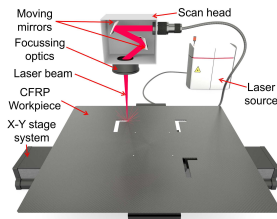
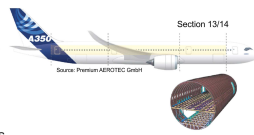


Why Laser Drilling of CFRP?

- ▶ Large borehole quantity in aviation industry
 - ▶ ~34 000 boreholes / plane (Airbus A350, section 13/14 only)
- ▶ Conventional drilling: Quality issues & significant tooling costs due to tool wear
- ▶ Laser drilling is contactless, force-free and wear-free
 - ▶ High cost-saving potential
 - ▶ No tool change required for different hole diameters
- ▶ Within the 'LaBoKomp' project the laser drilling was brought closer towards industrial application

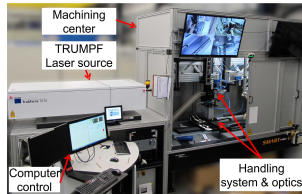


How it works

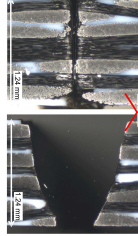
- ▶ Laser beam movement by scan head containing two highly dynamic mirrors
- ▶ Machining is performed by a multipass strategy
 - ▶ A small amount of material is ablated with each pass of the laser beam on the same contour
 - ▶ This strategy avoids thermal modification in the polymer
- ▶ The working field of the optical system can be extended by stage systems

System setup

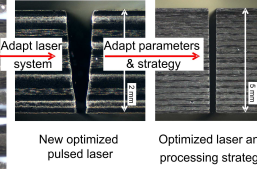
- ▶ Optimized laser source
 - ▶ Short-pulsed high-power laser by TRUMPF
 - ▶ Sufficient fluence is a crucial factor for efficient machining
- ▶ Handling equipment
 - ▶ High-precision 3-axis / 5-axis system
 - ▶ Different fixtures adapted to the machining scenario
 - ▶ Build-in cooling and exhaust
- ▶ Thermal monitoring
 - ▶ Temperature data is used for process monitoring and control
- ▶ Full documentation of machining parameters and thermal data



Continuous wave laser



Pulsed laser

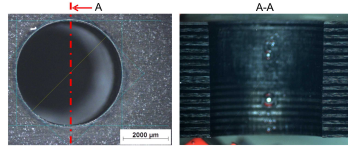


▶ Cutting kerf micrographs: Evolution of the laser machining quality

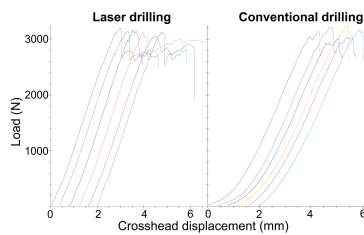
Process

- ▶ In-house developed software for machine & process control
 - ▶ Includes the control of each single component required for an efficient drilling process
- ▶ Allows for machining strategies with parameter adjustment for each ablation pass
- ▶ Combination of adapted laser specifications and strategies leads to high-quality results
 - ▶ No thermal modification
 - ▶ No taper, straight sidewalls
- ▶ Proven for material thicknesses up to 6 mm and various polymer types and fiber lay-ups

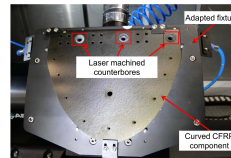
Evaluation & Demonstrators



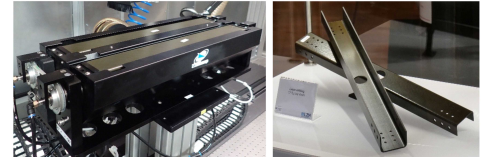
- ▶ Top view and cross-section of a laser-drilled Ø4.8 mm hole in CF/Epoxy
 - ▶ Roundness and cylindricity within a tolerance range of 30 µm



- ▶ Bolt bearing test (AITM1-0009)
 - ▶ Identical mean stress for both machining techniques



- ▶ Curved CFRP part containing laser-machined boreholes and counterbores
 - ▶ Monitoring & control of the counterbore surface by profile sensor



- ▶ CFRP C-profiles with varying borehole patterns
 - ▶ Fixture with up to 4 profiles being drilled on all sides in one process routine
 - ▶ Time per hole < 10 s for 2.4 mm thickness CF/Epoxy