Thermal Spraying with Diode Lasers

An innovative coating solution optimizes the coating of pipe walls.

Thomas Molitor

Fig. 1 Boiler tubes in biomass and incineration plants are exposed to extreme operating conditions. If unprotected pipes are used, a rapid and progressive oxidation process can lead to tube leakage in some cases within less than one year.

Boiler tubes in biomass and incineration plants are exposed to extreme operating conditions: To create vapor pressure within the pipes enabling an effective drive of the power-plant turbines, flue gas temperatures of up to 1000 °C must be realized within the combustion chamber of the boiler. But no pipe-material will stand the chemical processes induced by this procedure for a long time. So, in order to improve the lifetime of pipes, many power plant operators count on metallic or ceramic corrosion-protection coatings.

Temperatures of up to 1000 °C can occur in the combustion chamber of a boiler, but already at temperatures of 350 °C, the chlorine in the flue gas increasingly reacts with the iron of the ferritic pipe materials. A rapid and progressive oxidation process begins and reduces the wall thickness of the pipes, leading for unprotected pipes to tube leakage, in some cases within less than one year. To extend the lifespan of pipes, metallic or ceramic corrosion-protection coatings can be used. With their help, the material decomposition process can be delayed (**Fig. 1**) and the lifetime of the pipes can be tripled or even quadrupled. The investment in such a coating is mostly profitable if the lifetime of pipes is doubled because the exchange of corroded pipes requires new tubes plus a temporary shutdown of the whole boiler system.

Häuser & Co. in Duisburg is a manufacturer that is specialized in coating solutions for boiler tube systems. The medium-sized family enterprise is headquartered within the factory premises of the steel giant ArcelorMittal, founded 1995 by demerging from the former Thyssen AG. It uses thermal spray processes, tailored to realize protective coatings for metal components which are impinged by hot gases – processes that are partly patented by Häuser & Co. These processes were originally supposed to minimize the high-temperature corrosion in the waste heat boilers located above the Thyssen steel converters. After their spin-off, the coatings were further developed in view to corrosion and wear protection for power plants and waste incineration plants. However, customers requesting additional applications within the power plants soon required a further development of the plasma spray technology, along with an extension of business activities to other thermal spraying processes as well.

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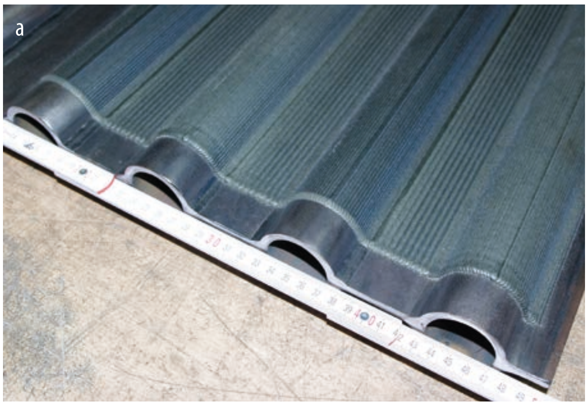

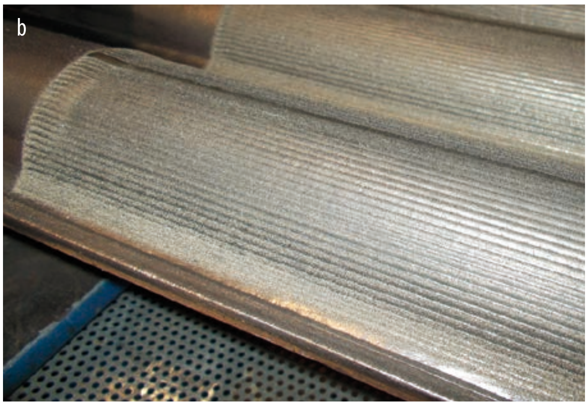

Fig. 2 At membrane walls ("finned walls", a), the boiler tubes are connected by metal bars ("fins"). The complex surface geometry of membrane walls (b), individualized at each single power plant, places high demands on the coating technology.

Laser instead of plasma

In such an endeavor, Häuser particularly wanted to improve the application field which, due to market development and own order situation, became increasingly important: the coating of membrane walls. At these pipe walls, also referred to as "finned walls", the boiler tubes are connected by metal bars – the "fins" (**Fig. 2a**). The complex surface geometry of these components, individualized at each single power plant, places high demands on the coating technology (**Fig. 2b**) and pushed the technology developed by Häuser to its economic limits.

While rotation-symmetric single pipes could be coated within a appropriate time, it was virtually impossible to transfer the process of thermal plasma spraying, including a subsequent heat treatment, in an economical way to the coating of membrane walls. In case of workshop-coatings of complete pipe walls with a length of up to eight meters and width of up to one meter, Häuser repeatedly had to defer to competitors, who realized protective coating-layers by welding instead of thermal spraying. For power plant operators, however, this process has disadvantages. Due to the high heat input of the conventional welding processes, the applied coating-alloy is mixed with the basic tube material resulting in Fe-enrichment and an unsatisfactory ratio regarding corrosion resistance and minimum layer thickness. Therefore, Häuser embarked on the search for a suitable process that could economically be put on a par with conventional welding techniques and could ultimately replace them by offering technical advantages.

The solution came during the visit of a Welsh supplier of spray powders, who was involved in the development of new coating processes in the course of a scientific-technical co-operation project, someone who was using a laser system with Laserline diode lasers. The knowledge gained by studying this laser application was then transferred by Häuser to their own spraying technology. The result was the so-called thermal laser spraying – a coating process that is a combination of thermal spraying and cladding, and combining the advantages of both technologies. During plasma spraying, a noble gas (ionized by an arc) serves as energy source while laser spraying uses the beam of a diode laser (**Fig. 3**).

When impinging the component's surface, the beam creates a calm molten pool with very low-impact depth. An argon

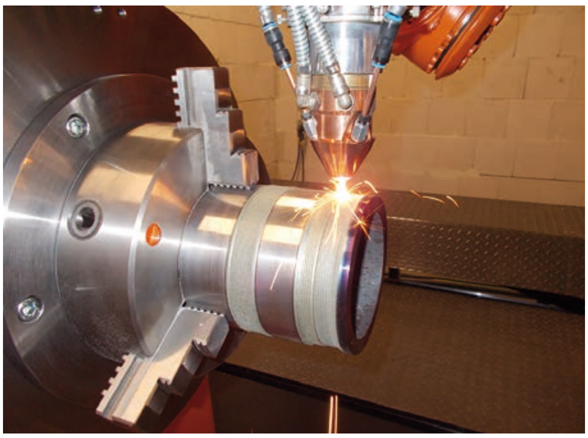

Fig. 3 By a beam-guiding fiber optic, the diode laser is integrated into a multiaxial robotic with flexible coating-head and, with the help of a Laserline processing optics, it is focused on the workpiece.

Fig. 4 Thermal laser spraying allows for excellent coating results, not only for the individually dimensioned membrane walls but also for industrial valves, shaft drives or – as shown here – a wear bushing.

stream blows the powder particles of the coating material into the pool where they melt. After solidification of the molten pool, a homogeneous and almost pore-free protective layer remains, which is bonded metallurgically to the base material. As the creation of a molten pool cannot be completely prevented – this procedure only succeeds using the plasma spraying process – a mixing of the applied coating with the basic material is also made – similar to cladding. However, this mixing-zone is much thinner than at conventional welding processes and actually so minimal that it does not influence the quality of the protective layer. Additionally, the heat input is so small that this coating process can be done without cooling the components.

Laserline diode lasers as thermal energy source

Häuser uses Laserline's diode lasers as beam source. The main reason is the excellent suitability of this laser type for surface treatment: The diode laser beam ensures an extremely steady impact on the focal surface because of its homogeneous intensity distribution. Furthermore, the power output of the laser can be finely regulated within milliseconds allowing, when combined with a fully automated process control, for an exact and 1:1 reproducible coating process. In this way, even complex surface geometries with different characteristics can be reliably coated with homogeneous layers. Accordingly, thermal laser spraying brings excellent coating results, not only for the individually dimensioned membrane walls, but also for industrial valves, bushings or shaft drives (**Fig. 4**). Besides the treatment of new workpieces, in addition this process is especially suitable for the repair and reprocessing of used components. For example, in the area of fitting technology, spindles and sealing plates, undersized due to mechanical material removal, can be repaired by thermal laser spraying. Also, roll journals or wear bushings can be repaired fairly easy.

The LDF 6000-100 diode laser used by Häuser offers a maximal 6 kW output power at a beam quality of 100 mm mrad. Within this power range and with the help of the new method, various coating materials (e. g. Inconel 625, Hastelloy C or Stellite 21) can be processed. By a beam-guiding optic, the laser is integrated into a multiaxial robotic with flexible coating-head and, with the help of the Laserline processing optics, it is focused on the workpiece. This technically sophisticated system allows economically feasible processing times and turns this new method into a very attractive alternative to the conventional deposition welding in every way. For coating, a 100 m^2 membrane wall with one laser spray equipment, Häuser currently estimates a period of four weeks. Because of the high operational stability of Laserline diode lasers, the availability of more than 99.5 % can be guaranteed.

Further application fields

The Häuser team is satisfied with the efficiency and high flexibility of the new method. Thanks to the gentle precision of the laser-supported surface treatment and the homogeneous coating results, the strict German TÜV guidelines can also be met. The pressure test, for example, which is compulsory after each boiler repair, poses no longer any critical challenge. For power plant operators or specialized providers tasked with plant maintenance, this means an enormous relief. By expanding the view to valves, shafts and other workpieces, it has become fairly apparent that thermal laser spraying can also be used for several other application fields in the coating sector.

Häuser & Co's TÜV-certified method has been further developed for applications in the maritime sector. Further application areas are very likely to follow.