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STRUCTURAL ADHESIVE JOINING OF TEXTILE REINFORCED THERMOPLASTIC COMPOSITES

THE TASK

The industrial use of thermoplastic fiber reinforced composites in large series production requires suitable and reproducible joining techniques. Adhesive bonding is here of particular importance since the technique allows for a uniform load distribution over large areas of the complex fiber reinforced composite structure. Compared to thermoset based matrix materials, thermoplastic polymers such as polyamides, polyethylene and polypropylene have advantages for high volume production of fiber reinforced plastic composites. Thus the joining process results must yield high strength and durable joints as well as short cycle times to allow for high volume series production.

OUR SOLUTION

The IWS group addressing bonding and composite technologies works on implementing automated processing steps, which enable the adhesive bonding of flat and curved fiber reinforced thermoplastic composites. The following process steps are studied and developed:

- surface pre-treatment,
- adhesive selection,
- adhesive application and curing,
- documentation of transmission strength and durability.

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Surface pre-treatment:
Thermoplastics with low surface energies such as polypropylene provide poor adhesion for adhesives and cannot easily be bonded for the use in structural applications. The adhesion can be improved by physical methods to pretreat the surface or by using special adhesives. Atmospheric pressure plasmas and laser radiation are especially useful to flexibly pretreat such surfaces. Both methods are primarily used to clean the surface (remove softeners, release agents etc.) and sometimes also to functionalize the nonpolar plastics surface. The plasma treatment deposits little heat, is automated and forms functional surface groups. In addition to surface cleaning and activation, laser surface treatments (structuring) can also increase the surface area. This permits the adhesive, in addition to chemical interactions, to also form mechanical anchorage with the polymer surface.

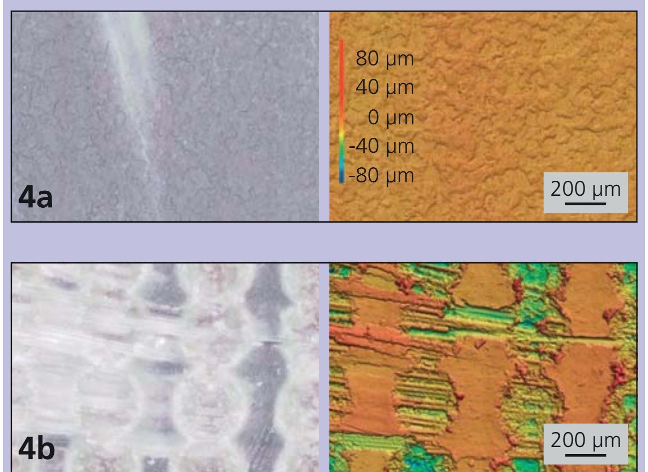
Adhesive selection, application and curing:
The bonding of highly stressed structural joints with fiber reinforced thermoplastic composites requires tailored adhesives based on polyolefins, epoxy resins, polyurethanes and acrylates. These adhesives were evaluated and the quasi static joint strengths were compared. In order to meet production throughput requirements, experiments were performed to accelerate the curing of thermally sensitive glass fiber reinforced polypropylene composites. The aim was to cure larger structures within a few minutes to get them ready for subsequent processing steps.

Ferromagnetic particles were added to industrial one-component and two-component epoxy resin based adhesives and the system was heated via high frequency induction. Curing times reduced from 60 - 90 minutes in conventional ovens to 3 - 5 minutes. The glass fiber reinforced thermoplastic components did not face high heat exposure, which is the case in conventional ovens. The induction heat is locally deposited into the adhesive layer.

RESULTS

Surface treatments with atmospheric pressure plasma and pulsed solid-state laser radiation yielded significant joint strength improvements of adhesively bonded structural fiber reinforced thermoplastic composites. Even after ageing tests, the strength remained high. The reference experiment used solvent cleaned samples. Here the bond failed adhesively at peel forces of 15 N m^{-1}. Laser structured surface were bonded and survived peel forces of up to 3800 N m^{-1} when they failed cohesively by delaminating. The different surface preparations of the reference sample and the laser structure sample are shown in Figure 4.

Surfaces of fiber reinforced thermoplastic composites (left: microscopy, right: surface topology) a) untreated and b) laser structured with local fiber exposure



An accelerated curing of the adhesive was achieved by high frequency induction heating. For this process to work, nanoscale super-paramagnetic particles (iron oxide particles in a shell of silicon oxide) were dispersed into the different adhesives. A motion controlled inductor excites the nanoferrites and cures the adhesive at temperature between 130 °C – 180 °C.

Mechanical testing yielded bonding strengths of the inductively cured adhesives, which were on par with those that were conventionally cured at room temperature or in ovens. In the case of glass fiber reinforced polypropylene the bonding strengths ranged from 8 MPa to 12 MPa depending on pretreatment and adhesive. The bonding process was also automated by coupling the pretreatment system (atmospheric pressure plasma head) and adhesive applicator (two component dispense and application unit) or the induction system with cooperatively working industrial robots (Fig. 2 and 3).

1 Function-integrating vehicle system unit

2 Driver cabin of the vehicle system unit at automated pretreatment and adhesive application station

3 Pyrometer controlled inductively accelerated adhesive curing with industrial robots

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