Potentials of precision laser processing of fiber reinforced polymer components

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AGENDA

1. Motivation
2. State of the art
3. Surface pre-treatment by pulsed laser
   ➢ Additional rib application on a organic sheet
   ➢ Coating by thermal spraying
4. Volume ablation
   ➢ Integration of sensor elements or inserts
5. Conclusion
1. Motivation

“The right material on the right place”

- Fiber reinforced plastics (FRP): high strength + low weight
- FRP will replace metal in more sections constantly
- Weight reduction and resource efficiency
- But: properties of the metal still required, locally
- In consequence: mixed material design, hybrid joining, metal coating on FRP
- High Reliability needs high adhesive strength of combined material
Direct writing precision machining with (ultra-)short pulsed lasers

- Minimized thermal influence on the components
- Burr-free, high-precision machining down to a few micrometers (lateral)
- Typical applications in the field of surface processing and low material thicknesses (especially cutting)
- Due to extremely high intensities practically no restriction regarding the material
Surface pre-treatment roughens and enlarges joining surface

Established surface processes on FRP: mechanical blasting, sanding, flame treatment or chemical processes

Current challenges:
- Damage to surface-near fibers
- No defined material removal
- Masking necessary for local, selective treatment
Special aspects of fiber-reinforced plastics (FRP):

- Inhomogeneous, anisotropic material-mix with distinctly different thermal, optical and mechanical properties of reinforcing fiber (glass, carbon, basalt, ...) and matrix (thermoplastic, thermoset, with / without pigmentation)

  → Challenging for laser processing

- (Ultra) short pulse lasers enable precise machining:
  - Selective or homogeneous material removal
  - Reproducibility within a large process window
  - No / minimal influence on reinforcing fibers and matrix

- Selection of laser wavelength, pulse duration, laser power and beam shaping for adaptation to material and machining target
3. Surface pre-treatment by pulsed laser

Advantages of laser surface processing

- Damage-free exposing of surface-near fibers
- Selective matrix removal enables form fit
- Defined material removal
- High design flexibility
- No mechanical load
- Localized treatment
3. Surface pre-treatment by pulsed laser
Overmolding of FRP components
Additional reinforcing rib structure on organic sheets

- Task: Replace metal load through system by rib reinforced FRP
- Selective matrix removal along provided rib contact area on organic sheet
- Injection molding of matrix material at room temperature on areas with exposed fibers
Testing the adhesive strength of rib application

- Pull-off-test in rib shape
- 3 conditions: untreated, selective matrix removal with continuous wave and short-pulsed laser

Five times higher adhesive strength with surface pre-treatment by pulsed laser compared to untreated surface
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3. Surface pre-treatment by pulsed laser

also applicable for:
- Adhesive joining
- Direct joining of multimaterial combinations, e.g. FRP to metal
- Surface patterning of metal component
- Clamping of components
- Heating of metal

3. Surface pre-treatment by pulsed laser

Metal coating on FRP by thermal spraying

- Thermal spraying of multi layer system: porous adhesion promoting layer protects the FRP before a solid functional layer is sprayed on top
- Pre-treatment by mechanical blasting not suitable for coating FRP
  - Fibers get damaged and stick out of the surface
  - Broken fibers, blasting particles and matrix fragments on the surface lead to shadowing effects during coating process
  - High rejects and low reliability are the consequences

→ Laser surface processing as an alternative?
3. Surface pre-treatment by pulsed laser

- CFRP specimens in three conditions
  (a) sand blasting, (b) selective matrix removal
  and (c) grid like surface pattern

- Wire flame spraying of aluminum as an
  adhesion promoting layer

40% increased adhesive strength with
laser patterned surface in first feasibility
study
Promising potential for exploitation in multiple applications

- Base layer of hard coatings for wear protection, e.g. slide bearings
- Electrically conductive layers for heated functionalities or electromagnetic shielding, e.g. battery cases
- Metalized FRP surface enables soldering joints
- Base layer for additive manufacturing direct on FRP-components
Goals:

- Ablation, drilling and cutting of fiber composite materials with the highest precision
- Without thermal damage through the use of short and ultrashort pulse lasers and highly dynamic beam deflection technology

Scope of application:

- Lightweight design, mechanical engineering
- Vehicle construction, aviation, machine building

From the surface to the depth - volume removal and separation
Health monitoring in FRP

- Task: maximize life circle time of FRP component
- Integrate sensor elements into crash relevant FRP elements
- Analyzing data to decide if FRP part needs to get replaced or not
- Important for volume ablation on FRP components:
  - No thermal damage
  - No pull-out effect
  - Volume ablation minimized to design requirements
### Laser Ablation vs. Milling

<table>
<thead>
<tr>
<th>Laser Ablation</th>
<th>Milling</th>
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<tbody>
<tr>
<td><strong>Advantages</strong></td>
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<tr>
<td>- Final shape same as contour of sensor or insert</td>
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<td>- Highest design flexibility</td>
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<tr>
<td>- No mechanical load</td>
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<tr>
<td>- No fiber pull out</td>
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<td>- Wear-free</td>
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<td><strong>Disadvantages</strong></td>
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<tr>
<td>- Middle process time (60 s/cm³) (limited to current laser power)</td>
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<tr>
<td>- Special tool for FRP required</td>
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<tr>
<td>- Final shape depends on tool geometry</td>
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<tr>
<td>- Risk of fiber pull-out</td>
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<td>- Carbon deposits increases wear</td>
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<td>- Manual post-processing</td>
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**Surface after treatment**

![Surface after treatment image](image1)

![Surface after treatment image](image2)

![Surface after treatment image](image3)
Integration of sensor elements in FRP components

- Volume ablation with pulsed laser ($\lambda=532$ nm, $P=10$ W, $t_p=8$ ps)
- Volume removal optimized to shape of sensor
- Overmolding of sensor-enhanced FRP component with short fiber reinforced polymer
5. Conclusion

Pulsed laser processing as surface pre-treatment on FRP

- Selective matrix removal exposes surface-near fibers and offers form fit for joining processes
- Increased adhesive strengths can be achieved in adhesive joining and injection molding
- Surface patterning offers higher adhesive strengths of the thermal sprayed coating than mechanical blasting
- Volume ablation by pulsed laser on FRP shows better surface quality than milling
Eager for your questions...now or Visit us at booth 4C17 or At the Fraunhofer IWS in Dresden

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