing a ring-shaped laser intensity distribution, is a game-changer. It opens up new application fields where the design can exploit its strength and pushes limits in existing applications. Its full 3D-capability due to the optical and mechanical concept provides significant benefits and major advantages in terms of processing speed, joint strength, robot programming and material consumption.

Although already prepared for an internal seam tracking from the optical point of view, further development in terms of software is required to provide this feature and make this system an all-in-one-solution for various applications.

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