Automated Solutions for the Reworking and Repair of Composite Structures

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Industrial and R&D Collaboration:
Mobile 5-Axis Milling System for Patch Repair Preparation

- BCT GmbH: Software, scanning, system integration
- CTC GmbH: Process development and serial maturity
- SAUER GmbH: Mobile machine
- WIWeB: Research & repair process development
  Wehrwissenschaftliches Institut für Werk- und Betriebsstoffe
Project “MARS”
Mobile Automated Repair Solution

- Prototype of mobile repair machine manufactured by SAUER and BCT

- Qualification of automated repair process for aerospace applications
- Initiation of industrial implementation
Challenges of today’s repair using sanding

- Time consuming
- Quality varies by worker skills and motivation
- Distinguishing the layers on the CFRP surface challenging

Required improvements

- Reproducibility
- High accuracy and surface quality
- Improved process efficiency
- Traceability and monitoring
- Flexibility
Maturity Steps [1]

- Wide range of experiments and test components to represent the test pyramid
- Comparison of manually and automatically generated surfaces
- Start with base of test pyramid on coupon level
Maturity Steps [2]

- Manual sanding
- Mobile repair machine
- Application
- Certification
- Qualification
Selected Material Removal Technology: Milling
Atmospheric Pressure Plasma for Surface Activation

- Optimal macroscopic geometry of milled surface for high structural strength
- Optimal microscopic surface condition for adhesive bonding
- The aim: Fast and reliable surface preparation by milling
Optimization of Milling Strategies and Tools

- Development and testing of cutting tools
- Cylindrical cutting tools with special edge geometries
- 5-axis milling strategies
Further Developments
Future Mobile Repair System

- Ultrasonic-based damage detection
- Fiber-oriented scarfing geometries
- Integration of atmospheric plasma
- Ultrasonic-based primer application
- Ultrasonic ply cutting capability
**Stationary vs. Mobile Machines**

**Reworking**
- To save new components from scrap
  - Stationary machine for parts of smaller size
  - Mobile machine for parts which do not fit into a reasonable machine tool

**On-aircraft repair**
- To minimize AOG
  - Mobile machine is a must
ULTRASONIC Machining of Composites
The Most Important Features of Mobile Machine

Framework made from CFRP
- Integrated cable guidance
- Integrated exhaust

Powerful Adaption
- 16 x 256 N suction power

Technical Data
- X-/Y-Axis: 500 mm
- Z- Axis: 200 mm
- C- Axis: 360° (endless)
- A-Axis : 270° (Torque)
- Dimensions: 1120 x 1120 x 720 mm
- Weight: 85kg

Flexible Spindle Concept
- ULTRASONIC-technology
- max. 35.000 rpm

Integrated Devices
- Laser-line scanner
- Atmospheric pressure plasma
ULTRASONIC mobileBLOCK

Benefits

- Up to 40 % reduced process forces for the prevention of fiber fraying and delamination
- Doubled feed rates possible thanks to ULTRASONIC
- Longer tool service life thanks to prevention of build-up edges
- Optimal particle discharge from the working area
- Sharp edges, clean exposure of individual laminate layers, perfect surfaces
Automated Process Flow for Repair and Reworking
From scanning of repair area to 5 axis milling of scarfing

- 3D optical scanning
- Data processing
- 5-axis adaptive machining
Generic Algorithm for Generation of Tapered and Stepped Scarfings [1]

- Circular scarfing
- Elliptical scarfing
- Rectangular / racetrack scarfing
Generic Algorithm for Generation of Tapered and Stepped Scarfings [2]

- Special scarfings for boundary areas
- Fiber-oriented scarfing
- Proprietary scarfings via CAD/CAM
Automatic Point Scan to Detect Topography
Automatic Line Scan & Data Processing
Automatic 5-Axis Milling of 3D Scarfing
Conclusions and Outlook

- Deviations from nominal shape play a decisive role in manufacturing and repair of composite components
- The automatic mobile repair system shows the huge capabilities of adaptive machining in composites applications
- Integration of further processes is under development
- Qualification of automated repair process for aerospace applications
Conclusions

Thank you for your kind attention!