Fraunhofer IWS Dresden

FRAUNHOFER-INSTITUT FÜR WERKSTOFF- UND STRAHLTECHNIK IWS

BONDING AND COMPOSITE TECHNOLOGY

Technologies for lightweight construction and resource efficiency

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Motivation

The development of adhesion and form fit-based joints to connect metals and plastics is a significant precondition for the implementation of numerous lightweight design applications. At the Fraunhofer IWS, along with bonding technologies, thermally induced techniques for direct joining are refined. These thermally induced methods make it possible to join thermoplastic materials or material composites with different parts. As a part of the business unit Joining, the Bonding and Composite Technology group extends the available expertise of the Fraunhofer IWS Dresden in the areas of laser beam welding, friction stir welding and magnetic pulse welding for comprehensive analysis and appropriate selection of efficient joining processes and the support of research partners in industry.

Offered services

- selection, test and comparison of different surface pretreatment techniques
- surface analysis
- selection, modification and characterisation of adhesives
- design-oriented adhesive bonding of a wide variety of materials (realisation of processes from laboratory scale up to industrial processes)
- engineering and optimisation of thermally induced joining processes
- mechanical characterisation of joints
- assessment of/ improvement in the degradation characteristics (ageing and corrosion resistance)

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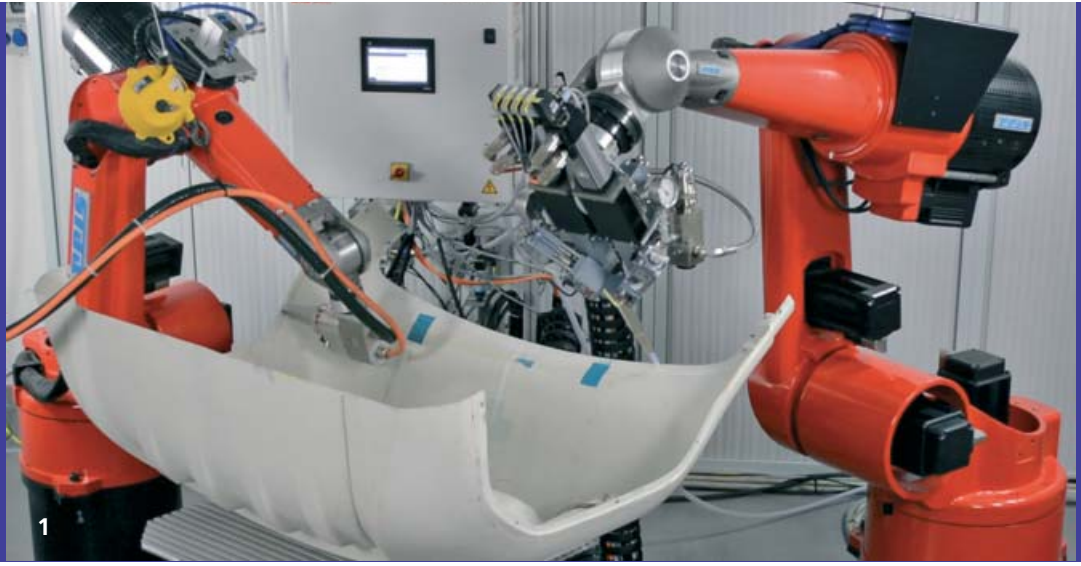

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Surface pretreatment - selection, testing and comparison of different techniques

Sufficient adhesion of the parts to be joined is a precondition for surface sensitive joints. To guarantee good adhesion on real components, the surfaces have to be pretreated.

Laser treatment is frequently used as a technology that provides stability in the long term and makes it possible to remove organic and inorganic contamination, coatings (e.g. paints) or residues from manufacturing (oils, lubricants) by means of Nd:YAG and fibre lasers in a selective and reproducible manner.

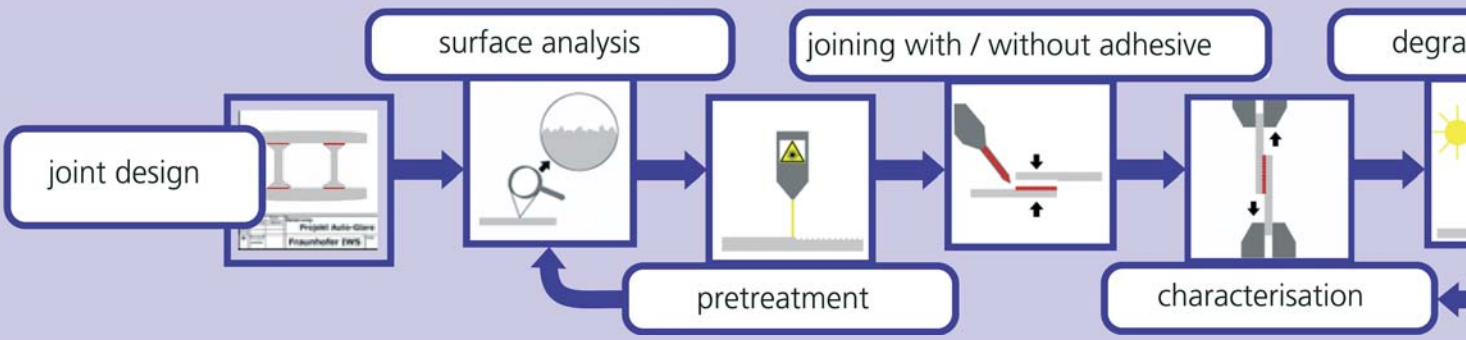
This removal by means of the laser not only cleans surfaces, but also significantly extends the areas available for adhesion. Thus, for instance, macrostructural texturing as a pretreatment for thermal direct joining of metals and thermoplastics provides an optimal form fit to achieve high joint strength.

In the manufacture of light metals, such as aluminum, adequate laser parameters can result in the removal of the native oxide layer and the formation of a new homogeneous oxide layer that provides a good foundation for bonding. As a function of the materials to be manufactured and productivity requirements, it is possible to apply either pulsed lasers of different wave length (UV, VIS, IR, NIR lasers) and continuous wave high-performance lasers.

Plasma treatment at air pressure is particularly suitable for the final cleaning of organic sedimentations, as well as the functionalisation of plastics. If precursors are introduced into the plasma by means of a carrier gas and are simultaneously polymerised, then coating layers for promoting the adhesion behavior can be deposited besides fine cleaning.

Productive treatment rates for technologies on an industrial scale can be obtained by multiplying of single plasma sources, as well as the use of the double rotation technique. Pressure and **suction blasting processes** are surface treatment techniques that can be run very inexpensively. In addition to cleaning and changes in surface topography, in both methods, silicate layers for enhanced adhesive bonding on the parts to be joined can be deposited (SACO® technique).

Adhesive bonding and thermal direct joining of parts consisting of different materials – process chain



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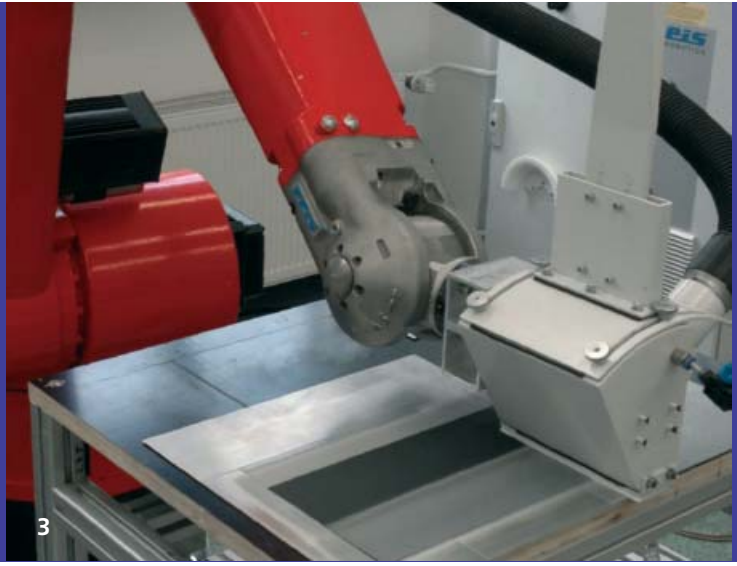
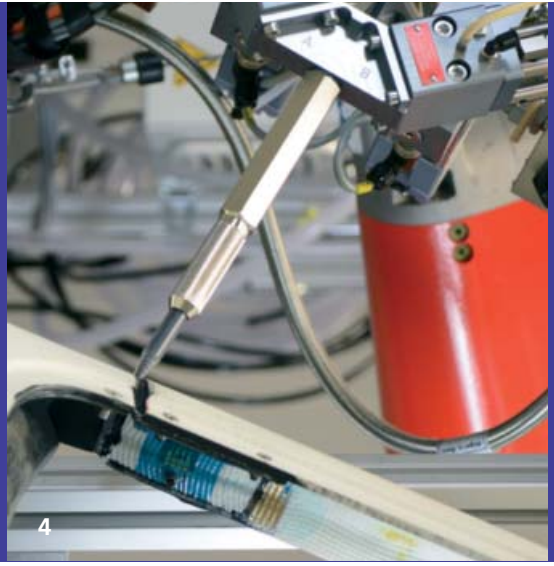


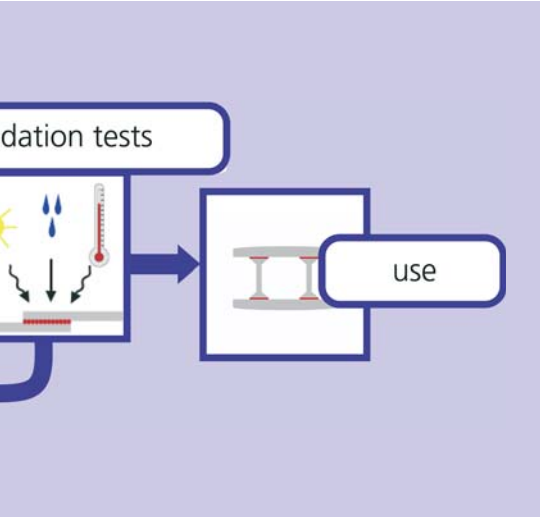


Other advantages of suction blasting processes are:

- careful material removal
- selective applications
- low-emission manufacturing due to integrated suction
- integration into the manufacturing process
- especially suitable for coated metals and fibre-reinforced polymers

Surface analysis

At Fraunhofer IWS, optical and electron microscopy are available to verify the pretreatment quality. Surface roughness values are determined via light-section procedures (Cyberscan), as well as laser scanning microscopy. It is also possible to characterise the surface wetting properties and polarities by means of contact angle measurement using various measurement liquids.



Selection, modification and characterisation of adhesives

An adhesive system that is suitable for a defined case of application is selected taking into account the material matching, surface consistency, and the required performance of the joint. To fulfill the customer's requirements, not only commercial adhesives, but also modified adhesive systems, are used.

To generate adhesive bonding with additional functionalities, such as electric conductivity, nanoparticles can be introduced in adhesives (carbon nanotubes, nanohorns, graphenes, conducting soots and nanoferrites). For this operation, various systems are available: a dual asymmetric centrifuge mixer, an Ultra Turrax disperser, a triple roll mill, an extruder, a high-pressure mixer and an ultrasonic sonotrode. Thus, for instance, the adhesive systems can be subjected to mechanical characterisation, rheological analyses, curing characteristics' exploration or measurement of integrated additional functions.

Design-oriented adhesive bonding of a wide variety of materials

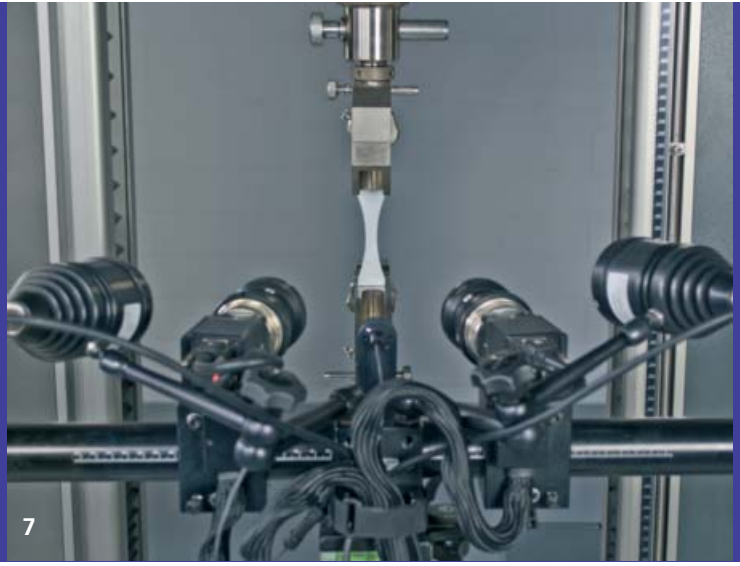
For design-oriented adhesive bonding to be performed on complex components, both adhesive deposition systems for manual use and dispensers with 2C mixing and dosing systems that are coupled with robots are available in the labs.

Drying ovens, as well as ultraviolet radiation or induction energy can be used to cure the adhesive. The available induction system with working frequencies from 400 to 600 kHz is to accelerate the curing of adhesives, either by local heating of the metallic joining parts or by ferromagnetic particles integrated into the adhesive.

1 Automated surface pretreatment by means of air pressure plasma and application of adhesive for adhesive bonding of an FRP driver's cab

3 Vacuum suction blasting for careful surface pretreatment

4 Application of adhesive in connection with a robot by means of a 2C adhesive application unit



Engineering and optimisation of thermally induced joining processes

If joint connections consisting of at least one thermoplastic part have to be created, in general, it is possible to work without adhesives.

Targeted heat input causes local melting of the thermoplastic material, which then solidifies on the second part to be joined and provides, assuming strong adhesion, sufficient joint strength. When joining a metal with a thermoplastic or a fibre-reinforced thermoplastic, the following heat sources can be applied:

- laser radiation
- reactive multilayer systems (RMS)
- induction
- hotplates

Both laser power and the beam positioned in space can be adjusted exactly, thus enabling high heating-up rates and, in turn, extremely short joining times.

Assessment of/ improvement in the degradation characteristics (ageing and corrosion resistance)

Accelerated ageing tests can be performed to assess the long-term ageing resistance of joints. As a result, test cycles can be executed according to the currently valid automotive or DIN standards. The climate cabinet is supplemented by a salt spray chamber, sun test equipment, a temperature controlled chamber for the process liquids, as well as a pressure cooker.

Mechanical characterisation of joining zones

To characterise the joint strength values achieved, the mechanical properties are determined by means of destructive tests carried out on a multi-axial material testing machine. In these tests, both one-axial load cases, such as tension, compression, bending or torsion, and multi-axial overlap loads in the form of tensile/compressive-torsion loads can be measured.

In combination with an optical measurement system based on digital image correlation, three-dimensional deformations on the surface can be recorded during the test and analysed afterwards. These parameters are used for simulation and joint design, as well as to characterise polymer systems.

System for large-area laser and plasma treatment

5 Air pressure plasma treatment of glass fibre polypropylene structures

7 Mechanical characterisation of an adhesive-bulk sample using digital image correlation