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

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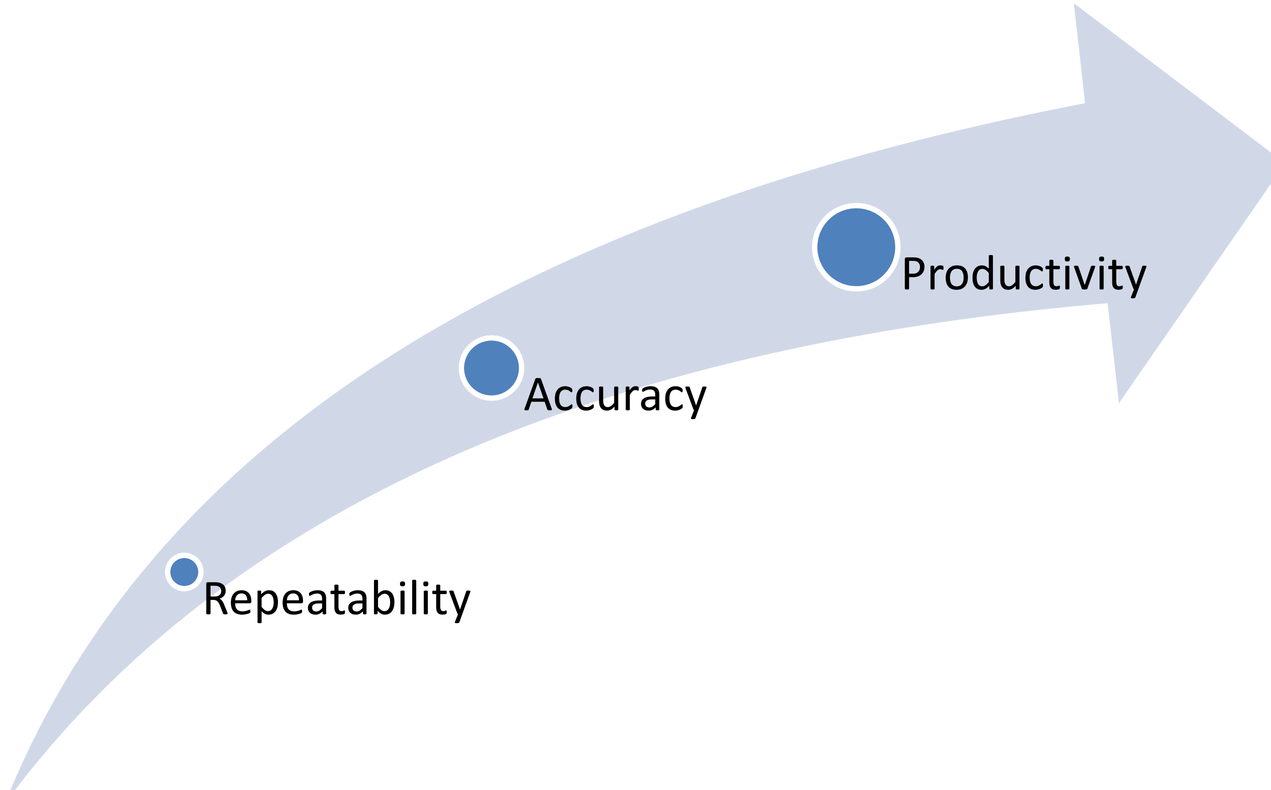
Composites

- 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.

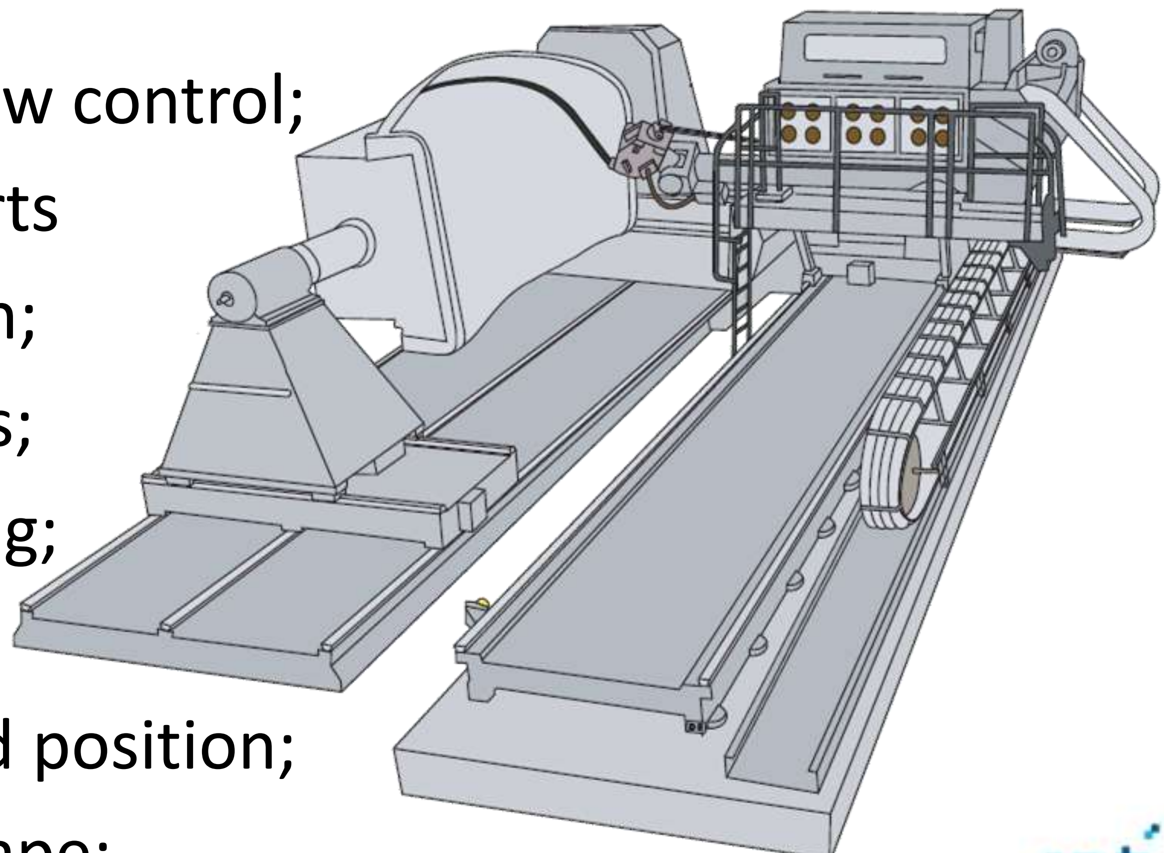
Automated Laminating Processes

- NC machines for automated lay-up composites parts;
- Substitute to hand lay-up process:



The Automated Fiber Placement Process

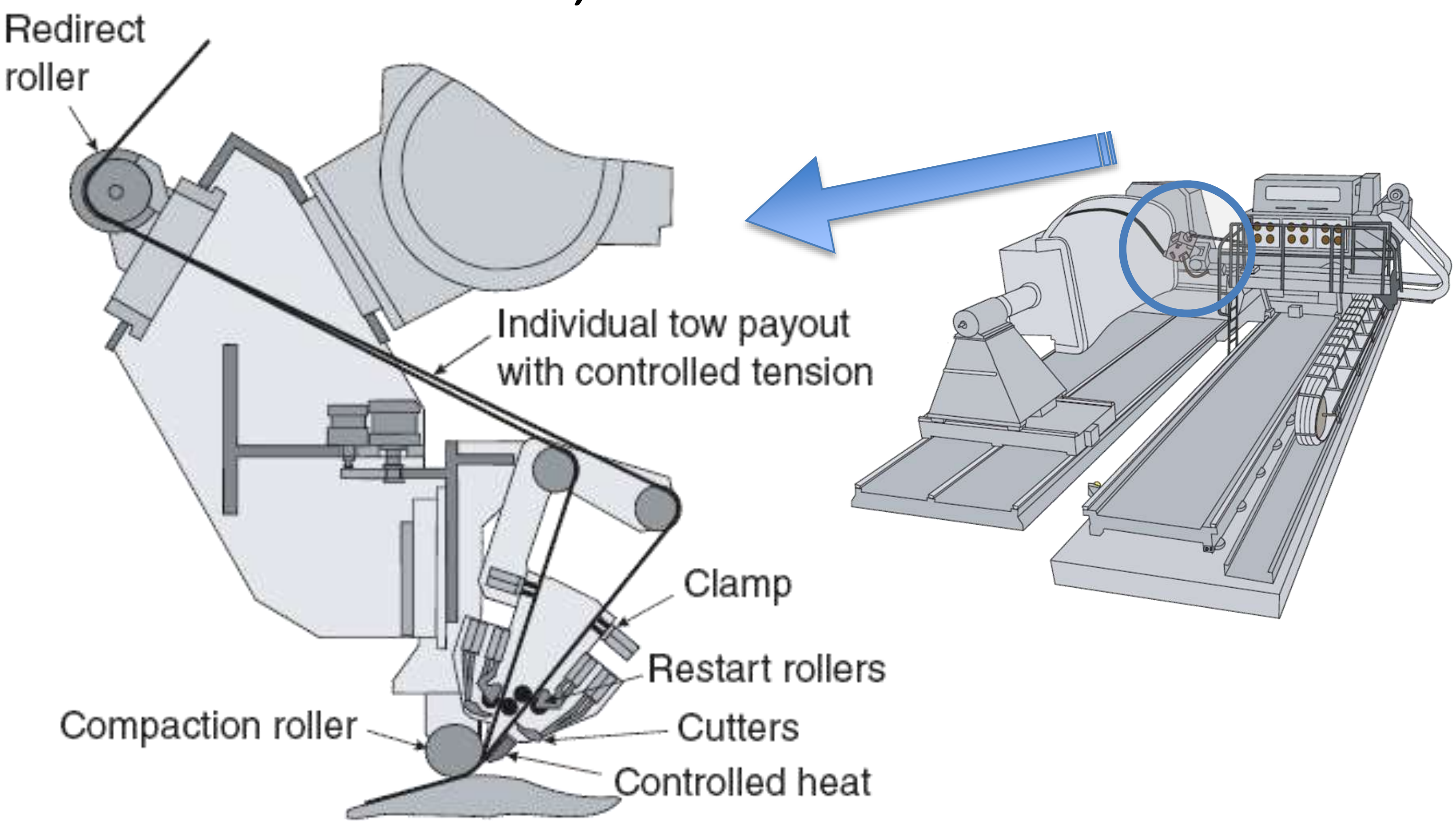
- Perform automated lay-up of composites tows onto a mould;
  - Individual tow control;
  - Complex parts
  - Compression;
  - Narrow tows;
  - Fiber steering;
  - Alignments;
  - Auto cut and position;
  - Near net-shape;



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

The Automated Fiber Placement Process

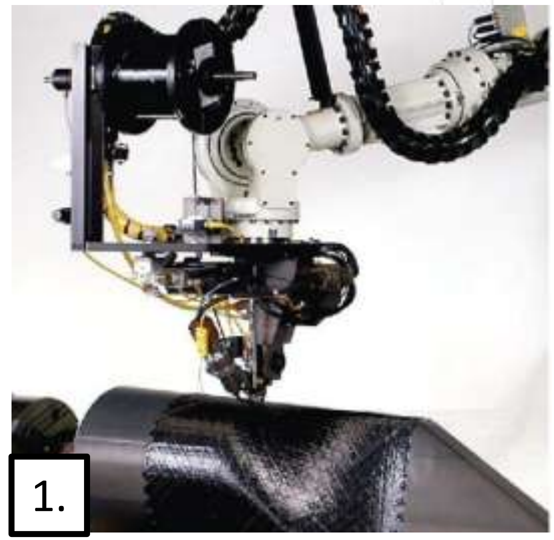
- Perform automated lay-up of composites tows onto a mould;

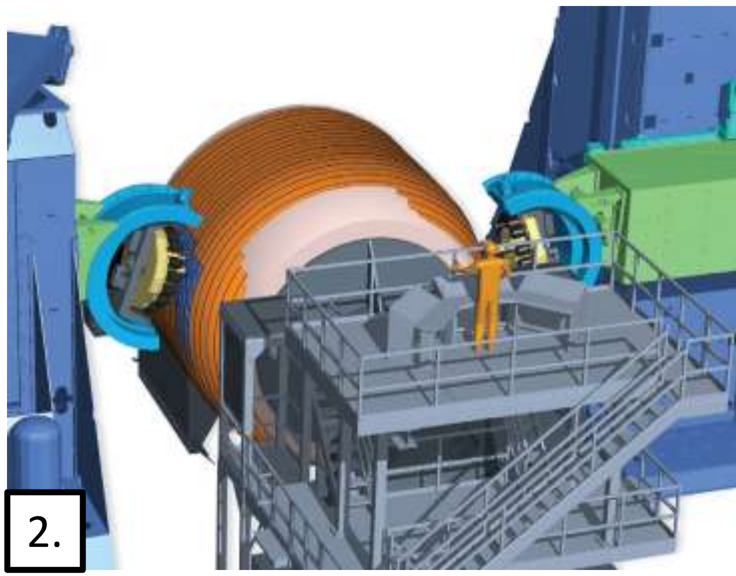


Source: Evans, D. O. (2001), *Fiber Placement*

The Automated Fiber Placement Process

- Machine examples:


1.


2.


3.

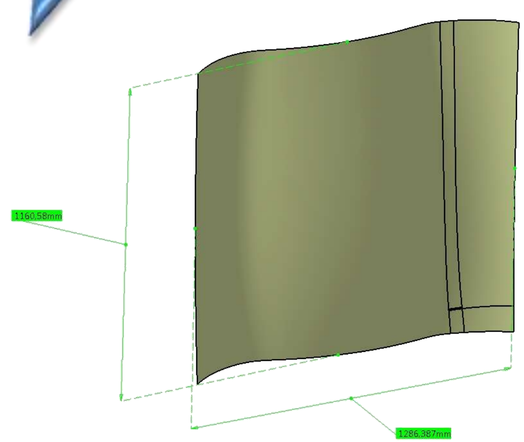
1. Robot platform: Coriolis;
2. Gantry: Electroimpact;
3. Rotational mandrel: MAG Cincinnati;

Source: Marsh, G. (2011), *Automating aerospace composites production with fibre placement*

The Automated Fiber Placement Process

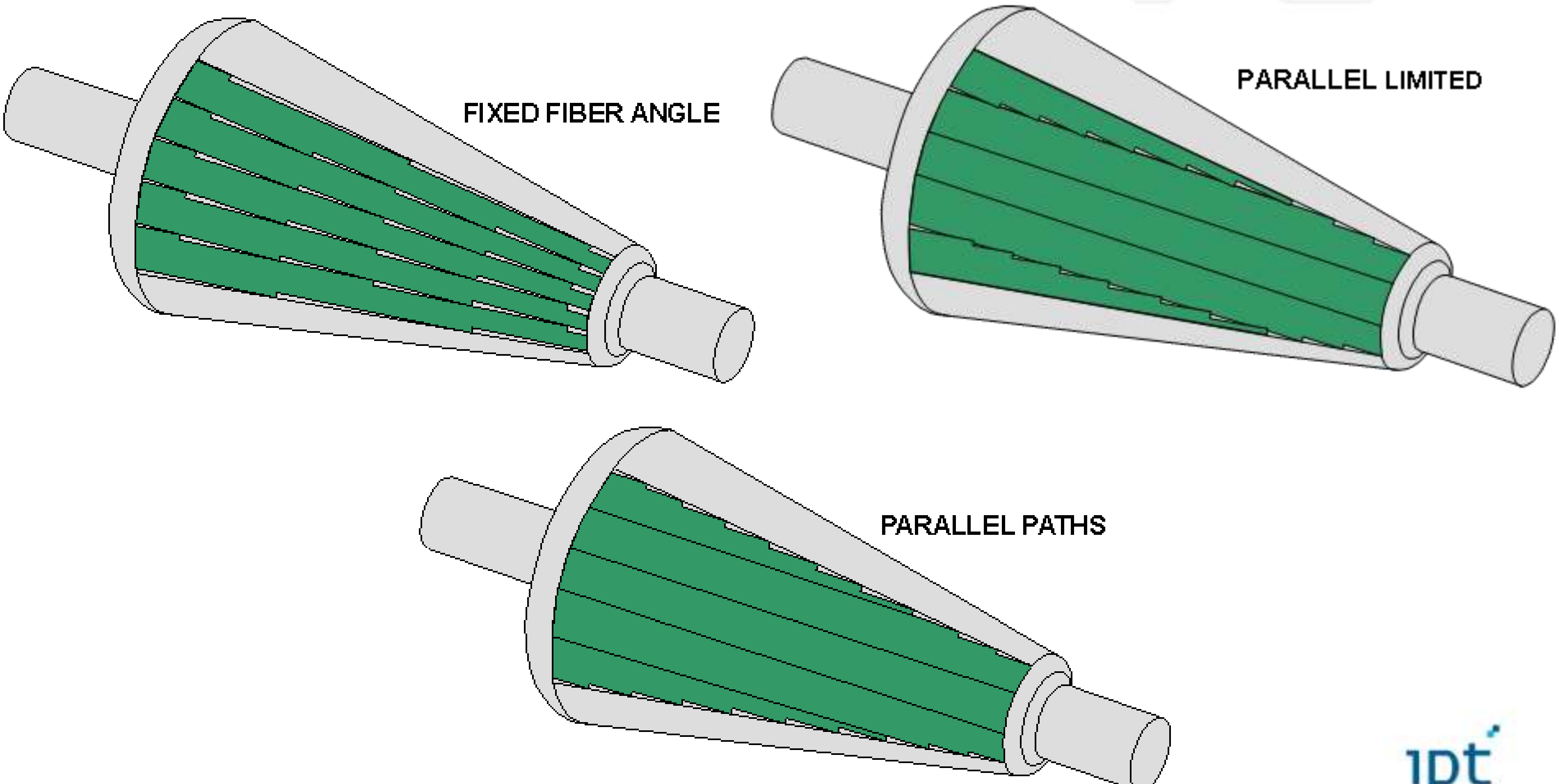
Coverage Algorithms

Manufacturing Parameters



The Automated Fiber Placement Process

- Coverage algorithms assessment:



Source: MAG IAS, LLC (2011), *Advanced Composite Environment V2.0 – Help Documentation*

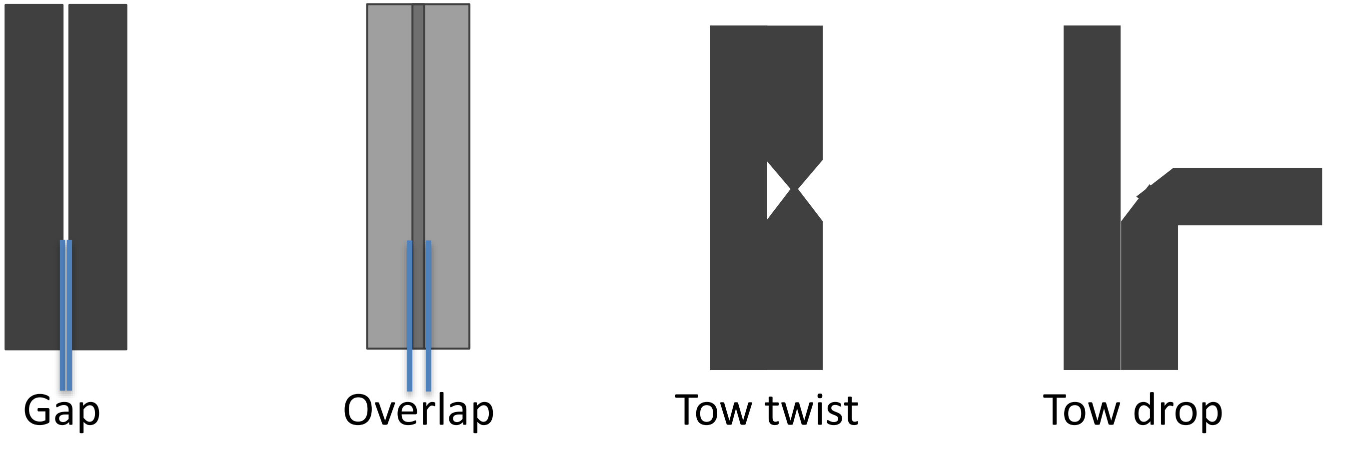
The Automated Fiber Placement Process

Main operational parameters:

- Feedrate;
- Tow temperature;
- Tow tension;
- Compaction pressure;
- and others.

Main induced defects:

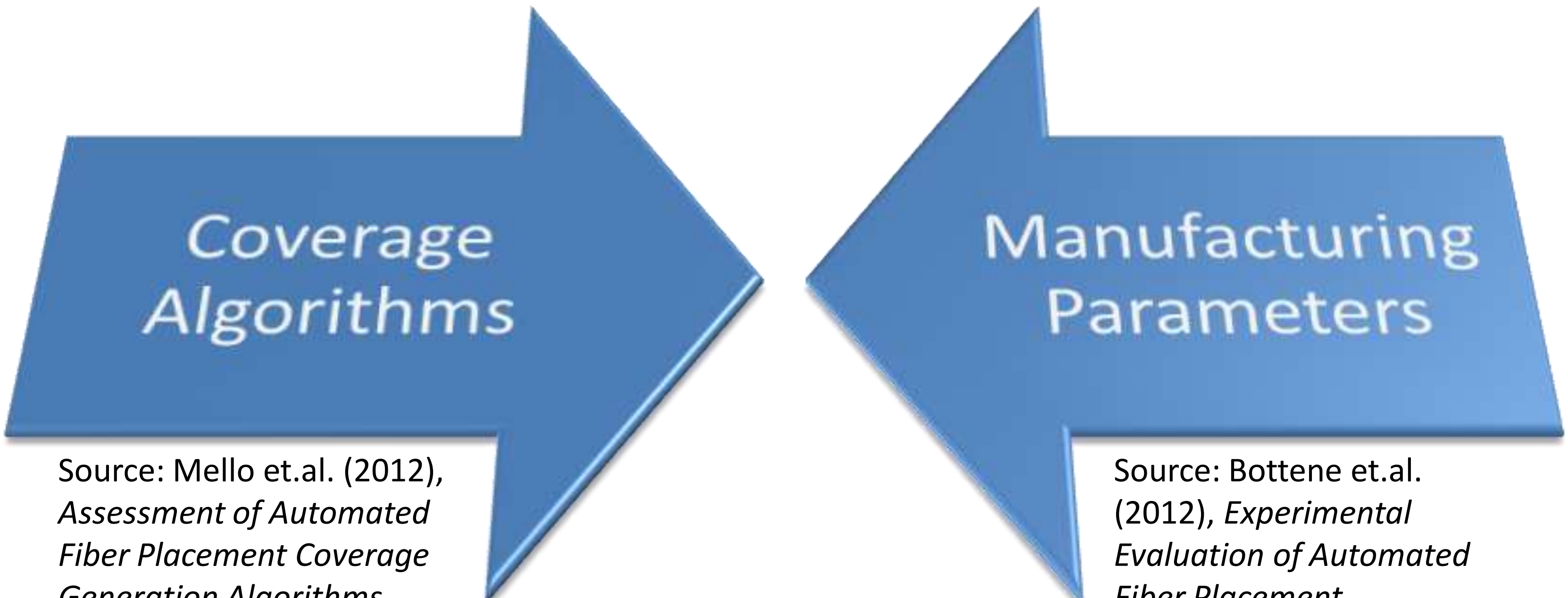
- Gaps;
- Overlaps;
- Tows twist;
- Tows drop;
- and others.



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

Objective

Evaluate coverage methodologies and manufacturing parameters…

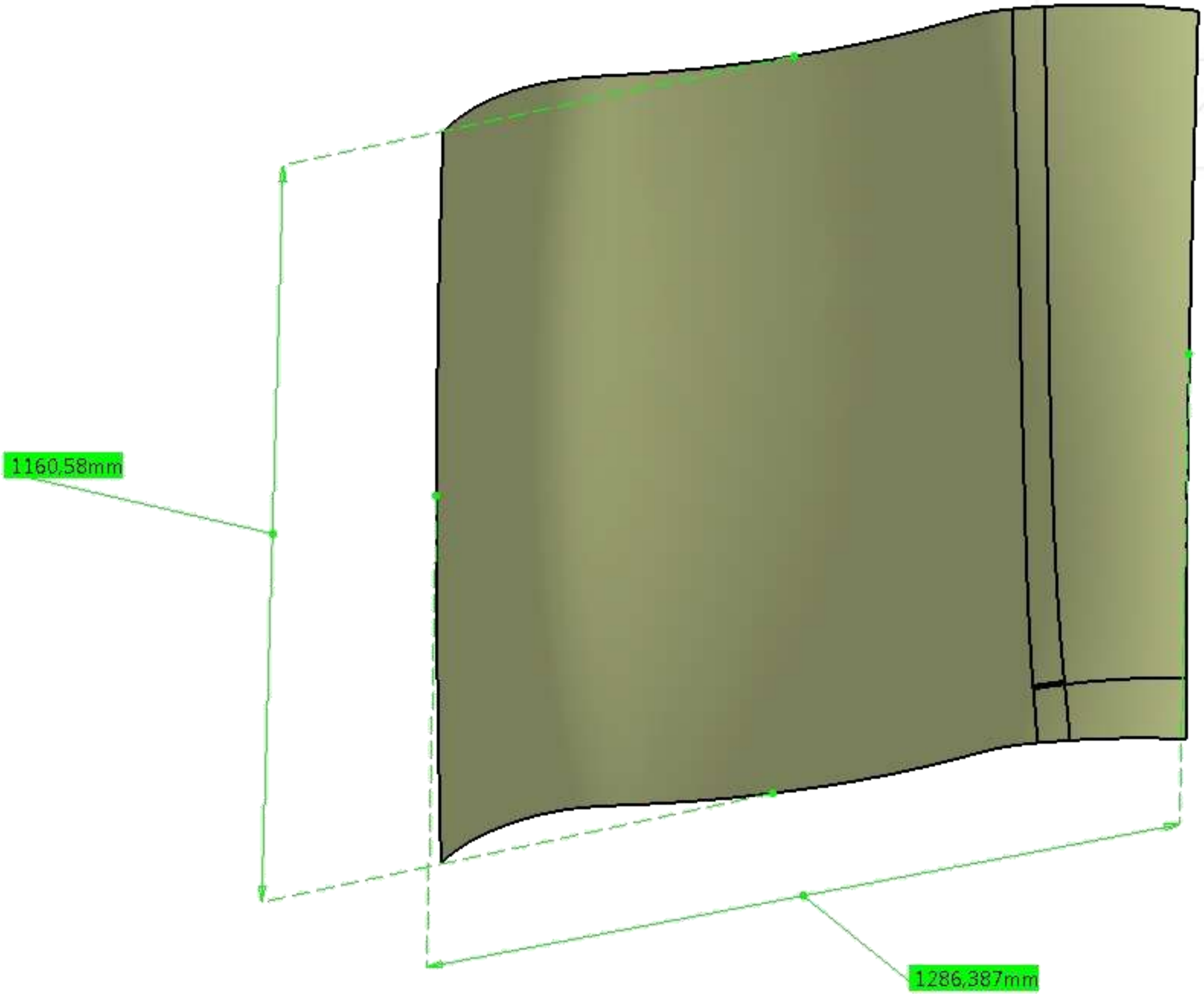


Source: Mello et.al. (2012), *Assessment of Automated Fiber Placement Coverage Generation Algorithms*

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

…for the production of a complex shape composite structure

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:

Parameter	Value	Unit
Feedrate	1270	mm/min
Tow temperature	90	°C
Tow Tension	2,22	N
Compaction pressure	1447,9	kPa

  - Maximum:
    - Gap: 1,5mm; Overlap: 1,58mm; FAD: 2°

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Methodology

- Group 2:
  - Objective: evaluate and stabilize the theory *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° .

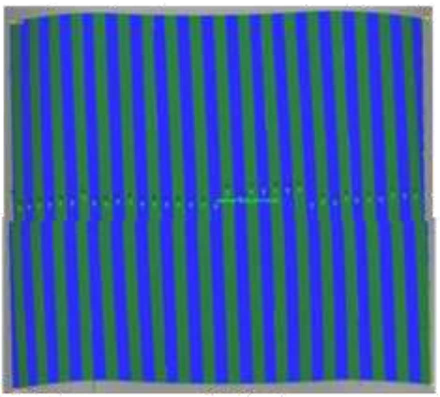
Materials

- 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;

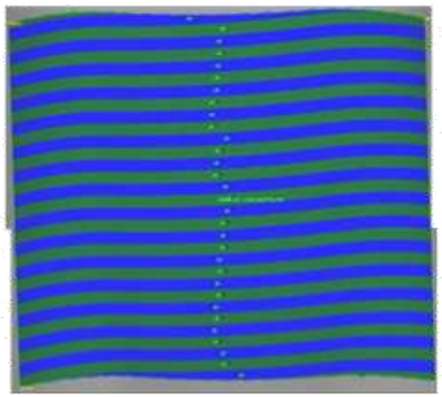
Results

- Group 1

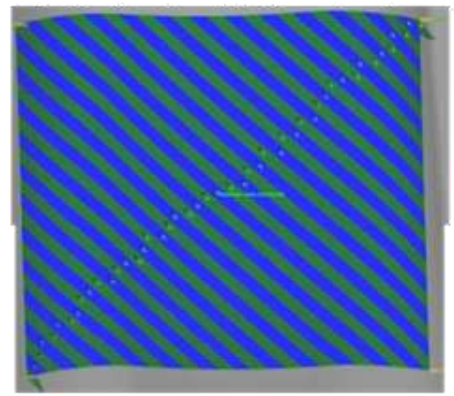
ACE - 0°



ACE - 90°

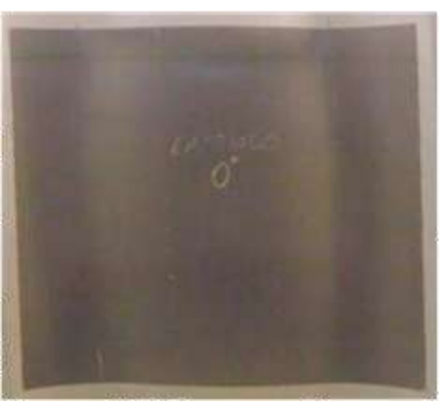


ACE - 45°



ACE - -45°

Laminate - 0°



Laminate - 90°

Laminate - 45°

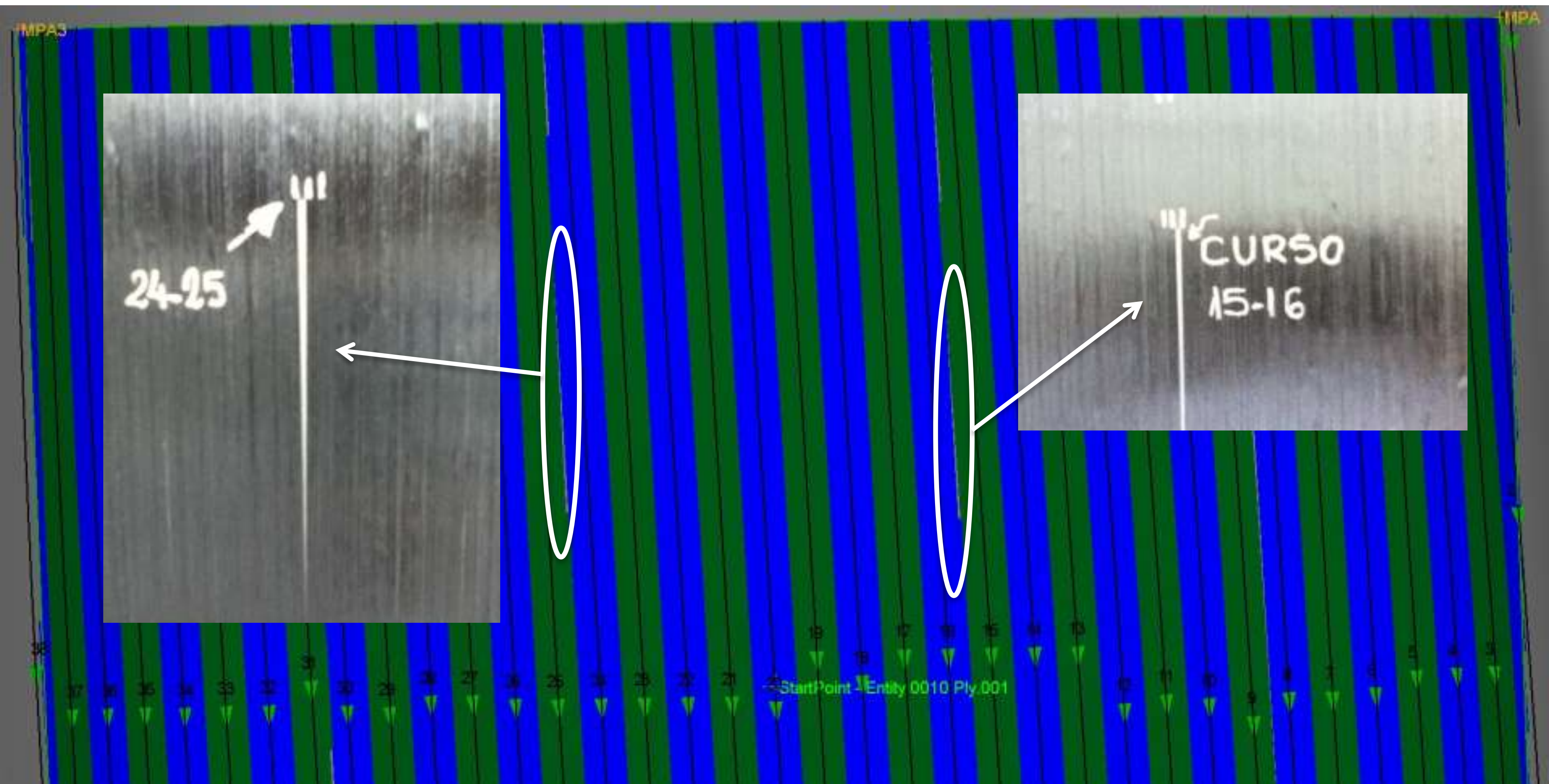
Laminate - -45°

Results

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

Results

- Group 2:

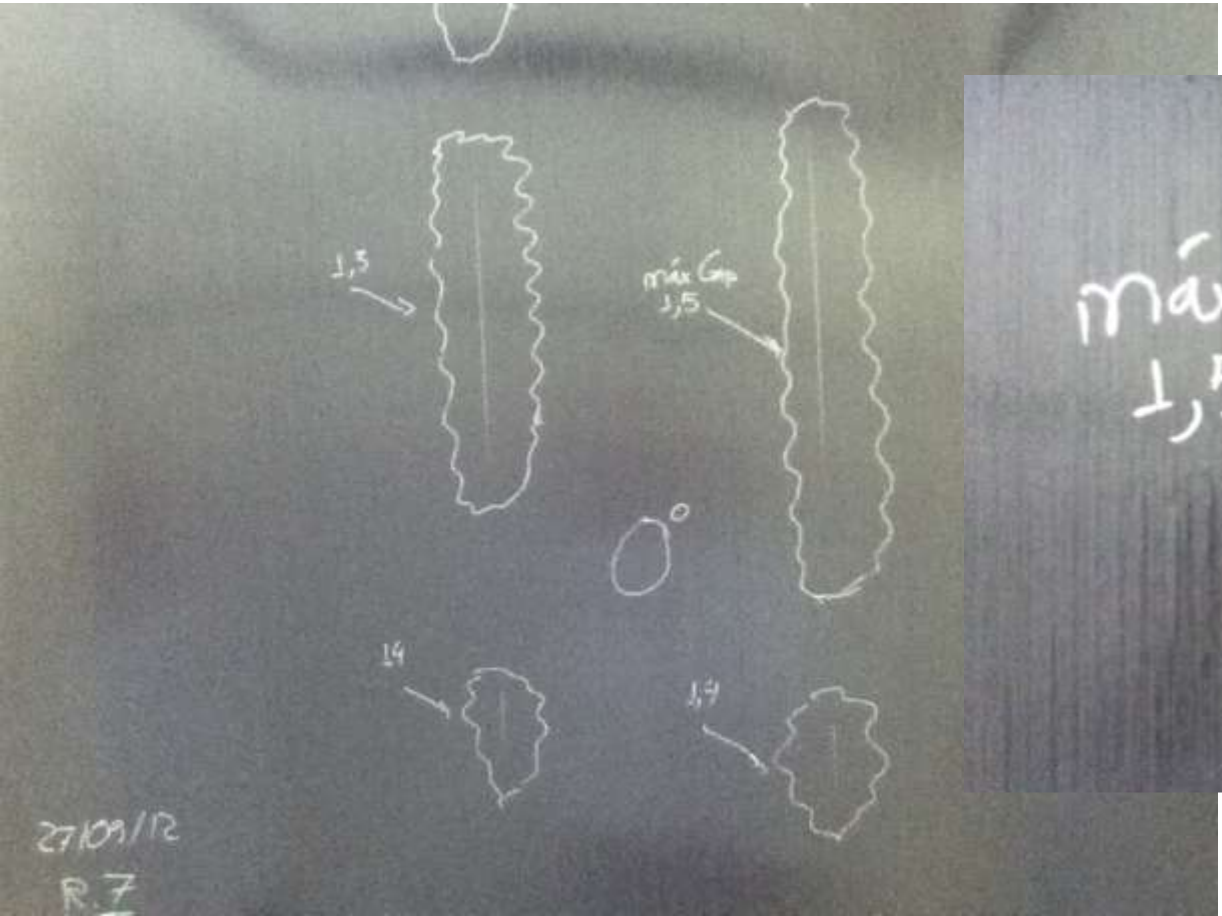


Results

- 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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