DEVELOPMENT OF AN AUTOMATED INSPECTION METHOD TO CHARACTERIZE PRE-BOND CONDITIONS OF CFRP ADHERENT SURFACES

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Abstract

Due to an increasing amount of carbon fiber reinforced plastic (CFRP) in aerospace, a revision of traditional joining techniques is necessary. Whereas welding and riveting are traditionally used for joining load-bearing metal parts, adhesive bonding techniques are more appropriate for a wide variety of lightweight structures.

The strength of adhesive bonding depends on many factors. In particular, the preparation of surfaces is crucial. In the majority of cases contamination of the surface may have a dramatic influence on the bonding strength resulting in the requirement for elaborate pre-treatments. As a consequence adhesive bonding is primarily used for non-load-bearing parts since quality assurance methods are difficult.

In order to take full advantage of the mechanical properties of CFRP parts, a new quality assurance technique is necessary.

Automation W+R has developed an automated inspection system that exploits the Aerosol-Wetting-Test (patented by IFAM). This system is designed for both industrial and laboratory environments.

Here we present first results of this newly designed system for a variety of materials with different surface conditions. Several release agents, as well as the effect of pre-treatments, were investigated using an automated test setup.

This reference based system can then be calibrated, with reference samples to achieve a reliable “ready to bond” signal for the investigated specimens.

First results underpin the great potential of this system in the domain of extended non-destructive surface inspection of large CFRP parts. The technique can be widely applied to numerous industrial applications, with subsequent increases in reliability and enhanced cost effectiveness.

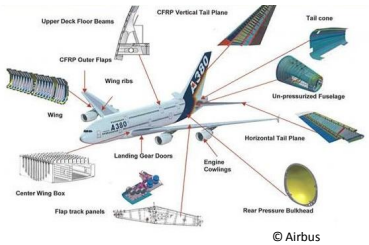
Development of an Automated Inspection Method to Characterize Pre-bond Conditions of CFRP Adherend Surfaces

F. Stark et al. 2015

automation bollautomation descam edixia winspect

Introduction

- More and more composite parts are used in aeroplanes
- Adhesive bonding allows the most efficient use of fiber composites in aircraft
- However, the potential of an adhesive bond in the aircraft sector is not yet fully exploited
- Decisive fiber composite components are still riveted



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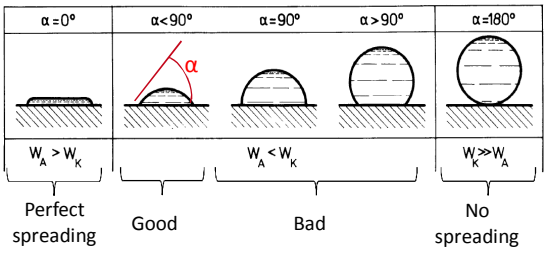
Introduction

- Low surface energies, contaminations with release agents, silicone, lubricants etc. have a negative impact on an adhesive bond
- Up to now "weak" or "kissing" bonds are hard or impossible to detect by means of NDT
- The quality of an adhesive bond must be produced and is only as good as the whole manufacturing process
- Surface treatment is a prerequisite for a reliable structural bonding

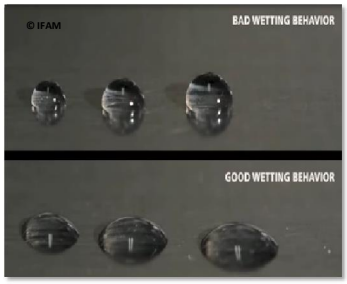
Is the surface ready to bond?

Introduction

- Goal: Automated monitoring of the wetting behavior of adherend surfaces



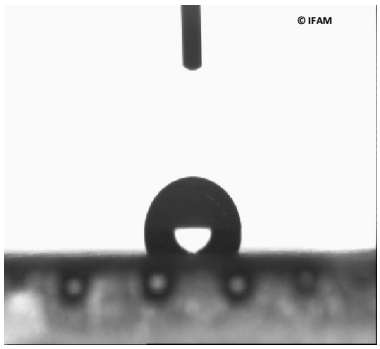
Wetting behavior of adhesives
(after Habenicht 2014)

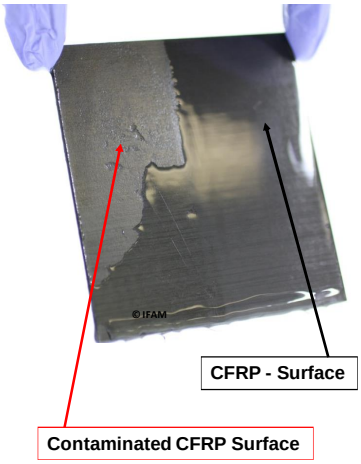


"God made the bulk; surfaces were invented by the devil"
(W. Pauli – Austrian-Swiss Physicist)

Introduction

- Contact Angle Measurement / Water Break Test





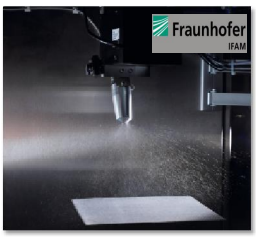
→Process integration difficult / expensive

Introduction

Requirements for an automated quality assurance system:

- Sufficient detection sensitivity
- Inline capability (automatized, short inspection cycles, compact and robust design of the test system)
- No adverse effect of the adherent surface
- Capable of investigating large areas
- Rapid further processing
- Results are objective and documented

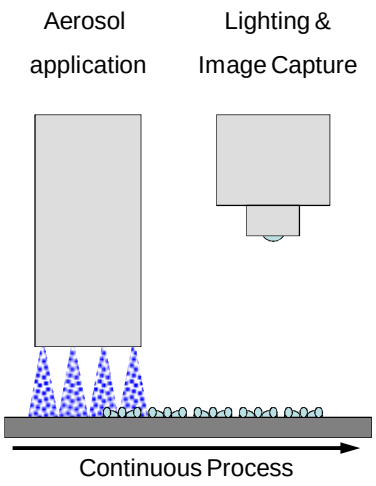
Aerosol Wetting Test Patented by Fraunhofer IFAM



The Aerosol-Wetting Principle

Operating Principle

- Application of an micro-aerosol of ultra clean water on an adherent surface
- Detection of the droplet size and distribution



The bonNDTinspect® System

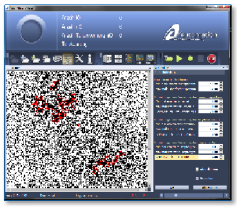
Setup / Function

The test system has a modular design and is divided into the following main groups:

- Sensor head
- Terminal box
- Test computer
- Software
- Operating unit /control panel for part inspection (including, monitor, keybord and trackball)

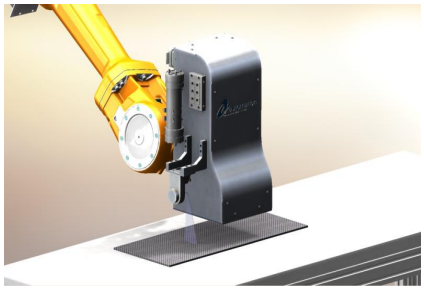
The bonNDTinspect® System

- Evaluation and application software VisionCheck®
- Image procession software analyzes the VisionCheck® distribution and size of the droplets over an AOI (Area of Interest) ï function
- Individual adjustment of parameters possible:
  - ÅAverage droplet size
  - ÅDistribution of the droplets
  - ÅPercentage of relative wetting area
  - ÅOutput of values for a set test window
  - ÅAccess to various test parameters

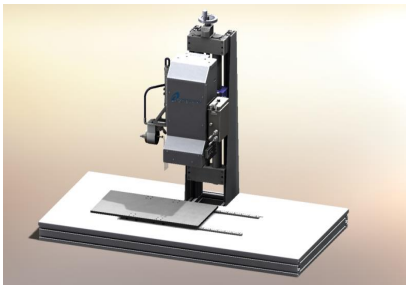


The bonNDTinspect® System

- **Versatile applicable**



ÅIndustrial Application (eg. robot based)
ÅSensor-Head moves



ÅLaboratory System (eg. test cell)
ÅSample moves on a linear axis system

The bonNDTinspect® System

- **Key figures**

- View of field: 30 mm to 20 m (line camera)
- distance (probe to sample): 70 mm +/- 2,5 mm
- Focus → 5 mm
- Flange for robot connection available
- Electrical communication via Gig / E and Harting plug
- CE certification available
- Aerosol is ultrapure water, evaporates without residue
- Test speed: Currently 50 mm
- Power supply: 230 V / Probe with 48 V

Applications & Examples

- **Use-case**:
- Inspection of smooth (CFRP, Plastics, Metal) surfaces prior to painting and bonding processes
- Detection of residual contamination
- Qualification of surface treatments (eg activation)
- Employable in industrial and laboratorial environments

- **Advantages:**
- Documented results.
- 100%-control in production
- One of the most difficult process steps is:
  - automated
  - standardized
  - objectified

Applications & Examples

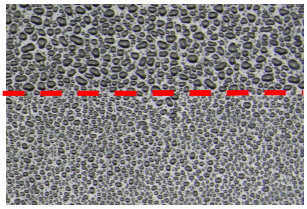
- **Application Coating Technology**

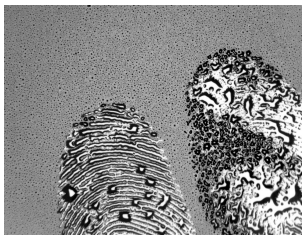
ÅPartly with silicone oil contaminated CFRP surface

ÅUpper part: clean, without contamination →large drops

ÅLower part: with silicone contamination →small drops

ÅDetection of fingerprints on CFRP and plastic





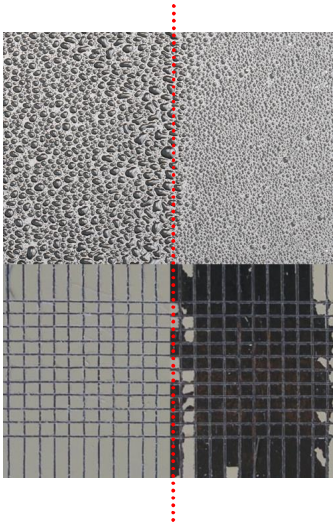
Applications & Examples

- **Application Coating Technology**

ÅDetection / Verification of an AP-Plasma on CFRP material

ÅActivated region (left) reveals big drops and good paint adhesion (cross-cut test → GT0)

ÅArea (right) with poor paint adhesion reveals significantly smaller drops



Applications & Examples

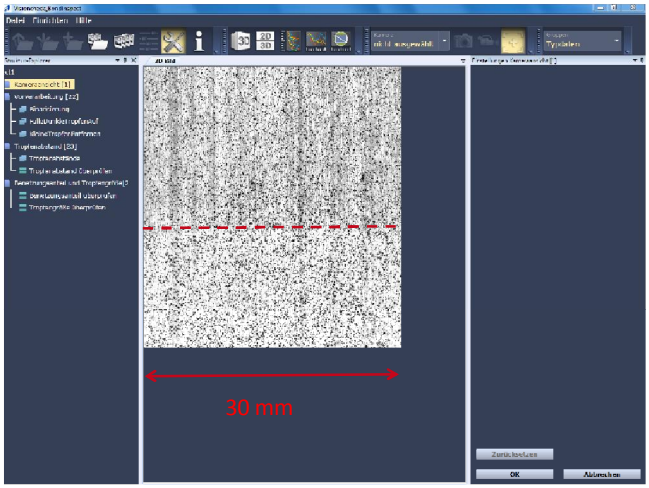
Inspection of a partly AD-Plasma treated CFRP sample

Camera view

Droplet pattern on a cfrp sample

Above the line:
No activation
(smaller droplets)

Below the line:
AD-Plasma treatment
(bigger droplets)



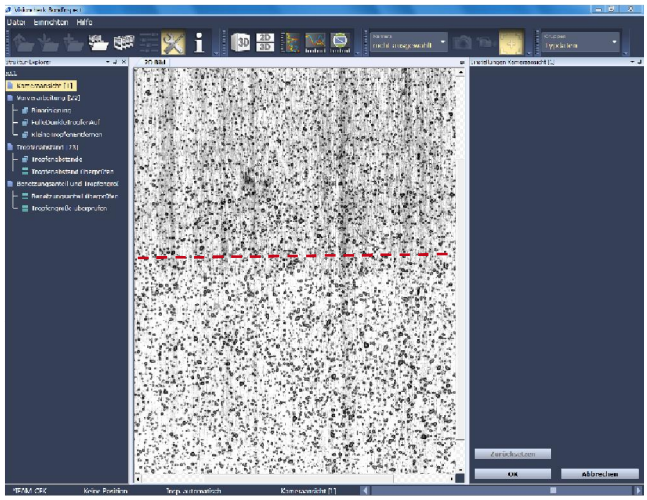
Applications & Examples

Inspection of a partly AD-Plasma treated CFRP sample

Camera view (zoom)
Droplet pattern on a cfrp sample

Above the line:
No activation
(smaller droplets)

Below the line:
AD-Plasma treatment
(bigger droplets)



Applications & Examples

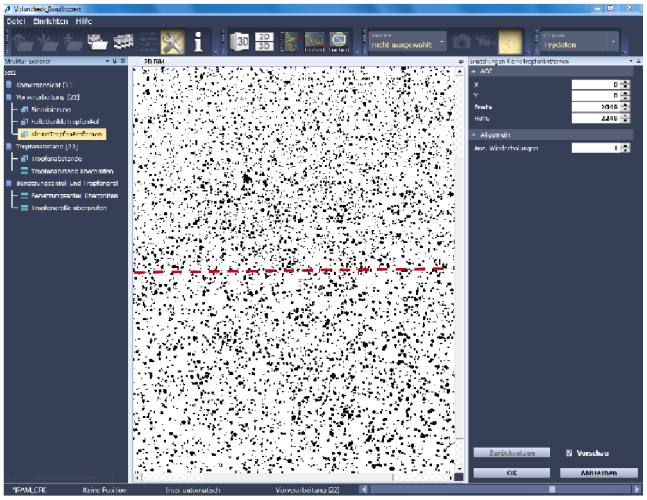
Inspection of a partly AD-Plasma treated CFRP sample

Camera view (binarized)

Droplet pattern on a cfrp sample

Above the line:
No activation
(smaller droplets)

Below the line:
AD-Plasma treatment
(bigger droplets)



Applications & Examples

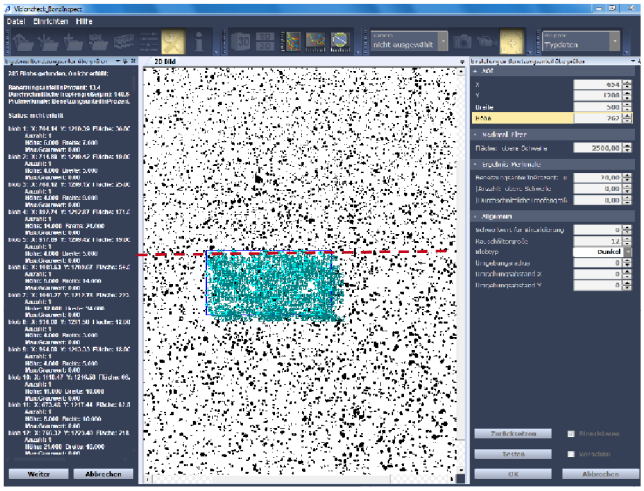
Inspection of a partly AD-Plasma treated CFRP sample

Droplet analysis

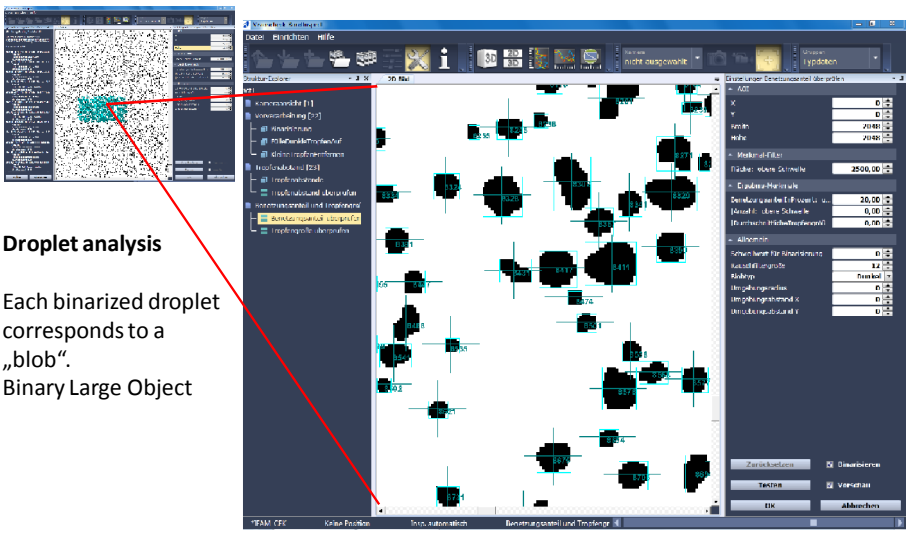
Droplet pattern on a cfrp sample

Above the line:
No activation
(smaller droplets)

Below the line:
AD-Plasma treatment
(bigger droplets)



Applications & Examples

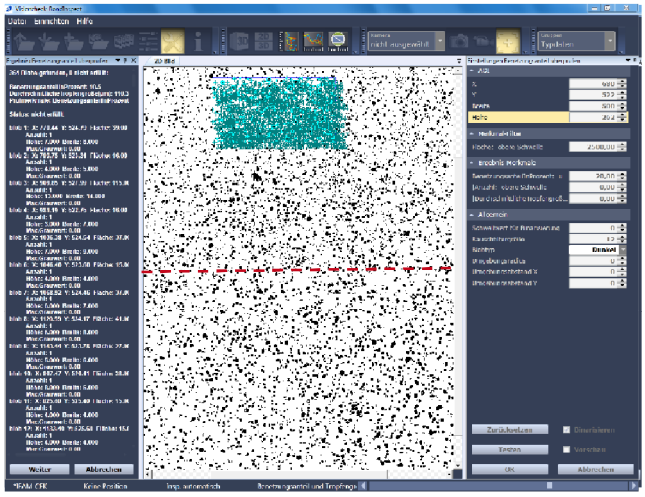


Droplet analysis

Each binarized droplet corresponds to a „blob“.
Binary Large Object

Applications & Examples

- **Inspection of a partly AD-Plasma treated CFRP sample**



Droplet analysis

Droplet pattern on a cfrp sample

Above the line:
No activation
(smaller droplets)

Below the line:
AD-Plasma treatment
(bigger droplets)

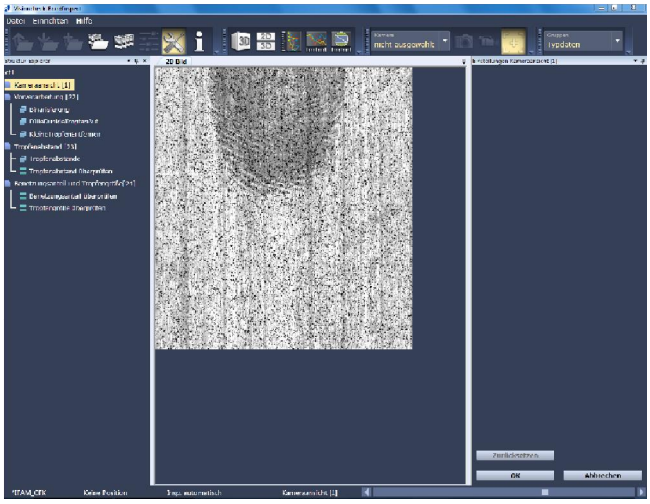
Applications & Examples

Inline analysis of a fingerprint on a CFRP sample

Camera view

Droplet pattern on a cfrp plate

A combination of contaminations cause a different pattern behaviour



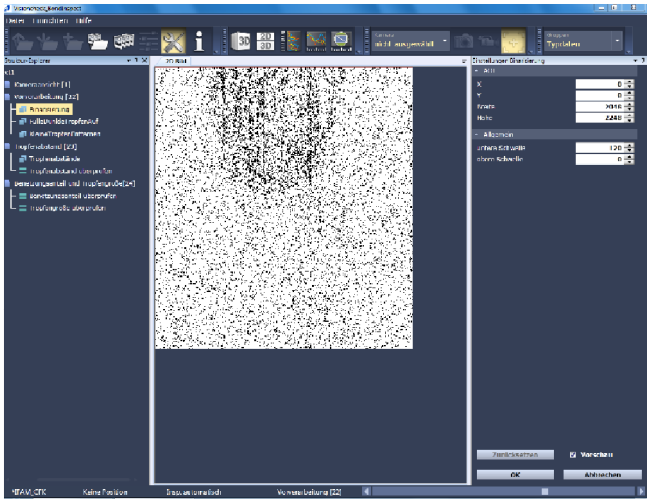
Applications & Examples

Inline analysis of a fingerprint on a CFRP sample

Binarized droplets

Droplet pattern on a cfrp plate

A combination of contaminations cause a different pattern behaviour

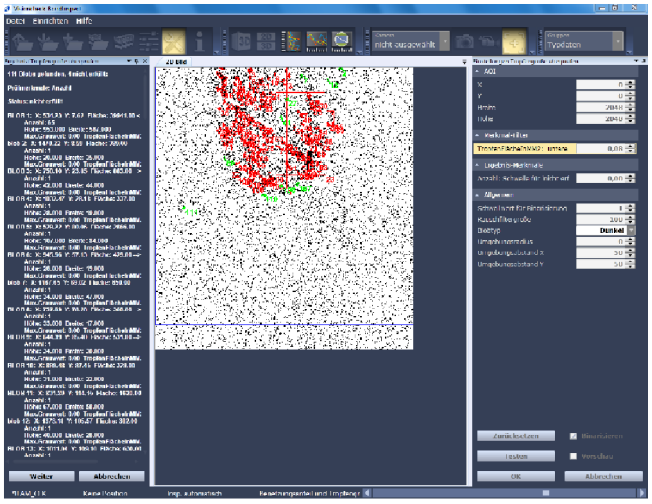


Applications & Examples

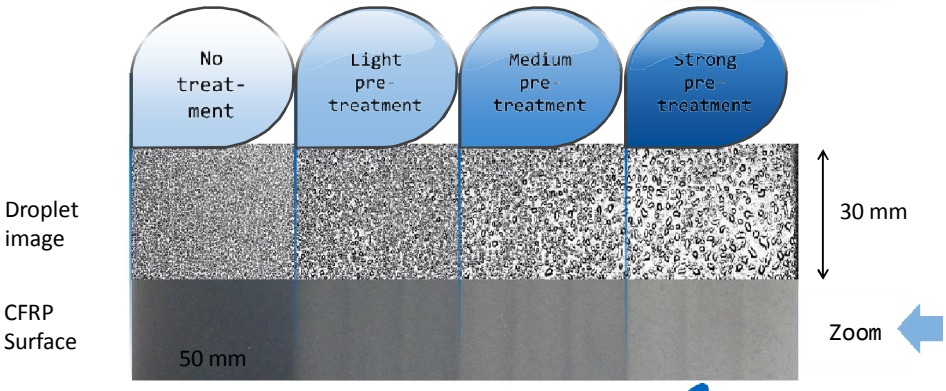
Inline analysis of a fingerprint on a CFRP sample

Binarized droplets with threshold
Droplet pattern on a cfrp plate

A combination of contaminations cause a different pattern behaviour



Applications & Examples



Summary & Outlook

- Successful implementation ï from invention to market
- Fully automated
- Inline capable
- Fast & Reliable
- Non-destructive testing
- Immediate further processing (bonding/painting) after testing with ultrapure water possible
- Ongoing long-term tests of components
- Workshop planned with industry and research partners to focus on typical problems in automotive and aeronautic industries