Excimer lasers clean CFRPs for optimised adhesive bonding

Carbon Fibre Reinforced Plastics (CFRPs) are composite materials that offer a highly desirable combination of physical strength and light weight. As such they are currently employed in aerospace applications, sailboats, racing bicycles and even in the manufacture of golf clubs.

Within the CFRP the carbon fibre, usually woven like a fabric, is bound within a plastic matrix, most commonly epoxy or some other polymer resin. The carbon fibre reinforces the plastic, providing load bearing strength and rigidity.

Joining methods

Creating CFRP structures often requires joining individually fabricated pieces. However, the use of traditional mechanical fasteners (screws, rivets, etc.) can damage the load carrying fibres and concentrate internal stress, and can increase the weight of the assembly. Adhesive bonding offers an alternative but achieving a high strength adhesive bond requires the removal of surface trace contaminants prior to bonding. This is critical, because bond strength is highly dependent upon surface cleanliness.

Techniques for surface pre-treatment

Several techniques are currently used for cleaning and preparation including mechanical abrading and grit blasting, but these methods have disadvantages. For example, most mechanical abrading processes suffer from low throughput speed and are usually performed wet, thus necessitating subsequent rinsing and drying. Grit blasting leaves residues that make cleaning necessary. In the aerospace industry, peel-plies (sheets laminated onto the CFRP surface prior to curing the matrix resin) are used for CFRP surface preparation. They are removed before adhesive bonding leaving a clean surface. However they increase CFRP manufacturing complexity and are not suitable for CFRP repair work.

Laser Treatment Advantages

Laser surface preparation involves ablating a thin layer of material from the CFRP, which removes virtually all contaminant residues. Laser cleaning requires minimal surface preparation, is performed dry, and does not require that the surface be cleaned of debris afterwards. Additionally, laser processing is compatible with the preparation of large surface areas, can be readily automated, and delivers highly consistent results because it is a wear and contact-free process. Laser surface preparation is applicable to CFRP repair applications.

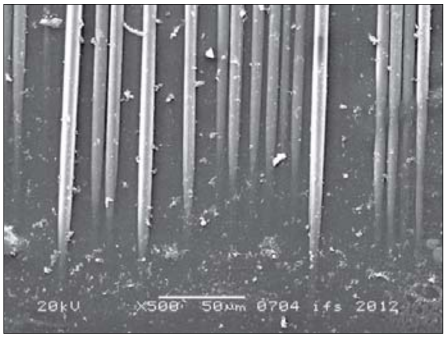

Figure 1: SEM photos of a CFRP surface after six pulses from an excimer laser. The fibres are clearly exposed but not damaged at 308 nm. Courtesy of Dr. Fabian Fischer, Technical University of Braunschweig, Germany.

An essential requirement is that the laser cleaning must not damage the bulk resin or load-carrying fibres. This can be problematic if infrared CW or long pulse lasers are used, such as the far infrared CO_2 or near infrared fibre lasers, because the removal of material results in significant residual heating of the bulk material, which can cause fibre damage as well as cracks in the matrix.

Excimer lasers are the most attractive source for CFRP cleaning for several reasons. They remove material primarily through photoablation, resulting in a negligible heat affected zone. The ability to regulate material removal rate by controlling pulse count, enables highly precise material removal. Also, excimer lasers offer high pulse energy (up to 2 J), in a large rectangular beam that can easily be shaped and homogenised to match the geometry of typical CFRP surface preparation applications. Together, this results in rapid material removal and high throughput, sufficient even for the larger CFRP parts.

Implementation

There are two basic ways to implement excimer laser CFRP cleaning: the line scan or the step-and-repeat method. These are illustrated in figure 2. In the line scan method the laser beam, shaped into a line, is swept continuously across the surface to be cleaned. The number of pulses to which a given spot on the material is exposed is determined by a combination of line width, line travel speed and laser repetition rate. If the line length is shorter than the width of the area to be cleaned, then several adjacent passes of the area are needed.

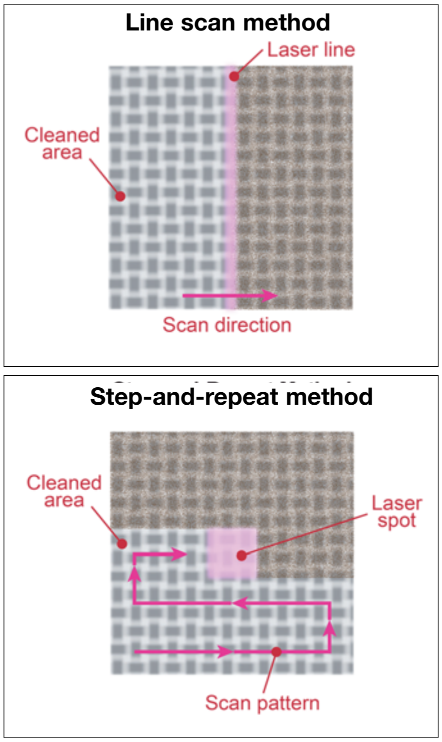

Figure 2: Schematic comparison of line scan and step-and-repeat methods for excimer laser cleaning. With both methods, the CFRP is typically moved and the laser is held stationary to create the scan.

In the step-and-repeat method, the laser beam is formed into a square or near-square. The laser spot is positioned at a fixed point on the CFRP surface, and an exposure is made (consisting of one or more laser pulses). Then, the beam is translated a distance corresponding to its width and the process is repeated. The entire area to be cleaned is sequentially exposed in this manner.

For both methods, the size and weight of typical excimer beam delivery optics usually makes it more practical and economical to move the CFRP under a stationary the laser beam rather than vice versa.

Excimer laser surface preparation promises to deliver superior results over other methods, and has proven to be highly reproducible, making it a consistent and stable process that is well-suited for volume production applications and repair work.

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