Automated Production of an CFRP-Aircraft Side Shell using AFP and Inductive Co-bonding technology

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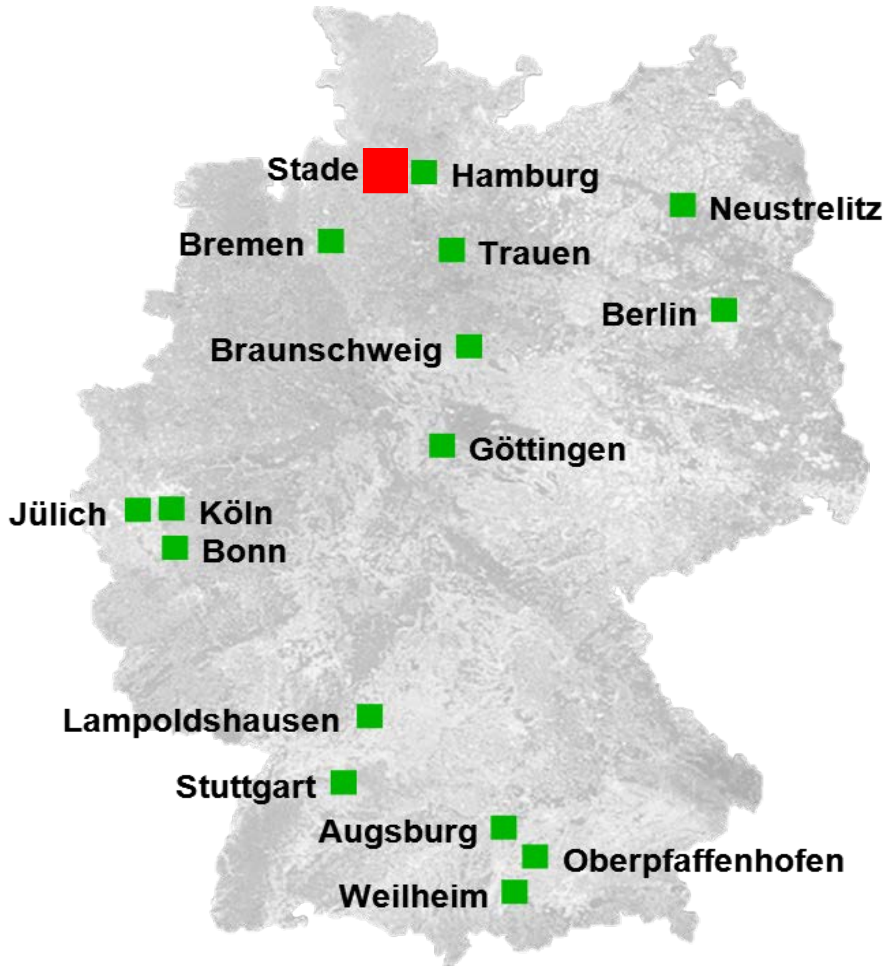
Content

- **Center for Lightweight-Production-Technology (ZLP) Stade**
- Research objectives of joint project MAAXIMUS
- Technological achievements for the manufacture of the fuselage shell
    - Quality Assurance in Fiber Layup Processes
    - Inductive Co-bonding Technology
- Summary and Outlook

Research Campus „CFK Nord“



Research Campus „CFK Nord“

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- ProductionTechnology Single Components
- Virtual Composite Product Development

Fraunhofer IFAM

- Assembly Technology
- Joining Technology
- Prototype Assembly

DOPAG Process Technologies

- Technology Development, Customer Service

DOW

- Fundamental Materials Research (e.g. novel resins)

Profile NTH

Technische Universität Carolo-Wilhelmina zu Braunschweig

TU Clausthal

Leibniz Universität Hannover

20.000 qm for cooperation and innovation

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Center for Lightweight-Production-Technology Stade

Main Research Areas

Automated Fiber Layup

- Robot based Multi-Head Fiber Layup research platform
- Holistic simulation of technology and process
- Online quality assurance and control

In- and Out-of-Autoclave Infusion Technology

- Biggest Autoclave Laboratory Unit of the world
- Dynamic autoclave control
- Process simulation using a virtual autoclave
- Sensor development and integration for quality assured production

Automated Textile Preforming and RTM Technology

- Fully automated process chain as research platform
- Isothermal processing for productivity increase
- Process assessment using integrated sensors and process simulation

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More Affordable Aircraft through eXtended, Integrated and Mature nUmerical Sizing

- **Highly-Optimised Composite Fuselage:**
- Enable a high-production rate: 50% reduction of the assembly time of fuselage section
- Reduce the manufacturing and assembly recurring costs by 10% compared to the ALCAS equivalent reference
- Reducing weight by 10%, compared to best available solutions on similar fuselage sections (F7X, A320 and TANGO fuselage)

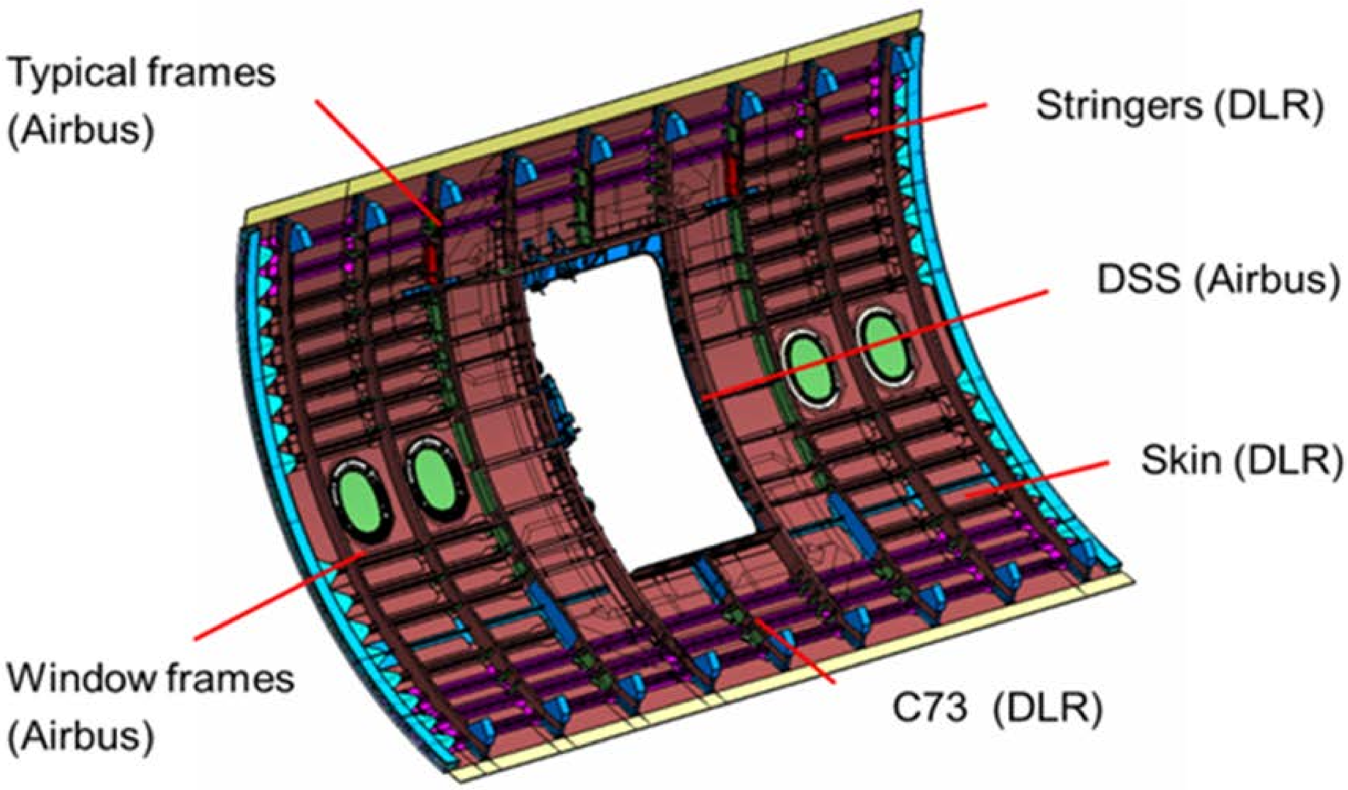
- **Faster Development:**
- Reduce by 20% the current development timeframe of aircraft composite structures from preliminary design up to full-scale test
- Reduce by 10% the non-recurring cost of aircraft composite structures from preliminary design up to full-scale test (ALCAS reference)

- **Right-First-Time Structure:**
- Reduce the airframe development costs by 5% compared with the equivalent development steps in an industrial context

http://www.maaximus.eu/

MAAXIMUS Full Scale Demonstrator

Fuselage shell with door-surround-structure of A 350 size



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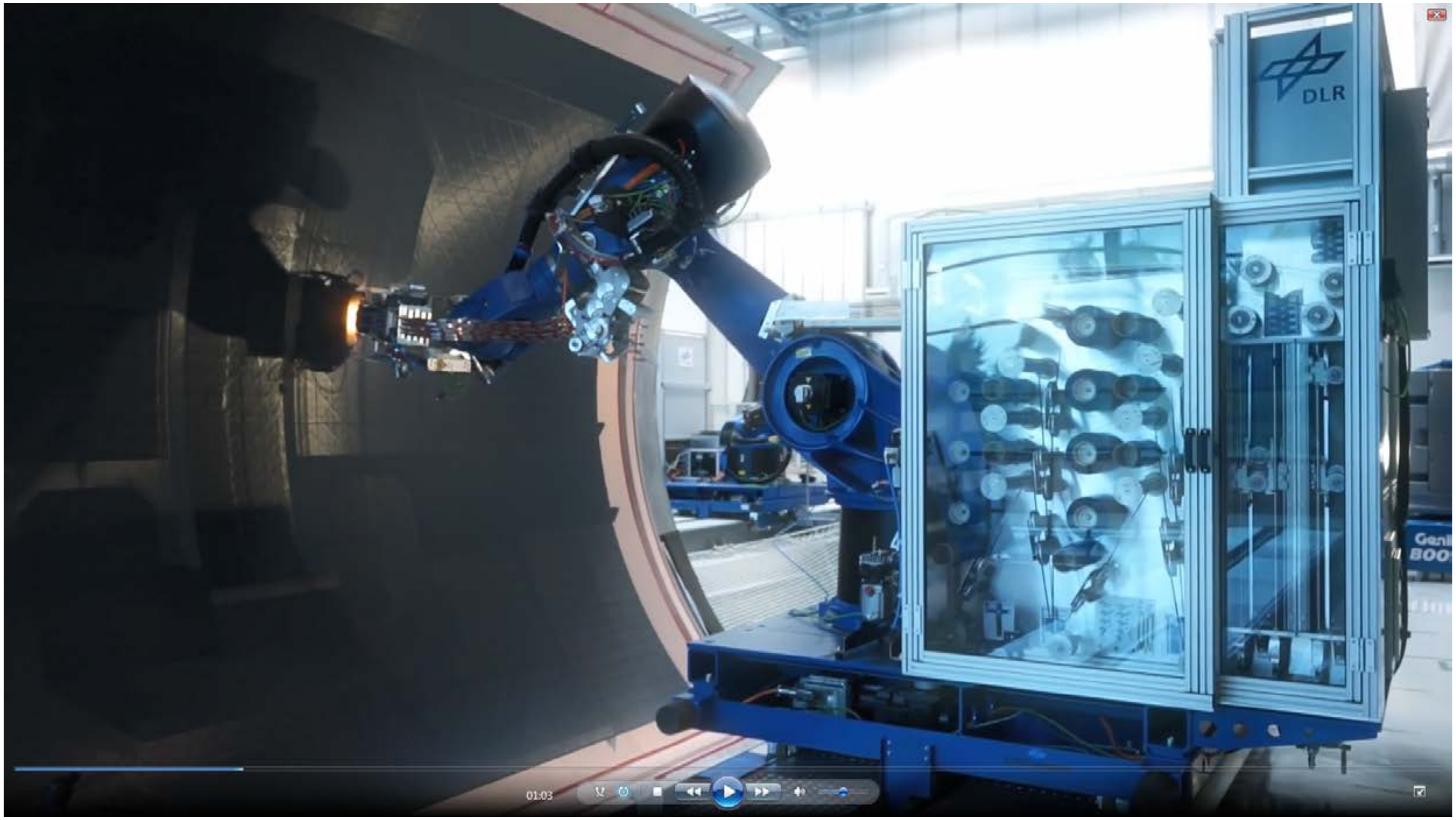
Video of manufacture of CFRP Side Shell



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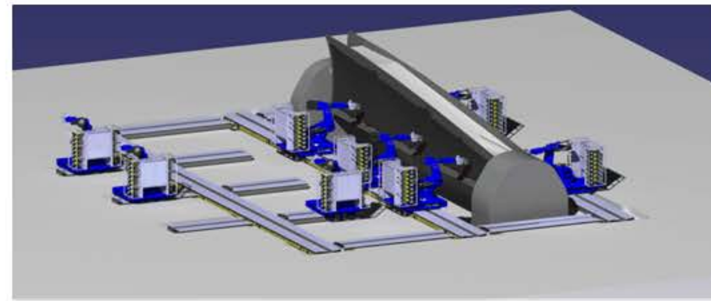
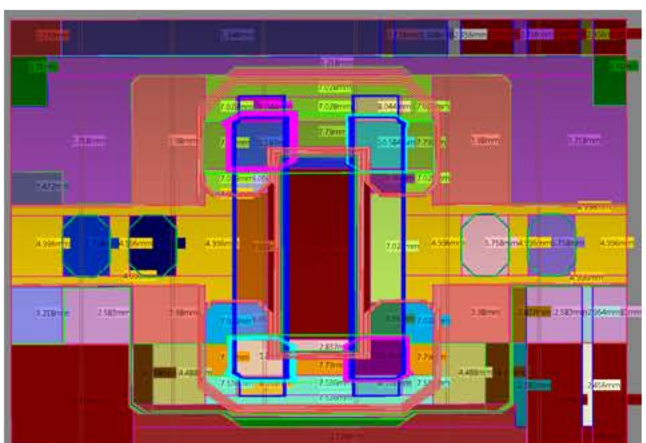
Challenges of the quality assured Fiber Layup

Manufacture of fuselage panel

- **Key facts**
    - More than 200 patches and full plies
    - unbalanced lay up in the door surround structure
    - Length 5.8m, width 4.2m, weight 180kg
    - Material: M21 e
- Manufactured with the Fiber Layup research platform



The Automated Finer Layup research platform



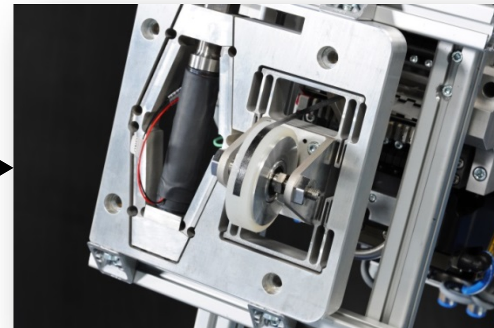
Iso-Thickness-Areas

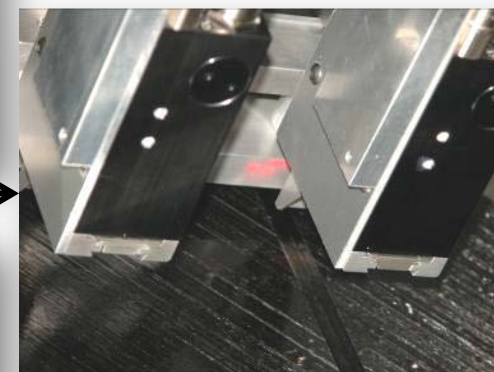
Fiber-placement-robot-unit working on shell

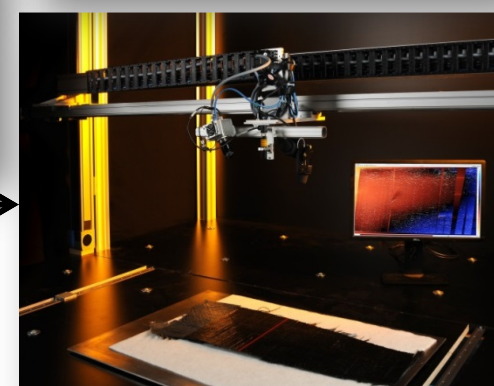
Quality Assurance in Fiber Layup Processes
Quality Improving Sensor Systems (QISS)

QISS

- Vibration Compensation
- Path/Position Correction referenced
- Path/Position Correction absolute
- Quality Inspection



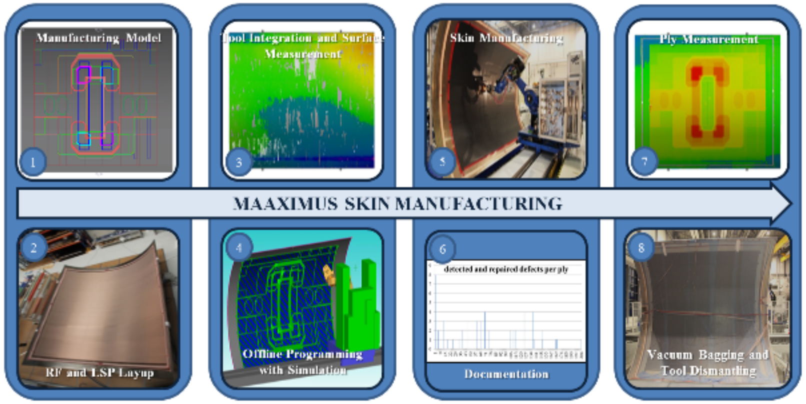


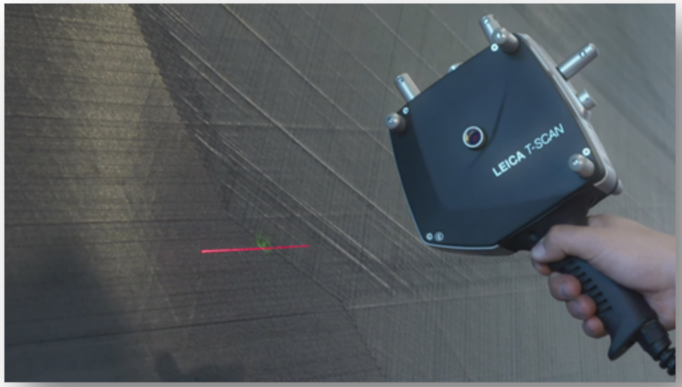


Quality Assurance in Fiber Layup Processes
Online Measurement Technologies

- Automated geometry measurement of large-scaled components
- Comparison to manufacturing model and/or offline programming and simulation
- Identification of thickness variations to analyse layup defects like bridging
- Export of geometries for ongoing processes like stringer integration

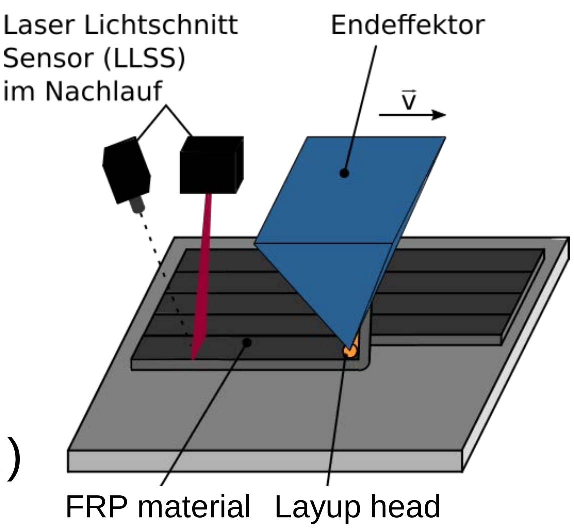
➢ Inline quality assurance by ply-wise measurements

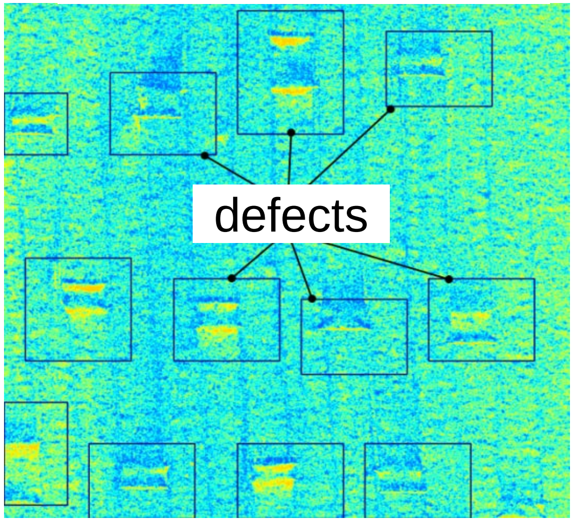




Quality Assurance in Fiber Layup Processes
Online Quality Inspection

- Online quality assurance sensor system for layup processes with detection, characterization and localization of defects:
  - Exceeding tolerances (gaps, overlaps, difference to CAD)
  - Process defects (missing tows, twists, bridging, …)
  - Foreign bodies
  - Material defects (splice, impregnation defects, bird eyes, …)
- **aim: sensor based and automated detection of defects to minimize time-consuming, manual inspection process**





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    - **Inductive Co-bonding Technology**
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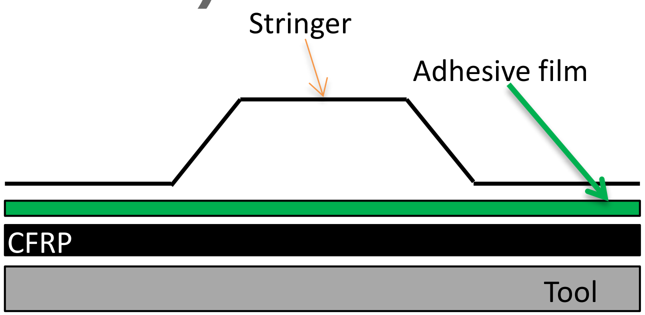
Inductive Pre-Bonding (Co-Bonding Process)

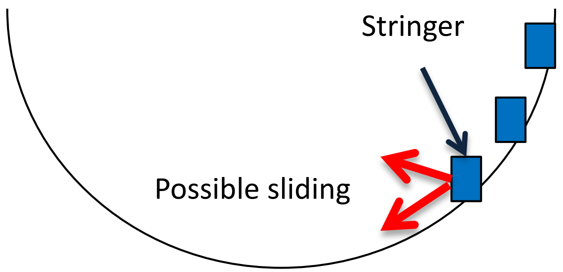
- Pre-Bonding (local fixation)
    - Max. temp CFRP: 60 – 70°C
    - Adhesive film working temperature: 45 – 55°C
    - Risk of sliding
        - Depending from position in fuselage section
        - Depending from sensitivity of the workers during vacuum bagging

- Final Bonding (global curing)
    - Autoclave process (180°C, 7-10bar)

- Example
    - Airbus A350 fuselage with over 5000 bonding positions
    - Time- intensive conventional heating systems



Príncipe of Co-Bonding



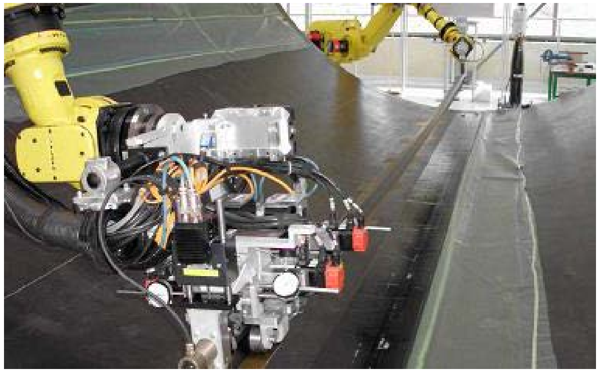
Risk of sliding

Source: Airbus: A lot of bonding points

Inductive Pre-Bonding (Co-Bonding Process)

- **State of the art**
  - Heating devices to pre-bond adhesive film (conduction)
    - Required time: 50 - 60 seconds
    - Fixation heating device during process with magnets
  - Heating by infrared to pre-bond adhesive film (convection, conduction)
    - Required time: 10 - 20 seconds
- **Technologie comparison (Heat transfer)**
  - Heat conduction 20 [W/cm2]
  - Heat radiation 8 [W/cm2]
  - **Inductive Heating 10^4 [W/cm2]**

Source Airbus: conductive heating device



Source PAG: Infrared heating device

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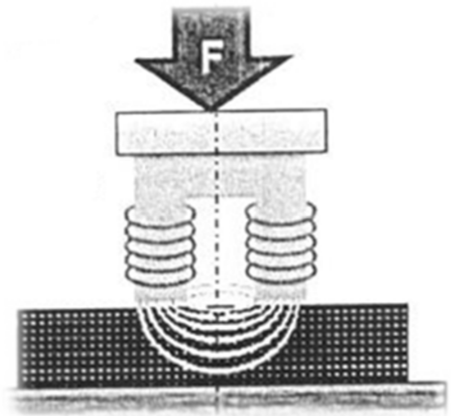
Inductive Pre-Bonding (Co-Bonding Process)

The theoretical background

- Generation of an electromagnetic alternating field
- Existence of a temperature field created through the heat loss caused by eddy currents



Electromagnetic field

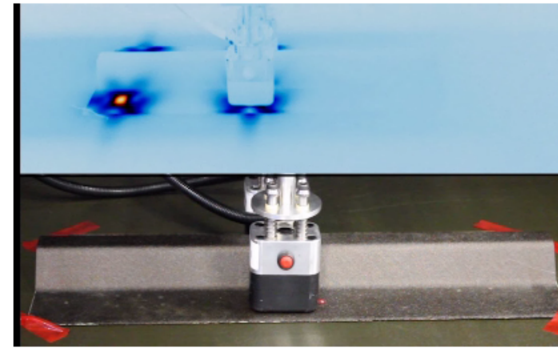
Research hypothesis:

Due to the electrical conductive properties of carbon fibers, inductive heating can be used with CFRP

- Inductive process can be designed by setting four parameters
  - Power **P**, time **t**, frequency **f** (penetration depth)
  - Force **F** (degree of compaction)
- Boundary conditions
  - Material, part thickness, lay up, degree of compaction

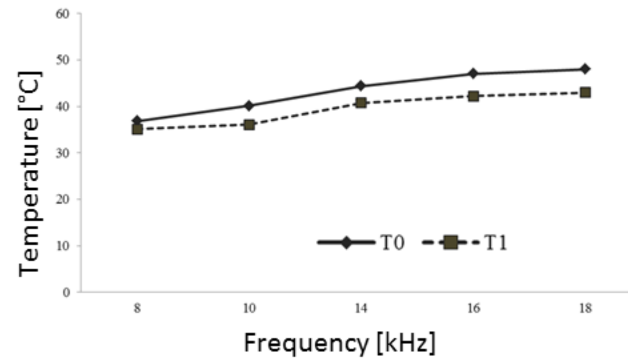
Induction unit

Inductive Pre-Bonding (Co-Bonding Process)



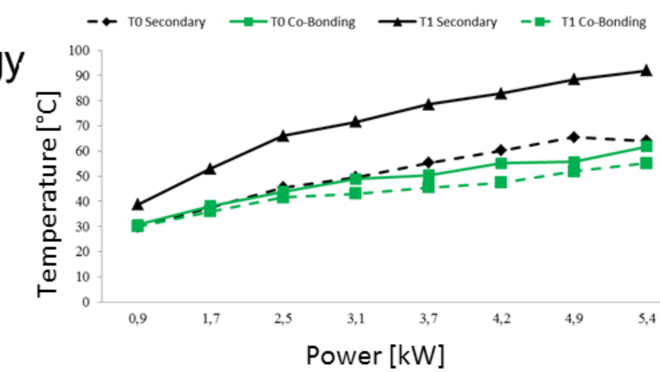
Results of Investigation

- Frequency trials
  - Warming the correct areas (not the tool, HOP)
  - Temperature sensors were placed
    - on the top of the stringer (T_0)
    - between stringer and skin (T_1)



- Comparison secondary and co-bonding process
  - Secondary bonding (skin cured, stringer cured)
  - Co-Bonding (skin uncured, stringer cured)
  - The cured laminate seems to absorb more energy than the uncured laminate
  - Possible explanation: Better compaction of the fiber structure and higher fiber volume content results in a better conductivity

→ **Every setup needs its own parameters**



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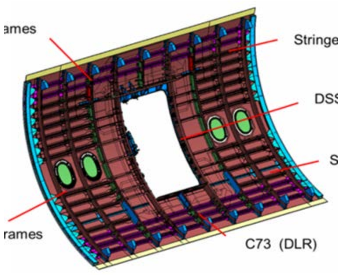
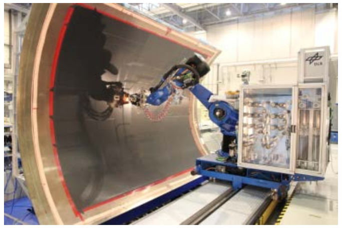
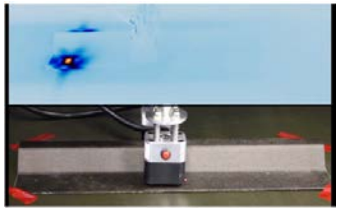
Summary and Outlook

Current status

- Technical objectives of project MAAXIMUS have been met
- Successful realization of a CFRP-fuselage-shell
- Sensor technologies for online quality inspection during fiber layup available and assessed
- Innovative technology for significant reduction of process duration for pre-bonding process + ability for automation







Future work:

- Proof potential for further cost reduction for Fiber Layup Processes using Multi-Head-Approach
- Integration of sensor technologies in Fiber Layup Technologies
- Online assessment of manufacturing defects and an appropriate adjustment if needed
- Try to bring inductive pre-bonding to industrial application

Thank you for your attention!

Source: Airbus Group

We gratefully thank the European Commission for funding the work in the project MAAXIMUS within the 7th framework program

SEVENTH FRAMEWORK PROGRAMME

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