ONE-STEP LASER-ASSISTED THERMAL SPRAYING

Steps against anisotropy and low homogeneity are among the challenges affecting classically sprayed layers. Based on laser assistance in the coating procedure, the Fraunhofer IWS team engineered a "one-step solution" to immediately apply homogeneous high-performance metallic coatings.

Copper-based coatings are materials offering outstanding application potential, for example in electrical and automotive engineering. This is primarily due to its excellent electrical conductivity. Relevant examples are, for instance, strip conductors of all sizes made of pure copper, tungsten-copper electrodes, forming dies and molds, welding equipment made of AMPCO copper, as well as copper-tin and copper-zinc sliding bearings. Materials currently processed include environmentally critical alloys, such as beryllium-copper, which have to be replaced as soon as possible. One of the challenges encountered in thermal spraying of electrically conductive materials is the oxidation of the feedstock during the process, which increases the coatings' electric resistance. Moreover, the typically anisotropic structure results in differing electric properties along and across the coating.

Low pressure for high profitability

The new low-pressure cold spraying technique (LPCS, German abbrev.: NDKGS), in which the engineers inject powder into diverging nozzle sections at approximately six bar provides an attractive solution. LPCS systems are typically compact in design and mobile in use, and costs amount to only about ten percent of the investment required for a high-pressure cold gas spraying system. However, feasible particle velocity values impart the risk of particle-to-substrate bonding defects. To refine layer adhesion, only specially mixed powders including uncongenial ceramic particles are currently in use. However, the enclosed hard particles have a negative influence on the layer microstructure; they represent layer defects and contribute to inhomogeneities. This limits the range of applications for LPCS as a coating solution.

Laser impact on coating structure

A comparison of coatings obtained with commercial copper powder including alumina particles, fabricated without (top) and with (bottom) laser support. Positioned such that it runs ahead of the spraying particle beam, the laser spot improves bonding to the substrate.

Hybrid copper coating without alumina particles

Guided in an overlapping way and following the spray beam, the laser enables the fabrication of pure copper coatings without any pores and cracks.

Universal hardware systems with laser beam energy

One solution to overcome the anisotropic structure and the bonding defects is additional heat in the process, excactly where it is needed. Fraunhofer IWS engineered a new hybrid laser spraying head which can not only be integrated into LPCS, but also into conventional spraying systems. The laser beam offers advantages as an energy source for hybrid coupling with thermal spraying processes thanks to its targeted selection, precise controllability and low total heat input. Users can exploit the laser beam's energy intentionally for substrate pre-treatment, process support, and layer post-treatment. The key to solving the anisotropy and adhesive bond strength problem lies in the positive metallurgical effects that are used intentionally after the spray structure has been formed during the laser-induced heat treatment in the ongoing process. In commercial high-power lasers, the physically limited laser wavelength absorption commonly amounts to between 860 and 1,024 nanometers. Multiple reflections in the sprayed particles' jet and the splat-like morphology of the emerging spray layer significantly improve the values. New laser beam sources in visible green and blue wavelength ranges hold additional potential to achieve at least 40 percent radiation absorption. These types of high-power lasers are innovative beam sources whose application potential is still widely unexplored. Above all, they offer the possibility to implement the technically realized solution for the mentioned copper materials with high relevance for later industrial employing.

Improved bonding without admixed oxide

Making use of the new hybrid laser spraying head, the IWS scientists verified the achievable metallurgical effects in practice. Even using conventional spray powders containing aluminum oxide (alumina), simultaneous laser support reduced the pore and defect percentage in the solidified sprayed structure. Moreover, as a result of the laser impact an oxide admixture becomes superfluous, since dense, adhesive coatings are formed nevertheless. The binding mechanisms of the layer to the substrate even go beyond the otherwise characteristic type of purely mechanical bonding and exhibit advantageous amounts of a melt metallurgical bond. As a result, the one-step laser-supported spraying process provides very promising coating solutions offering a wide application potential for all those coating systems demanding further improved bonding and intentional coating morphology modification.

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