Laminating Carbon Preforms

Ultrasonics. Activated by ultrasonic vibrations, carbon fiber layers can easily be bonded and formed in a reproducible manner by using a thermoplastic adhesive fabric. Potential savings as a result from the increased level of automation and reduced energy and time consumption make this approach promising to the industry.

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Carbon has only 20 % of the weight of steel and can be strained four times more than aluminum. Advantages for machine and automobile construction are the low mass and great fatigue strength – carbon is used in aviation applications, race cars, sporting equipment and furniture. However, CFRP is still expensive. The manufacturing processes need developing and enhancing for its use to be competitive. A study by the carmaker VW found that the industry is prepared to pay EUR 450/kg in additional costs for lightweight construction in civilian aviation, but only EUR 10/kg in automotive construction. A Golf automobile from 1975 weighed 800 kg; the current Golf VI weighs over 1,200 kg. The current objectives for lightweight design are also interesting, e.g. in electric vehicles where the aim could be to reduce battery size rather than increase mobility range.

Preform Assembly with Ultrasonic Vibrations

There are two distinct steps in the production of preforms: Lamination of the individual layers or compaction and then the processing of the bonded layers into preforms. Ultrasonic technology can be employed for both steps.

Ultrasonic welding is an established process generating heat to thermally bond thermoplastics and thermoplastic composites. Electric voltage is converted into mechanical vibrations in the ultrasonic frequency range. A welding tool, known as a sonotrode, passes the vibration into the material under pressure. For industrial use ultrasonic frequencies of 20–35 kHz are common with amplitudes of 10–200 microns. At 20 kHz the tool vibrates 20,000 times per second while travelling less than the width of a human hair. In continuous processing a stationary sonotrode or a rotating drum sonotrode can be used. The counterpart is called anvil. If the anvil has an engraved design, the result is considered spot welding or embossing. The melt heat results from friction with neighboring surfaces, leading to decreasing viscosity, and from the movement of molecules in the liquid polymer. Studies have however come to the conclusion that when using ultrasonics for carbon composites only friction between adjacent filaments produces heat. **Table 1** shows the comparison of ultrasonics with other technologies.

Fig. 1. Thermoplastic adhesive fabric between layers of carbon (figures: Herrmann Ultraschall)

Ultrasonics Activates an Adhesive Fabric

Herrmann Ultraschalltechnik GmbH & Co.KG, Karlsbad, Germany, has researched the use of adhesive fabric and other binders in the ultrasonic lamination of carbon fiber mats in a major lab-based project and has obtained positive results. The polymer-based fabric can be manufactured in various widths and weights. Its structure is similar to a par-

Procedure	Advantages	Disadvantages
Spray-on adhesive	Known technology Simple integration Low-cost	Because of solvent, adhesive is a critical consumable Health concerns related to adhesive Dirtying of nozzles Dirt levels in general One spray system per layer Heating-up phase
Sewing	Known technology No heating-up phase Low-cost No dirt	Thread causes holes in composite Lower speed
Heated rolls	Known technology Simple integration Faster than sewing No dirt	High energy consumption/no specific introduction of energy Heating-up phase Ramping not possible Long cooling-off phase for material
Ultrasonics	Instant use Lower energy consumption Specific use of energy Faster process 11 layers possible Reproducible process	Higher investment Undulation possible, but controllable

Table 1. Comparison of ultrasonic technology with other methods

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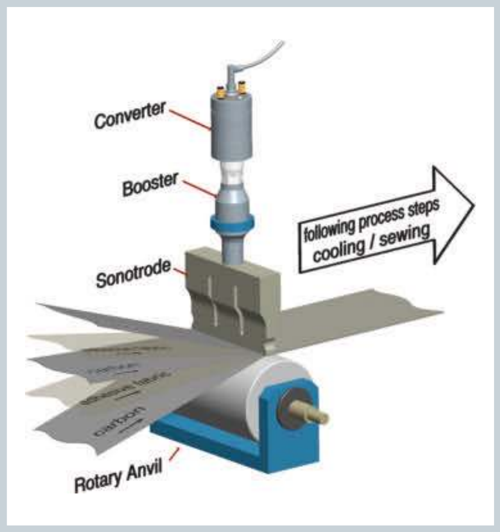

Fig. 2. The principle of ultrasonic lamination

allel non-woven fabric, i.e. it does not have a uniform surface but features small cavities. This provides a flexible, breathable composite **(Fig. 1)**.

The relevant process parameters, in particular the force needed to melt all adhesive fabric layers while retaining the carbon filament structure and fiber orientation, were defined following the DOE principle. The carbon fiber and adhesive layers were passed between the anvil roll and stationary sonotrode. The adhesive fabric is then activated by ultrasonic energy producing friction with neighboring surfaces **(Fig. 2)**. Pictures from an infrared camera show heat development in the layers while the welding tool stays cool **(Fig. 3)**.

The main process parameters are material speed, force and amplitude, while achieving maximum speed of welding for maximum mechanical laminate stability. The immanent risk of undulation has been eliminated in the lab via structural measures for material transport. Ultrasonic activation also meets the needs of sequential activation, both in terms of sonotrode width and product length **(Fig. 4)**.

Conclusion

Ultrasonic welding is a clean and fast way to activate and bond carbon materials. Due to controlled parameter settings, ultrasonic technology enables the rolls to travel faster through precise compression force settings and reduced cooling time. The higher investment costs are recouped through speed, reduced energy requirements and processing flexibility. Feasibility studies for the automotive and aviation industries are underway. ■

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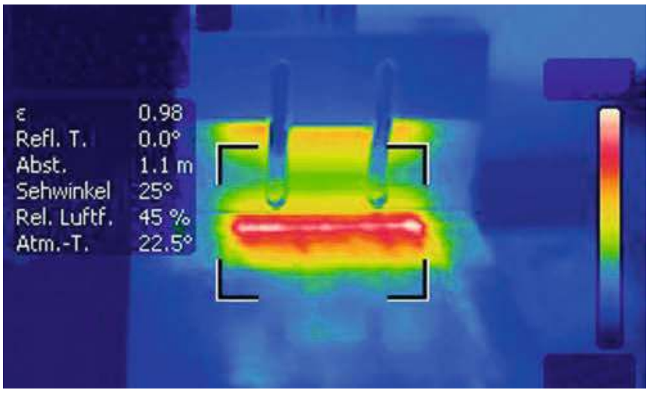

Fig. 3. Infrared-camera shows heat development in material layers – welding tool does not heat up

Fig. 4. Lab setup with stationary sonotrodes: welding carbon fiber mats with ultrasonic vibrations