Efficient CFRP-Manufacturing Using Multiple Industrial Robots

German Aerospace Center
Institute of Composites Structures and Adaptive Systems

Markus Schreiber
Dominik Delisle
Motivation

Within the project GroFi, the German Aerospace Center (DLR) in Stade developed an innovative plant concept for a fully automated fiber placement (AFP) process using multiple robot units working simultaneously on one or more parts.

One task of the project EWiMa was the demonstration of a multihead layup with two coordinated fibre placement robots for the first time.
Outline

Development Steps of the DLR MultiHead Approach

GroFi® Concept  Modelling  Simulations  Verification

Next Steps

Outlook
DLR MultiHead-Approach

GroFi® Concept

GroFi® Research Platform

- Up to 20m x 5.5m part size
- Up to 8 lay-up units (Kuka KR-500-2 with Siemens Control)
- Separated production and maintenance area
- Combined usage of different technologies (AFP, ATL & DFP)

Robust
Flexible
Cost Efficient
Time Efficient
**DLR MultiHead-Approach**

**Modelling**

**Objective**
Collision-free, time optimised coordination of several layup units to increase the productivity of fibreplacement processes

**Challenges**
- Unique plant concept
- Non-static, overlapping workspaces of the layup units
- No preemption of running tasks

**Solution basis**: Quay Crane Scheduling Problem

**Similarities:**
- Rail bounded system (One-dimensional movement)
- Each job can be done by any robot unit
- Precedence constrains between jobs

**Deviations:**
- Quay crane: no movement during the processing of jobs

Source: www.konecranes.com
**DLR MultiHead-Approach**

**Simulations**

**Offline Simulation**

**Steps:**
- Single-Head NC generation (ACE V2.0)
- Kinematik simulation / Time correction (DLR)
- Scheduling (DLR)
- MultiHead-Simulation (DLR + EasyRob)

Online collision control
**DLR MultiHead-Approach**

**Verification – Demonstrator production**

**MultiHead Demonstrator (June 2017)**
- Generic wing cover design with representative patches and critical features
- 313 plies
- Span 8m
- Maximum Wing Chord 2760mm
- Maximum thickness 20mm (159 plies)
- Use of an Coriolis patent concerning the fiber guidance system

**Constraints**
- 2 AFP layup units working simultaneously
- Manufacturing pauses during particular evasive movements
  -> additional safety for the first multi-head demonstration

<table>
<thead>
<tr>
<th>Feedrate / Speed</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Surface (non 0°)</td>
<td>30 m/min</td>
</tr>
<tr>
<td>On-Surface (0°)</td>
<td>25 m/min</td>
</tr>
<tr>
<td>Off-surface</td>
<td>60 m/min</td>
</tr>
<tr>
<td>Cut on the fly</td>
<td>8 m/min</td>
</tr>
</tbody>
</table>
DLR MultiHead-Approach
MultiHead Demonstrator - Impressions
**DLR MultiHead-Approach**

Results – Simulation Validation

Two Step Analysis

i. Simulation Validation

ii. Improvements of the MultiHead Approach
   (regarding the 8m generic wing cover)

Simulation Validation

<table>
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<td>Average velocity for off-surface movements</td>
<td>0.7 m/s</td>
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Logged process data

(only on-surface motion)

Simulation

(including TCP approach and lift off)

Representative subsection of the MH-demonstrator (12Plies)
**DLR MultiHead-Approach**

**Results – Simulation Validation**

**Two Step Analysis**

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**Simulation Validation**

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→ Movement behaviour of the layup units is well reflected

→ Less than 2% Variance

**Representative subsection of the MH-demonstrator (12Plies)**

- Logged process data
- Simulation

Process time [s]

<table>
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<th>Overall Variance</th>
<th>480s</th>
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<tr>
<td>Additional safety aspects (not represented by the simulation)</td>
<td>410s</td>
</tr>
<tr>
<td>Actual variance</td>
<td>70 s</td>
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**DLR MultiHead-Approach**

Results – Simulated Improvements

**Two Step Analysis**

i. Simulation Validation

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   (regarding the 8m generic wing cover)

**Comparison**

- MultiHead (2 units) vs. SingleHead
- Regarding the entire manufacturing process

→ **Fiber deposition: 45% time saving**

→ Synchronization: Additional safety
   Can be reduced in future processes

→ NC loading: Due to the data structure of the GroFi research platform. Can be optimized for industrial use
DLR MultiHead-Approach

Outlook

- Online (re-) scheduling
- Production scheduling considering the whole complexity of the GroFi plant
- Manufacturing process of n parts using m layup units
- Multi-technology processes
- Part adapted plant design
  Calculation and comparison of different plant designs
Thank you!

Markus Schreiber M.Sc.  
German Aerospace Center  
Institute of Composite Structures and Adaptive Systems  
Ottenbecker Damm 12  
21684 Stade  
Germany  

Telephone +49 531 295-3759  
E-mail markus.schreiber@dlr.de  
Internet www.DLR.de