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CORE COMPETENCE AUTOMATION AND DIGITALIZATION

In addition to the diverse materials science and process engineering research activities, the research into the field of the key technologies of automation and digitalization completes the competence spectrum of Fraunhofer IFAM. The focus here is mainly on processes that need to adapt constantly and with great precision to components with low shape accuracy as well as changing production processes and human participation in the production.

This core competence encompasses IFAM's key areas within the categories of joining, sealing, surface treatment, processing, and printing, including the interaction with a digitized production environment (Internet of Things, Big Data), as well as queries stemming from customers or project partners in the context of joint projects. Here, solutions are being developed for a holistic quality assurance of production processes, materials, material composites, and coatings through the use of innovative methods to capture, evaluate, and visualize measurement data as well as the use of intelligent materials.

The automation and digitalization solutions of Fraunhofer IFAM serve to increase the effectiveness and efficiency of manufacturing and repair processes, improve ergonomics and work safety in production, optimize the product lifecycle by monitoring both quality and conditions, improve product quality, and reduce process costs.

Fast and quality-assured processes are essential for series production. Fraunhofer IFAM offers automation solutions that can recognize components as well as tolerances, even in very large lightweight structures with low dimensional stability, and adapt to them individually and with high precision. With the motto "precision through measurement technology and sensors instead of heavy steel construction", Fraunhofer IFAM attaches particular importance to lightweight, mobile, and modular system components that can be linked to highly versatile production systems via Industry 4.0 architecture.

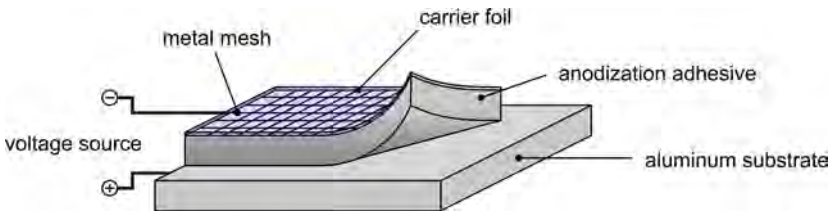
An overarching competence component is quality assurance – in the manufacture, assembly, and repair of components and structures. The continuous monitoring of the condition of component surfaces through customized inspection methods is an essential goal in the optimization of application-specific manufacturing processes. This is supported by a range of comprehensive training programs that cover multiple products and branches of industry for the certification of personnel, during which a technology transfer takes place, bringing scientific knowledge and methods into industrial application.

> **www.ifam.fraunhofer.de/automation-digitalization**

1 *Assembly plant for aircraft hulls with flexible imagery to correct the shape and position of large components.*



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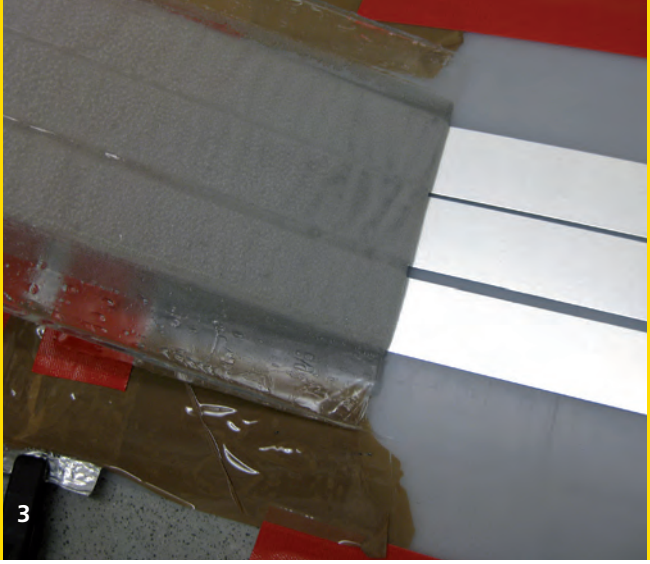
INNOVATION IN FIBER-METAL LAMINATE (FML) PRODUCTION FOR AIRCRAFT CONSTRUCTION

Besides the ongoing efforts of the aerospace industry to reduce fuel consumption through advanced lightweight construction concepts for new aircraft structures, the need for a resource-efficient and cost-effective processing of the materials used during aircraft manufacture is increasingly becoming the focus of developments. Both goals can be achieved through the use of modern fiber-metal laminate components (FML) in combination with new automated manufacturing processes. For this purpose, the current research project "NFM-GLARE", as part of the Aerospace Research Program V-II, will cover various aspects of the surface treatment of thin aluminum sheets used in FML production as well as the automation of individual manufacturing steps.

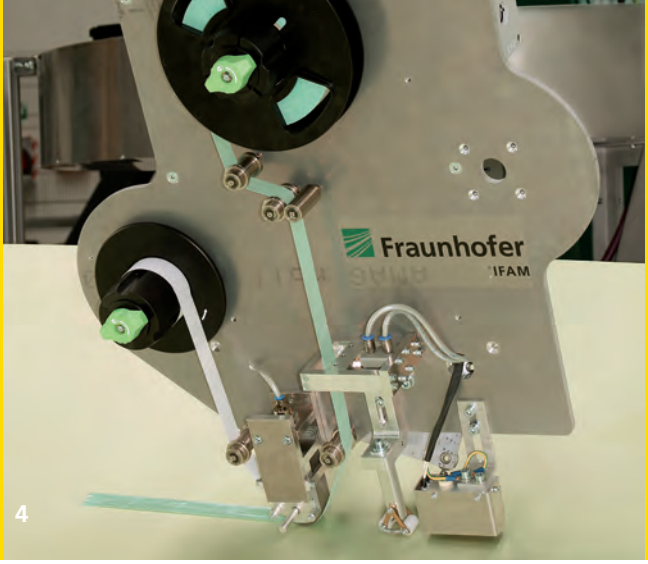
Surface treatment of aluminum sheets

Aluminum sheets used for FML components in aircraft construction are currently protected against corrosion by a combination of anodization (phosphoric sulfuric acid anodizing, PSA) and the application of a chromate loaded adhesive primer. Furthermore, the outer aluminum sheets are covered by an additional coating consisting of a primer and a top coat. At the cutting edges, local corrosion protection measures are used in the form of manually applied chromate loaded conversion coatings. For the thin aluminum sheets used in FML production, alternative pre-treatment techniques for corrosion protection and to achieve the necessary adhesion properties were tested in the above-mentioned project, investigating laser, plasma, and anodizing tape techniques. In view of the required corrosion protection and adhesive strength, these methods were compared with the current production method, i.e. the anodization of aluminum sheets via the PSA process. Suitable parameters for the treatment of various sheet thicknesses were evaluated for atmospheric pressure plasma technology in order to minimize the heat-induced deformation of the thin sheets. Based on this, for corrosion protection, suitable plasma polymer coatings on a silicon organic basis with appropriate barrier properties against corrosive media were chosen. Overall, the results showed that the aluminum sheets, which are delivered in an undefined surface condition, must first be treated with an ablative process in order to subsequently conduct the suitable plasma treatment that leads to improved adhesion and corrosion resistance.

The anodizing tape enables a dry surface pre-treatment of aluminum parts during production or as a local application. All components required for anodization are integrated into the functional tape. As the tape can be removed without residue, subsequent cleaning processes are simplified, which is advantageous in the case of rework or repair. It could be shown that the anodizing tape forms structured oxide layers on the sheet materials of the aluminum alloy AA2024. The oxide morphology is comparable to that of the PSA oxide, which allows a good adhesion performance of the adhesive primer or the adhesive. In addition, initial tests on local sur-



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face treatments for adhesive repair concepts of FML skin fields were undertaken.

The resulting adhesion properties of all investigated non-bath processes meet, at the current state of development, the basic aircraft requirements. For industrial use, however, additional properties must first be tested or validated, such as the fatigue behavior and the corrosion resistance of adhesively bonded joints.

Automated FML manufacture

The construction of FML laminate occurs through the manual alternate deposition of thin aluminum sheets and fiberglass prepregs with different fiber orientations. FML shells are composed of smaller sheets, where the edges are connected by splices with alternating overlaps of aluminum and glass fiber layers. Interlaminar aluminum doublers serve as gap holders, while tape strips fix the components and fill the cavities created by the offset layer. To stiffen the shells, aluminum stringers are placed onto the uncured FML and an adhesive film is manually applied to the base of the stringer to secure it against slipping.

One of the objectives of the NFM-GLARE project is the automation of the previously manually executed application of adhesive tape strips and stringers. The developed end effector for automated adhesive film application meets a wide range of special requirements. In robotic operations, its weight is below 100 kg, including a module that allows automated tool change. Its orientation refers to the deposition tooling and it calculates the exact tracks onto which the tape is to be placed. In order to ensure a precise application, it actively drives the tape from the inserted supply roll, separates it from both the liner above and the carrier paper beneath, cuts it with a clean edge without damaging the carrier paper, and pressures it onto the laminate with a pressure roller. This allows tape strips of any length to be applied, even onto uneven laminate surfaces in cylindrical or spherical areas of the FML shells. An infrared unit integrated into the end effector ensures the adhesion of the adhesive tape, irrespective of the ambient conditions. The range of services is completed by an automatic monitoring of the filling level, pressure, process temperature, and applied tape lengths.

The tape can also be used to attach the aluminum stringers, which, due to their length of six meters, are deposited by two cooperating robots. The specifically constructed roll grippers enable the necessary longitudinal movement of the stringers as well as the fine control of pressure and local heating for precise attachment.

Customer

The collaborative research project NFM-GLARE is supported by the Federal Ministry of Economic Affairs and Energy within the framework of the Aerospace Research Program V-II, funding number 20W1517D; duration of the initiative: Sep. 1, 2015 - Aug. 31, 2018.

1 *Atmospheric pressure plasma technology: Nozzle array for automated robot-guided treatment.*
2 *Anodizing tape; schematic sketch of the application principle.*
3 *Anodizing tape; peeling off the anodizing tape following anodization.*
4 *Adhesive film end effector for automated deposition of tapes.*