Development of Composite Complex Geometries Structures – An Automated Fiber Placement Application

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Composites

• The material for affordable structures:
  – High strength/weight ratio;
  – Lay-up directions based on part requirements;
  – Less material waste;
  – Complex part production.

• Applications:
  – Aerospace and aeronautic ...
    • Automotive;
    • Energy;
    • Infrastructure;
  • Oil and gas;
  • Medical;
  • others.
Automated Laminating Processes

- NC machines for automated lay-up composites parts;
- Substitute to hand lay-up process:
The Automated Fiber Placement Process

• Perform automated lay-up of composites tows onto a mould;
  – Individual tow control;
  – Complex parts
  – Compression;
  – Narrow tows;
  – Fiber steering;
  – Alignments;
  – Auto cut and position;
  – Near net-shape;

Source: Evans, D. O. (2001), *Fiber Placement*
The Automated Fiber Placement Process

• Perform automated lay-up of composites tows onto a mould;

Source: Evans, D. O. (2001), Fiber Placement
The Automated Fiber Placement Process

• Machine examples:

1. Robot platform: Coriolis;
2. Gantry: Electroimpact;
3. Rotational mandrel: MAG Cincinnati;

The Automated Fiber Placement Process
The Automated Fiber Placement Process

- Coverage algorithms assessment:

Source: MAG IAS, LLC (2011), Advanced Composite Environment V2.0 – Help Documentation
The Automated Fiber Placement Process

Main operational parameters:
- Feedrate;
- Tow temperature;
- Tow tension;
- Compaction pressure;
- and others.

Main induced defects:
- Gaps;
- Overlaps;
- Tows twist;
- Tows drop;
- and others.

Source: Bottene, et.al. (2012), *Experimental Evaluation of Automated Fiber Placement Manufacturing Parameters*
Objective

Evaluate coverage methodologies and manufacturing parameters...

...for the production of a complex shape composite structure

Source: Mello et.al. (2012), Assessment of Automated Fiber Placement Coverage Generation Algorithms

Source: Bottene et.al. (2012), Experimental Evaluation of Automated Fiber Placement Manufacturing Parameters
The case of study
Methodology

• Three main testing groups:

1. Standard laminate;

2. Theory *versus* real – ratio analysis;

3. Enhanced parameters evaluation.
Methodology

• Group 1:
  – Objective: evaluate the difference between the simulated and real results.
  – Lamination: single ply, 0°, 45°, 90° and -45°.
  – Manufacturing parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedrate</td>
<td>1270</td>
<td>mm/min</td>
</tr>
<tr>
<td>Tow temperature</td>
<td>90</td>
<td>°C</td>
</tr>
<tr>
<td>Tow Tension</td>
<td>2,22</td>
<td>N</td>
</tr>
<tr>
<td>Compaction pressure</td>
<td>1447,9</td>
<td>kPa</td>
</tr>
</tbody>
</table>

– Maximum:
  • Gap: 1,5mm;  Overlap: 1,58mm;  FAD: 2°
Methodology

• Group 2:
  – Objective: evaluate and stabilize the theory \textit{versus} real ratio;
  – Lamination: single ply, 0°;
  – Three laminations;
  – Coverage parameters based on Group 1 results.

• Group 3:
  – Objective: production of a laminate with enhanced final quality;
  – Lamination: single ply, 0°.
Materials

• Carbon fiber tow:
  – Hexcel Hexply M21/IM7;
  – Carbon fiber with pre-impregnated epoxy resin.

• MAG Cincinnati VIPER 1200 fiber placement;
  – Up to 12 tows (1/8in width);
  – Usable area: 3,0m diameter and 4,0m length.

• Mandrel:
  – Double curvature complex part;
  – Representative rear fuselage section.

• Manual magnifier: Peak 10x – 0,1mm resolution;
Results

• Group 1

ACE - 0°  
ACE - 90°  
ACE - 45°  
ACE - -45°  
Laminate - 0°  
Laminate - 90°  
Laminate - 45°  
Laminate - -45°
Results

• Group 1:
  – Gaps:
    • Theory to real – values had decreased;
  – Overlaps:
    • Theory to real – values had increased;
  – Fiber Angle Deviation (FAD):
    • Values were not compared – difficult to measure.
  – Ratio:
    • Impossible to define.
Results

• Group 2:
Results

• Group 2:
  – Gaps:
    • Ratio: from 10% to 54%;
  – Overlaps:
    • Ratio: from 96% to 153%;
  – Measures standard deviation:
    • 0.17mm (under machine and material specification).
  – Standard ratio:
    • 10%.
Results

- Group 3
  - Requirements achieved - maximum Gap: 1,5mm
Conclusion

• Experimentally tested ratio: 10%;
  – Possible to produce parts over 10% simulation limits;
  – Enlarge AFP applications.

• Complex shape composite structures:
  – Fiber Placement can be applied.

• Future work:
  – Evaluation of the manufacturing parameter direct associated with the ratio;
  – Test different geometries for ratio evaluation.
Thank you

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