MATERIALS PROCESSING SPANS MANY INDUSTRIES AND ENCOMPASSES AN EVER-WIDENING RANGE OF APPLICATIONS, SUPPORTED IN TURN BY A BROAD SPECTRUM OF LASERS, INCLUDING CO₂, FIBER, DIRECT-DIODE, DIODE-PUMPED SOLID-STATE (DPSS) AND EXCIMER LASERS. THIS MARKET IS HUGE AND DIVERSE – FROM MONOLITHIC – AND NEW PROCESS DEVELOPMENT, OR SIGNIFICANT ADVANCES IN LASER TECHNOLOGY ARE DRIVING GROWTH IN KEY APPLICATIONS. AS A RESULT, LASER MANUFACTURERS HAVE RESPONDED WITH AN EVER-EXPANDING RANGE OF PRODUCTS AND TECHNOLOGIES, AND THIS DIVERSIFICATION AND SPECIALIZATION SHOWS NO SIGNS OF ABATING.

LASER CLADDING

Cladding involves the creation of a new surface layer on top of a base material. It is a widely used process for improving the surface and near-surface properties (e.g., wear, corrosion or heat resistance) of (usually) new metal part, or to resurface a worn component so it can be machined back to original dimensions.

Cladding is employed in several industries; examples range from hard teeth for gears to corrosion-resistant large pumps and shafts for shipping and oil/gas rig applications. Traditional techniques for cladding are thermal spraying and arc welding. In thermal spraying, the clad material is melted by a flame or electricity, then sprayed onto the workpiece, which usually remains <200 °C. It is a fast, relatively inexpensive process that results in minimal peripheral heating. However, it produces a thin coating rather than a true metallurgically bonded layer. This can lead to problems with adhesion and poor wear resistance, especially to pinpoint loading.

In arc welding methods, some type of plasma arc is established to melt the surface of the base material. The clad material is then introduced in either wire or powder form and is also melted by the arc, forming the clad layer. The result is a true metallurgically bonded clad layer. But significant mixing of the substrate and clad materials, called dilution, can occur, which affects the final properties of the surface layer, requiring thicker cladding. And the intense heating can cause part distortion, resulting in the need for major postprocessing machinery. Moreover, when cladding with powder, capture rates of approximately 80 percent are typically achieved.

In contrast, laser cladding can deliver most of the advantages of thermal spraying and arc welding, with virtually none of their drawbacks. The laser melts the cladding material (in powder or wire form) as well as a thin surface layer of the substrate. The result is a metallurgically bonded clad, with very low dilution and minimal part distortion, and a powder-capture rate of up to 95 percent.

In the past, laser cladding was performed with CO₂, various types of Nd:YAG and, more recently, fiber lasers. Although these yielded clads with better adhesion and wear characteristics, practical factors related to cost, speed and implementation impeded widespread adoption of laser cladding.

LASER MANUFACTURERS HAVE RESPONDED TO THIS NEED BY DESIGNING HIGH-POWER DIRECT-DIODE SYSTEMS SPECIFICALLY FOR CLADDING APPLICATIONS. IN THESE PRODUCTS, HIGH-POWER DIODE LASER BARS ARE PACKAGED AS A 2-D ARRAY TO REACH MULTIKILOWATT OUTPUT-POWER LEVELS. THESE COMPACT LASER HEADS DELIVER HIGH ELECTRICAL EFFICIENCY, LONG-LIFE RELIABILITY AND ROBUST OPERATION IN HARSH MANUFACTURING ENVIRONMENTS. BROAD RANGE OF LASERS MAKES NO COMPROMISES ON OUTPUT POWER, LENGTH OF LINE PROFILES, WIDE RANGE OF OUTPUT BEAM SHAPES.”
Also, over the past five years, fiber lasers have made substantial inroads in the cutting market. However, first-generation fiber lasers do have some practical and cost limitations relative to CO₂ lasers; their architecture does not support field serviceability, which can have a significant impact on the cost of ownership. This limitation has been addressed in second-generation fiber lasers, which use a modular architecture and monolithic diode arrays for pumping, rather than multiple individual diodes with separately spliced fibers. This enables simple field replacement of components if needed.

Determining which laser technology is best for a given cutting application requires a detailed cost analysis and some process evaluation in the applications lab, but the market typically splits as follows. Most nonmetals, such as plastics, have poor absorption at the near-IR (around 1 µm) output wavelength of fiber lasers. This leads to charring and thermal damage rather than clean cutting. In contrast, the longer-wavelength (10.6 µm) CO₂ output is well absorbed by most organic materials, including plastics, fabrics, leather and wood. Thus, applications such as sign cutting and engraving are dominated by low-power (<1 kW) CO₂ lasers. For steel of up to a few millimeters in thickness, >1-kW CO₂ or fiber lasers can both do the job. For situations where this is the only task, such as making outer skins for white goods such as washing machines, fiber lasers are a safe choice.

New materials-processing composites

Looking to the future, new materials will displace metals in many industries. For example, carbon fiber-reinforced plastics (CFRPs) are composite materials that possess a highly desirable strength-to-weight ratio. They were developed primarily for aerospace applications, but can now be found in products ranging from automobiles, sailboats and racing bicycles to golf clubs.

A CFRP consists of two main components. The first is the reinforcement, which provides load-bearing strength and rigidity. It is carbon fiber, usually woven like a fabric. The second part is the matrix, usually consisting of epoxy, which surrounds the reinforcement and binds it together.

Larger CFRP structures, such as airplane bodies, are typically constructed by joining individual pieces. This can be accomplished using conventional mechanical fasteners (screws, rivets, etc.), but this approach has several drawbacks; e.g., drilling through holes for fasteners can damage the load-carrying fibers. Also, stress concentrates around fasteners, meaning that reinforcement may be required, which increases the total assembly weight. As a result, adhesive bonding has become widely used for joining CFRPs.

As with any adhesive application, good bonding requires a pristine surface, free from dust and chemicals/lubricants such as mold-release agents. However, any surface cleaning must not cause any damage to the underlying CFRP and especially the load-carrying fibers. Several techniques are currently in use for the cleaning and preparation of CFRP parts prior to adhesive bonding. Mechanical abrading is mainly used, but there are a variety of other blasting processes as well as the removal of so-called peel plies (sacrificial outer layers). All have well-known drawbacks.

The excimer laser has a long history of thoroughly cleaning surfaces without causing damage; e.g., with rare artwork. It is now proving ideal for CFRP surface preparation for several reasons. First, compared with a 1-µm wavelength, the deep-UV excimer output is absorbed on the resin surface and removes material primarily through photoablation, rather than the thermal mechanisms typical with longer laser wavelengths. This results in essentially no HAZ and enables highly precise material removal. Next, the large rectangular beam produced by excimer lasers can easily be shaped and homogenized to match the geometry of typical CFRP surface preparation applications. Finally, excimer lasers offer a unique combination of high per-pulse energy and repetition rate in the UV, thus supporting rapid material removal and high throughput even with larger CFRP parts.

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