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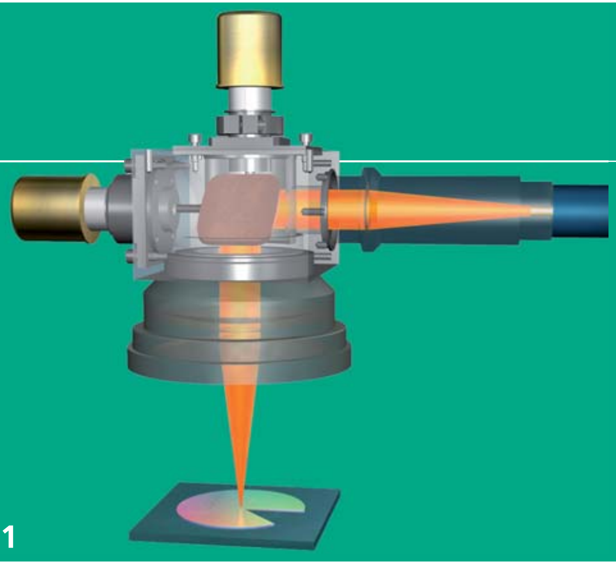

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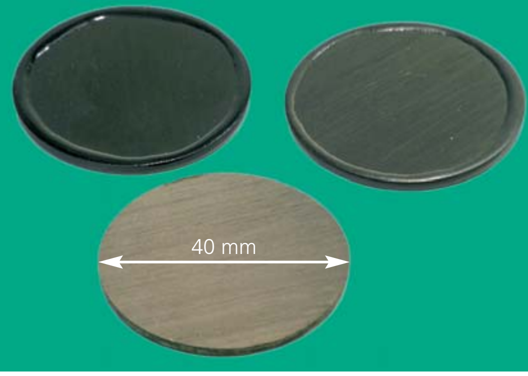

EDGE SEALING OF REMOTE LASER CUT FIBER-REINFORCED POLYMERS

THE TASK

For the cutting of fiber-reinforced polymers, remote laser cutting using beam sources with continuous emission offers several advantages compared to classic mechanical cutting technologies, such as milling, drilling or water jet cutting. High hardness and brittleness of the glass and carbon fibers, in conjunction with the viscoelastic properties of the polymeric matrices, usually result in high tool wear. The forceless and non-contacting laser beam makes it possible to cut edges with continuous manufacturing quality, without delamination, with high productivity; furthermore, the technique makes the technology a good candidate for automation (Fig. 1 and 2).

A heat affected zone occurs in this technology. As a result of the thermal laser impact, the matrix material moves away from the cutting edge, because the decomposition temperatures of the polymers and the reinforcement fibers are clearly different (Fig. 3). There remain exposed fiber ends with a capillary effect and an irregularly structured plastic component margin. The large surface broken through by filaments means that more water can be absorbed, which, in turn, negatively affects the material properties.

Independent of the cutting method, corrosion primarily of carbon fiber-reinforced plastics (CFRP) starts at and propagates from the exposed fiber ends. Graphite is a noble material according to the electrochemical properties. This requires countermeasures, when the less noble lightweight material aluminum is used in structural joint connections.

OUR SOLUTION

We at Fraunhofer IWS Dresden studied the extent to which the remote laser cutting of fiber-reinforced plastics in general results in higher water absorption. We also considered the extent to which edge sealing by the deposition of plastics on laser cut near-net-shape machined structural CFRP components enhances the characteristics in a humid environment.

For this purpose, comprehensive experiments on laser cut and milled CFRP multilayer composites of orthogonal structure were performed. Fine-weighing of the circular test specimens, which have been aged in water bath at 60 °C for a longer period, makes it possible to quantify the absorbed humidity, so that the processing techniques can be compared.

The sealing capabilities of several thermoplastic and thermoset plastics were assessed. Here, not only the barrier's effect on water input, but also handling of the un-crosslinked one- or two-component polymers were important for an automated post-treatment of edges. Low-viscosity epoxy and unsaturated polyester resins were studies as thermoset sealing systems, with polypropylene as the processed thermoplastic. The base material is a CFRP with epoxy matrix and high-strength HT fibers, which was pressed into a prepreg.

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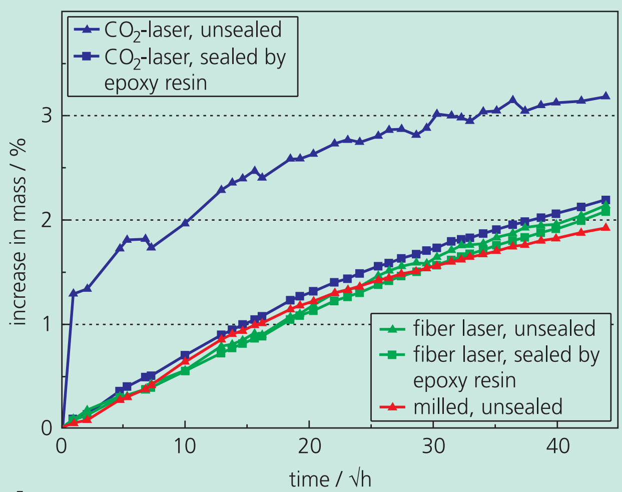
RESULTS

Heat affected zones of up to 500 µm emerge in the CFRP multi-layer composites during CO_2 laser cutting. This phenomenon is caused by the wavelength that offers rather poor focusability in comparison to fiber lasers, so that interaction between the laser and the material takes a long time. The long ends of the filaments, which are exposed, are capillaries with a substantial storage capacity.

The fiber composite weight significantly increases during the aging of the specimens in a water bath (Fig. 4). After the first weighing, the free water absorbed through the capillaries is included in the measurement. Under operating conditions, it is conceivable, that free water is constantly present on the edges and can thus diffuse into the plastic matrix. Consequently, cutting of CFRP by means of the CO_2 laser is not suitable.

Subsequent edge sealing of the CFRP material processed by the CO_2 laser has a great impact. Such post-treatment avoids sudden water absorption by the material and shifts the saturation curve into the range of mechanically machined, unsealed CFRP material (Fig. 4).

Saturation curves of CFRP with various edge states



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Clearly better results are achieved when cutting CFRP by fiber laser. Water absorption is commensurable with the results gained for milled specimens. When the wavelength of the laser in use is changed, the processed material absorbs less water. Subsequent edge sealing does not provide essential improvements in the water absorption properties.

Epoxy resin provides the best processing characteristics for post-treatment of the cutting edges; it reliably adheres to the CFRP base material. Moreover, there are available fast curing systems that can be activated by ultraviolet light or another energy source, which are suitable for an automated process with short cycle times. However, subsequent deposition of polypropylene is not useful. The melt deposited neither adheres to the CFRP nor offers any barrier effect. Neither is the use of polyester resin an alternative, since the strong vibration in conjunction with curing causes the sealing to delaminate.

1 *Remote scanner for cutting of fiber-plastic composites – principle structure*

2 *CFRP specimens cut by fiber laser, without post-treatment (bottom), and post-treated by epoxy resin (top left) and polyester resin (top right)*

3 *Microscopic image of a CFRP edge, remote laser cut (cross section)*

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