Advanced Industrial Solutions for Laser Beam Cladding

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Abstract

Laser beam cladding has been established for some years as precision manufacturing technique in the industry. An important precondition for success in the industrial mass production are the current stable operating and commercially available CO_2 Nd:YAG, and High Power Diode Lasers as well as the relates system technology. The modular cladding system COAXn represents a flexible processing tool for laser cladding applications and guarantees a stable and controllable manufacturing process as well as the highest precision in material deposition. It consists of different powder nozzle bodies, tips, adapters, media supplies, and process monitoring devices, which are compatible among each other. Thus, for various lasers, optics, workpiece geometries, and cladding materials required by the user, an optimal unit can be composed easily. The basic nozzle is designed for a minimum focal length of the laser focusing optic of 70 mm and a rotation-symmetrical as well as rectangular power density distribution. Nozzle inclinations do not influence the powder supply, and even working in three-dimensional space with moving nozzle is possible without any effect on the powder stream. The minimum powder focus is about 1 mm, and the powder efficiency can amount to 90 % when the melt pool is larger than the powder spot. Experiences with up to 6 kW laser power even in long-time operation do exist. A number of these cladding units has been established for years in industrial applications of repair and surface protection of aeroengine parts, motor and turbine components as well as moulds and tools. The nozzle system is commercially available and has been developed to meet the particular demands of the industrial users.

1. Introduction

Laser beam build-up welding has been established in the fields of repair and surface protection for years. CO_2, Nd:YAG, and diode lasers up to 6 kW are in use for this purpose. To meet the special requirements of each certain application, robust and variably designed welding heads are necessary, which guarantee a stable and well-defined supply of the cladding powder into the laser induced melt pool. Meanwhile, the coaxial nozzle type is the most common setup to get optimum cladding results. For industrial use, these nozzles must be easy to handle, the effort for maintenance should be low, and spar parts like nozzle tips have to be easily to change. Often also extra narrow and lightweight heads are required for complex applications in CNC machines or robots. Finally, the powder focus has to be unaffected even under extreme welding positions with moving and inclined cladding head.

2. Modular system of coaxial powder nozzles

The current constructive design of the coaxial heads consists of three modules: powder supply and distribution, nozzle tip unit, and adapter/adjustment unit. These modules are available in a large number of different shapes, sizes, and materials, and they are compatible among each other. Thus, a flexible construction kit permits the quick composition of a cladding head which is precisely adapted to the requirements of the particular application. Fig. 1 shows an example of a complete cladding unit.

Fig. 1: Cladding unit with laser optic, adapter, and coaxial nozzle

Fig. 2 illustrates the function of the coaxial nozzle: Up to four powder components are blown into an expansion chamber. There a powder-gas-cloud is formed, which is distributed homogeneously around the laser beam. After this, the powder stream passes through specially shaped channels, which transfer it into a quasi laminar flow parallel to the axis of the laser beam. Finally, the ring-shaped slit of the nozzle tip focuses the powder stream onto the laser spot.

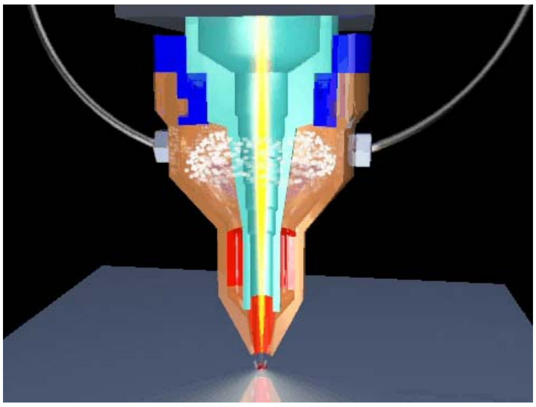

Fig. 2: Principle of the coax nozzle

3. Performance

The minimum diameter of the powder focus is about 1 mm. This guarantees a powder efficiency of 60 - 90 % if the width of a single track is not less than 1.5 mm. Using metal powders (specific weight ≈ 8 g/cm^3, grain size = 25 - 90 µm), typical feeding rates lie between 4 and 50 g/min. An additional gas flow partially protects the melt bath from oxidation. Inner and outer parts of the nozzle are intensively water cooled, so that uninterrupted machining times of many hours are possible.

Fig. 3: Technical variants of nozzle bodies and tips

The nozzle is designed for a minimum focal length of the focusing optic of 70 mm and a preferentially rotation-symmetrical power density distribution. Normally, the powder focus is 13 mm below the nozzle tip.
To provide good powder efficiency and high quality claddings, the powder focus must be at the level of the melt bath. The nozzle tip is easily exchangeable. The commonly availab-le tip variations permit other working distan-ces, e.g. 20 or 30 mm, additional cooling, va-rious edge angels of the powder stream, as well as, on request, a non-circular shape of the powder focus.
Fig. 3 und 4 show examples of some nozzle compositions. The weight of the lightest noz-zle of aluminum is 290 g compared to 1500 g of the larger and extra robust bronze nozzles. All the media necessary for the cladding process (powder, gases, water) are supplied to the nozzle body via convenient quick-snap connections. The integration of the cladding unit into standard CNC machines, like milling or turning machines, is easy and inexpensive.
Because of the homogenous particle distribu-tion, the powder supply is independent from the welding direction. So nearly any desired contour can be generated in a layer. In addi-tion, nozzle inclinations do not influence the powder supply. Even working in three-dimen-sional space with moving nozzle is possible without any effect on the powder stream. A related application for laser cladding using ro-bots shows Fig. 5.

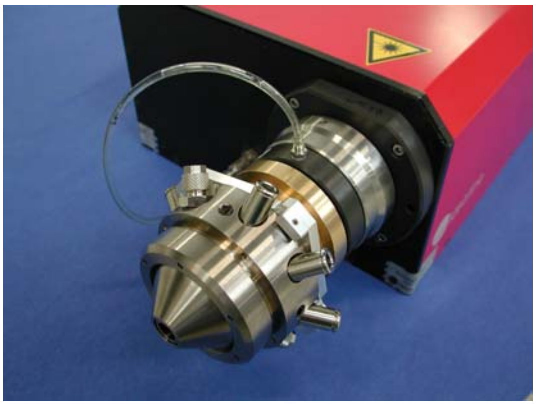

Fig. 4: COAX8, directly coupled with a High Power Diode Laser

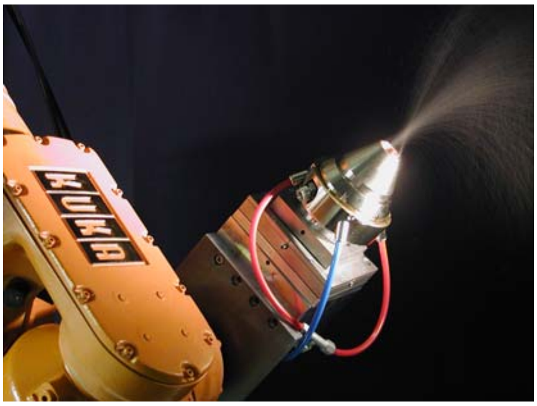

Fig. 5: COAX10 in a robot guided 3D cladding system

4. Applications

With respect to the rising demand within the last years, until now approximately 30 cladding units have been developed for users in different branches. Noteworthy examples are the repair of turbine blades and seal fins of gas turbines and aeroengines, surface protection of car engine components and wear parts, repair of metal forming tools and mould inserts as well as the direct manufacturing of complex shaped sections of tools. The Figures 6 – 8 show some of these applications.

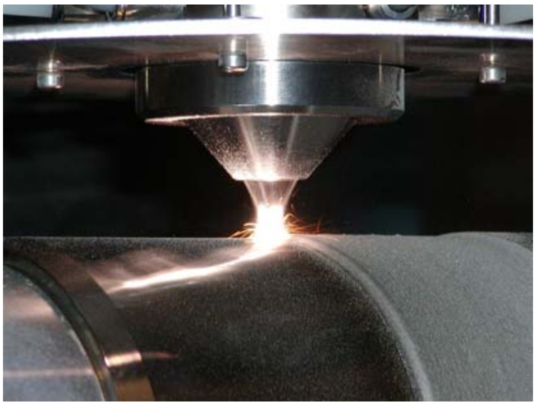

Fig. 6: Cladding of oil drilling tools

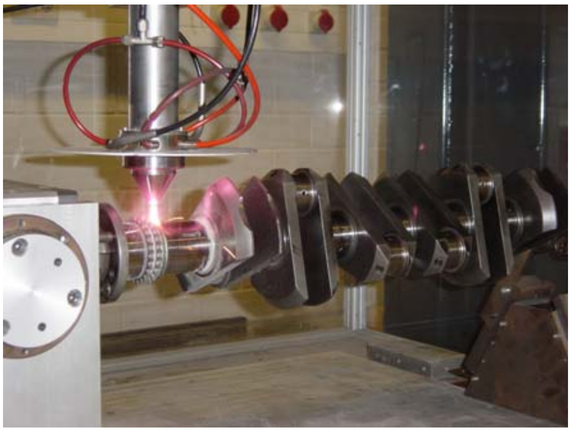

Fig. 7: Repair of car engine crankshafts

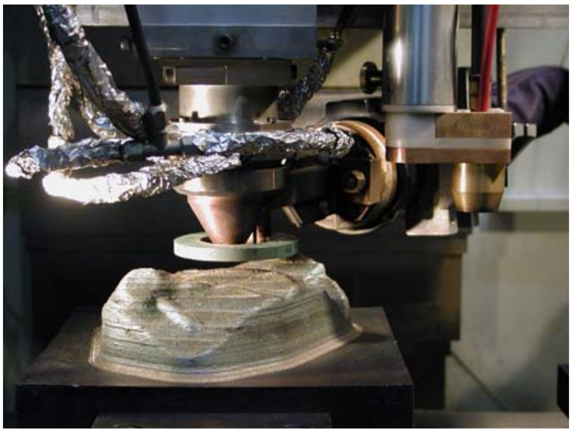

Fig. 8: High-speed generation of a tool section by induction assisted laser beam build-up welding

6. Meet the authors

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