BONDING WITHOUT ADHESIVE – DIRECT JOINING OF METALS AND THERMOPLASTICS

The thermal direct joining technique enables quick adhesive joining of thermoplastic components with metal. After laser structuring, the metal is pressed with the plastic and locally heated. The thermoplastic melts due to heat conduction, penetrates into the structures, and adheres to the surface. In this way, bonding can be done in a few seconds.

Advanced lightweight design frequently demands the combination of metal and plastics, both with and without fiber reinforcement. For this purpose, the scientists need efficient process chains, using optimized pre-treatment and joining technologies tailored to specific stresses, as well as adapted tools for process simulation and characterization of properties. Fraunhofer IWS researchers, therefore, focus their work on developing productive solutions for direct and form-fit joining. They combine many years of experience in general bonding technology with modern system engineering developments in the field of remote laser technology.

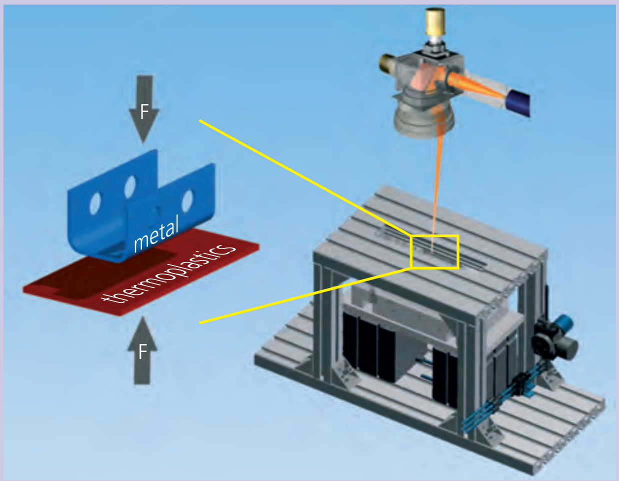
Pre-treatment makes the difference

Since thermoplastics and metals have very different physical properties (such as the melting temperature or thermal expansion coefficient), the optimization of the adhesion between these joining partners is very important. For this reason, the researchers developed a laser ablation process being able to generate structure depths of 100 micrometers and more. Continuously radiating high-power lasers are focused on the metal via a remote or scanner optics and quickly deflected. This process removes contaminations adhering to or inside the boundary layer from the surface. At the same time, the resulting topology ensures that plastic which penetrates later can be anchored in undercuts by a positive fit. In addition to the option of a local laser pre-treatment, another advantage is that chemical cleaning by solvents or pickling baths is unneeded.

Quick heat by laser or induction

The intrinsic joining procedure is very simple: the pre-structured metallic joining partner is pressed with the thermoplastic. At the same time, the metal is heated in the joining zone, so that the thermoplastic's melting temperature is achieved at the interface. The higher the temperature gradient in the metal, the lower the losses due to thermal conduction during the process. A special challenge is the homogeneous heating of the metallic joining partner. The use of two-dimensional laser beam oscillation makes it possible to shape the beam dynamically and easy to control. If it is not possible to directly heat the metal

Principle of laser induced direct joining

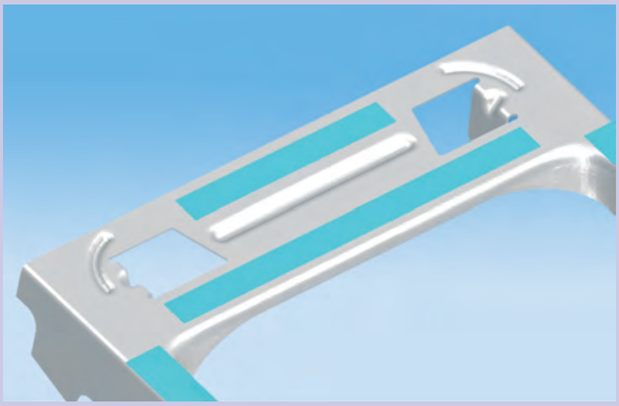


by the laser beam, an applied magnetic field generates eddy currents in the metal, whose losses result in a quicker temperature change. Here, it is a particularly demanding task to dimension the inductor to suit the joining contour.

Simulation tool optimizes heating process

To transfer the basic technological principle to real part designs in a time-efficient manner, the team developed a heating simulation, as well as process and path planning tools. They optimized the heating process of the metallic joining partner using the simulation tool "COMSOL". This tool enables them to design the inductors in a way adapted to contour. The laser structuring process also offers advantages when using a "CAD/CAM" system. The researchers can select material-specific parameter records from a database and apply them to the surfaces being structured. Then the CAD/CAM programming tool generates the NC programs – both for the remote optics and the machine axis system. Together with industrial and research partners, the Fraunhofer IWS Dresden evaluated the technique developed by applying a complex technology demonstrator. In this process, the scientists replaced a pure welding assembly made of mild steel with a multi-material design made of an organosheet and metallic cover plate to demonstrate the lightweight potential. In addition to thermal direct joining, the researchers also created direct joints using the web-slot design between metal and organosheet. In basic experiments, the transfer strength values were specified under different load states as input data for part dimensioning and design, and the material characteristics were summarized on a material data card. After part design and definition of the joint design, planning of the laser structuring paths was completed. The researchers also used simulation software tools for modeling to optimize the heating process. They generated many test demonstrators that successfully passed the mechanical tests. This thermal direct joining process is characterized by short process times, robust process guidance, and ease of automation. The laser surface pre-treatment is also highly suitable for environmental protection, since it works without etching baths or leaching agents. Above all, the process is suitable for applications in which complex fiber composite parts are joined with metallic constructions.

Path planning for local laser structuring



1 Formed organosheet shell (right), support structure for passenger car center arm rest and cover plate.

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CONTACT

Dipl.-Ing. Annett Klotzbach

Bonding and Composite Technology

☎ *+49 351 83391-3235*

✉ *annett.klotzbach@iws.fraunhofer.de*