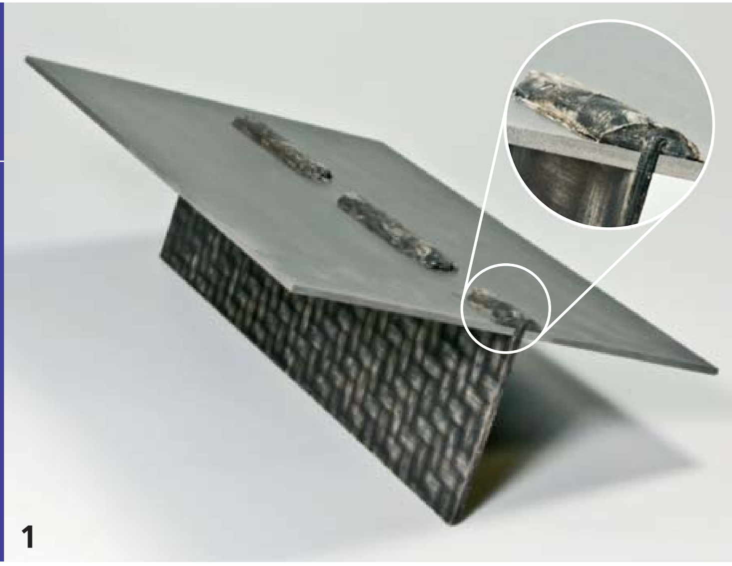

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THERMOMECHANICAL JOINING OF METAL AND FIBER-REINFORCED PLASTICS

THE TASK

Both the automotive and aircraft industries tend to use material composites. Various materials are combined to use their specific advantages depending on the load situation. In many innovative designs, either mixed metallic materials (such as a mix of steel and aluminum) or hybrid structures made of dissimilar materials (such as metal and fiber-reinforced plastics) are in use.

A big challenge in hybrid design is to connect the join partners, which is much more complicated than for monolithic structures. Each material match demands its own customized joining concept based on the requirements of the material, production and design, so that joints of sufficient quality and resilience can be created and reproduced.

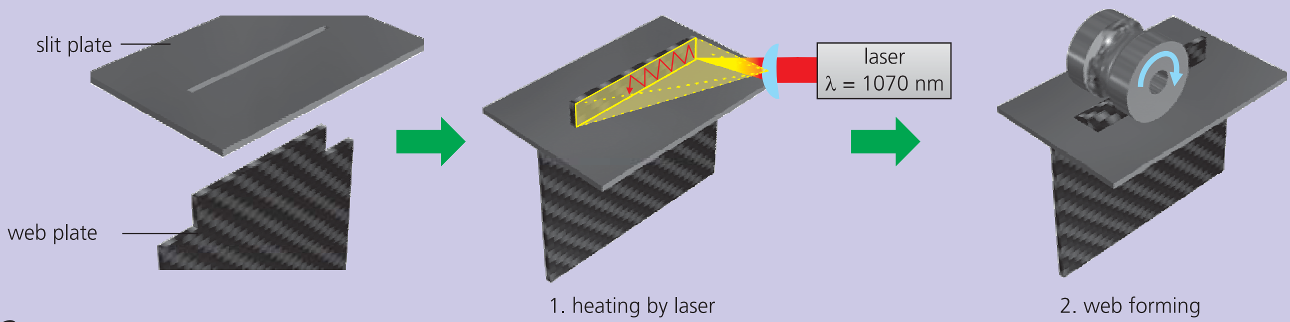
The Fraunhofer IWS Dresden was faced with the challenge of engineering a laser technique capable of joining metal and fiber-reinforced plastics in a T-joint configuration and examining the joint strength.

OUR SOLUTION

The Fraunhofer IWS Dresden developed a self bridging deck-plate connection registered as patent (Patent No.: DE1020111 20269 A1), which has already been used to join two form fitting metal sheets. This principle was applied to join an organosheet (fiber-reinforced thermoplastic) as web plate with a metal sheet as slit plate (Fig. 1).

Once the sheets are fitted together, the projecting part of the fiber-reinforced thermoplastic web plate is heated by means of a fiber laser (wavelength l = 1070 nm). The fiber laser makes it possible to locally precisely position, adjust and control the heat input. Two-dimensional and high-frequency beam ejection by means of a scanner system guarantees homogeneous plastic heating. The heating temperature is paid special attention; for subsequent forming, it must remain in the range between the plastics' melting and decomposition temperatures. Forming the heated plastic web into the desired geometry with a specific forming die finally generates a stable form fit in all 3 spatial directions (Fig. 2).

Web-slit principle



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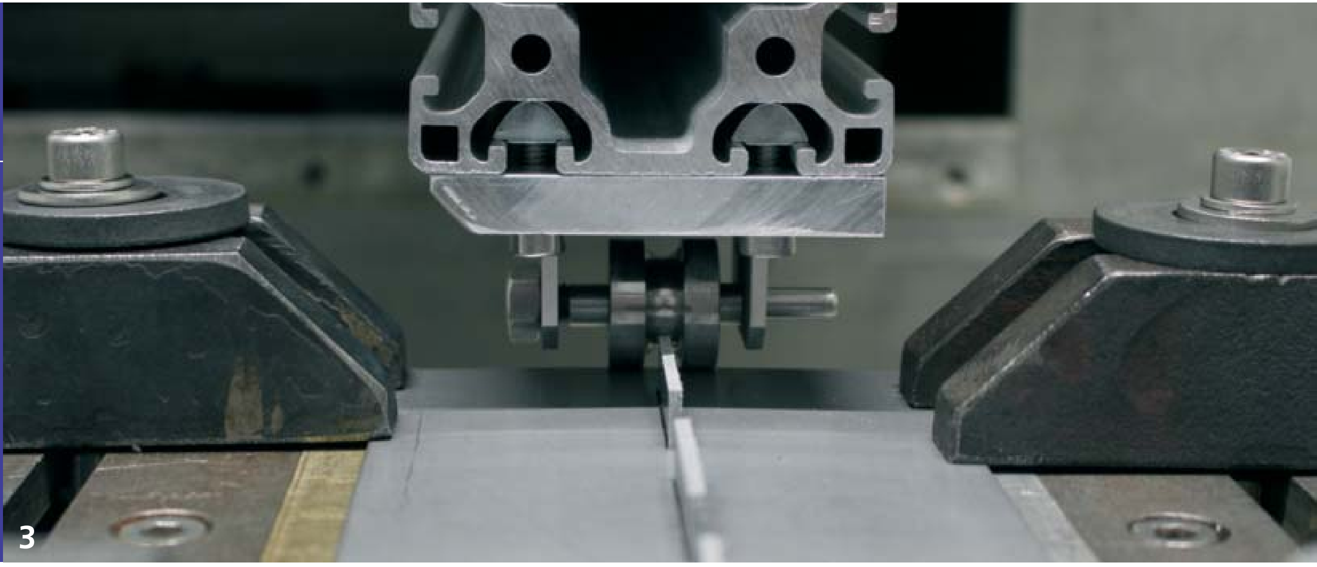

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RESULTS

A specific heating period is required for the greatest homogeneous fusion of the fiber-reinforced plastic web both in terms of the thickness and across the length and height, and in consideration of the low thermal conduction of the plastic. This heating period varies as a function of the chosen material (PP, PA, PE etc.), material thickness and heating strategy (web heating on one or both sides).

The roller tools proved to be particularly suitable for web forming, because their use can largely avoid fiber damage due to low bending radii during forming. Thus, for instance, the groove-roller tools (Fig. 3) create cross section geometries from the molten web projects that are similar to rivet joints (Fig. 4), and are highly reproducible and promise outstanding joint properties.

Cross section images of two formed fiber–reinforced plastic webs

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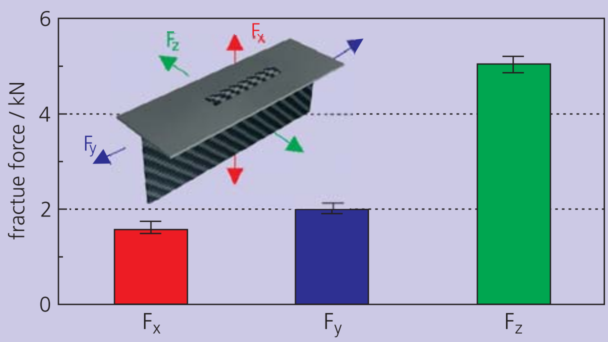
The hybrid joints were mechanically tested in three load directions for strength assessment and to analyze failure characteristics. Maximal fracture forces of the hybrid joint can be absorbed in the tensile shear direction, transversely to the web (in Fig. 5: Z-direction), which is crucial for the design of the components with these hybrid joints.

The fracture forces for a web length of 20 mm shown in Figure 5 were measured for the joint of a steel slit plate (S355; 1.5 mm thick) with a plastic web reinforced by a fiberglass fabric (E-glass / PA6; 2 mm thick) and a forming geometry similar to that of a rivet are given in Figure 4 (right).

Fracture forces in 3 loading directions of a web-slit joint, material combination steel-GRP



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Further research and investigations at the Fraunhofer IWS Dresden were aimed at improving adhesion and tightness between the plastic and the metal sheet. Pre-treatment by means of laser structuring on the metallic join partners allows significantly higher combined tension and shear forces to be transferred.

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1 Fiber-reinforced plastic = metal composite

3 Groove roller tool to form geometries similar to those of a rivet joint

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