An Innovative Vision for Composite Materials:
A Platform Connecting Analysis, Design and Manufacturing

Massimiliano Moruzzi
Product Manager
Autodesk
We may make statements regarding planned or future development efforts for our existing or new products and services. These statements are not intended to be a promise or guarantee of future delivery of products, services or features but merely reflect our current plans, which may change. Purchasing decisions should not be made based upon reliance on these statements.

The Company assumes no obligation to update these forward-looking statements to reflect events that occur or circumstances that exist or change after the date on which they were made.
Agenda

- Composite Design State of The Art
- Our Vision: A Connected Platform
- How Manufacturing Data drives Design
Composite Design: State of The Art
Today’s Composite Design Process Flow

- **Engineering Kickoff**
  Inputs: Loft, Initial Surface loads, Materials.....

- **Structural Analysis**

- **Producibility** (hand layup, ATL/AFP, Forming)

- **IML surfaces**

- **Design Rule/Strategies Validation**

- **Substructure design** (frames, ribs, spar…)

- **Release Documentation** – ply books, MBD

It is mainly a Cascade approach
Today’s Automotive Design Journey

It is mainly a Cascade approach resulting.....
Composites: Black Metal?

- How do we exploit the benefits of composites when all Design Software are based on metallic methodology?
- Is Design in Assembly Context the future for composite?

Example Bolted Aluminium Wing Skin

CFRP Wing Skin (Prior to bolting)
Composites: Black Metal?

- Is Today’s Automotive Design flow adequate for composite materials?
- How Design/Simulation Software can help to improve composite design and manufacturing processes?

Example Bolted Aluminium monocoque

Composite Automotive monocoque
The best fiber direction is not always a straight line!!!
A Cartesian Design Rosette does not allow to unlock Composite Material benefits!!!
Manufacturing is Ahead of Design!!!
Our Vision:
A Connected Platform
Autodesk: Composite Vision

- Innovative Platform based on Holistic Approach for and End-to-End Solution
- Concurrent Engineering Platform
- Enables Design For Manufacturing
- Generative Composite Design…not black aluminum
Benefits of collaborating with Autodesk:

...more than a link between Design and Analysis

- Highly Skilled Team of Engineers in Composite Applications
- Highly Reliable Modeling tools to guide and monitor all phases
- Strong Collaboration with Material Suppliers and Material labs
- Provide Pilot project to validate Process Flow
Universal Platform

Global Product Data Interoperability Summit | 2015

AUTODESK

CATIA

PTC

Altair

ANSYS

Bentley

MSC Software

SOLIDWORKS

SIMULIA

SIEMENS
Flexible, unified, geom-based pre/post for Nastran, CFD, +

CAD connected and cloud-enabled for solving and collaboration

Built for optimization and goal driven design
Portfolio of Solutions

Global Product Data Interoperability Summit | 2015

Autodesk® Composite Suite: From Design…to…Manufacturing
How Manufacturing Drives Design
Autodesk: Deep Investment in Manufacturing Technologies

- **truPLAN**: Advanced “Design For Manufacturing” application for composite structures.
- **truNEST**: Nesting Solution for Automated Preforming line.
- **truFIBER**: Programming Suite for Tailored Fiber Placement.
- **FORMING**: Design and Predictive Analysis for dry textiles or prepregs forming processes.
TruPLAN: Generative Composite Design

Material Manufacturability Qualification Tests
- Bi-axial & Unidirectional Tape or Tow
- Dry or Prepreg

Material Manufacturing Parameters
- Thickness
- Fiber Orientation
- Resin Content
- Wrinkle
- Buckling
- Steering
- Warping
- Compaction

MMP database
Material Manufacturing Parameters

Optimum Layup Strategy
For both Material and Layup Machine

TruPLAN
Advanced Material Kinematics Kernel

Convex

Full manufacturability checking
Ensuring parts free

Reliable Material data
TRUPLAN: MATERIAL MODELING

Bridging

Wrinkle

GAP/LAP

Layup Defects

Modeling Defects

Element Shearing

Element Spreading
Tow Steering Trials

- Tow steering using different:
  - Tow widths (1/4” vs 1/8”)
  - Resin systems (different level of tackiness)
  - Substrate (bare tool surface or woven ply)
- Steering radii varied until minimal defects were obtained
- Results used to define “Warn” and “Limit” steering values

Gaps

Minimal or no tow defects
TRUPLAN: MATERIAL ANALYSIS KERNEL

Fiber Path

Material Compaction Analysis

Surface Update

Material Orientation Analysis
Capturing Material & Manufacturing Constraints

Global Product Data Interoperability Summit | 2015

Large Scale Additive Continuous Fiber

Test Lab

Composite Materials Tested

<table>
<thead>
<tr>
<th>Material (Thermoset matrix/carbon fibre)</th>
<th>Tow/tape width (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTM44-1/IM7</td>
<td>1/4</td>
</tr>
<tr>
<td>MTM44-1/HTS</td>
<td>1/4</td>
</tr>
<tr>
<td>977-3/IM7</td>
<td>1/4</td>
</tr>
<tr>
<td>MTM44-1/HTS</td>
<td>1/8</td>
</tr>
</tbody>
</table>

Mfg. Process Parameters

<table>
<thead>
<tr>
<th>Variable</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFP Head(s)</td>
<td>¾&quot; and 1/8&quot; where indicated</td>
</tr>
<tr>
<td>Tool</td>
<td>Release Aluminium flat plate tool</td>
</tr>
<tr>
<td>Speed, $V_6$ (mm/s)</td>
<td>300</td>
</tr>
<tr>
<td>Roller Compaction Force, $F_R$ (lbs)</td>
<td>80</td>
</tr>
<tr>
<td>Nitrogen Gas Temperature, $T_{N2}$ ($^\circ$C)</td>
<td>150</td>
</tr>
<tr>
<td>Nitrogen Gas Flow Rate, $\dot{V}_{N2}$ (fpm)</td>
<td>100</td>
</tr>
<tr>
<td>Tool Temperature, $T$_T ($^\circ$C)</td>
<td>Room temperature (20$^\circ$C)</td>
</tr>
</tbody>
</table>
Composite Materials Layup Tests

Test Layup Mould

Carbon Fiber – Carbon Fiber

Curvilinear Fiber Path

Heated aluminium tool

Bare tool surface or woven ply

8 tows of 51mm wide

Carbon Fiber – Metal Interface

Multiple of tow fold-over

Tow fold-over

Defect-free

Steered tows

Compressible wrinkles

Woven ply surface

Radius decreases

Zoom in of 1,250mm

1,250mm

1,350mm

1,500mm

2,000mm
Mapping Topology-Material-Manufacturing Correlation Function

Material & Manufacturing Knowledge can be Mapped to Voxels describing a discrete Design Volume
TRUPLAN: EXPERIMENTAL VALIDATION
WING SPAR CASE STUDY
Steering Results for +45° Ply, Bands 10-12
a) Fiber placed part exhibiting considerable steering defects (Courses 10-12)
b) Simulated part in TruPLAN steering analysis exhibiting considerable steering defects in the same region (courses 10-12)
TruPLAN Steering Results
a) Fiber placed part with relevant courses/bands (16-17) in the case of -45° ply
b) Simulation from TruFIBER for layup (courses 16-17)
c) Simulation from TruPLAN for steering (white line represents center line for course 16).
Capturing Structural Constraints

- Analyze “As Built”
- From Black Metal to Optimal use of Composite!!!
Total Manufacturing Process Tracking

- Expiration dates for all plies
- In/Out time for all plies
- Remaining shelf life for plies
- Which Roll Each Ply Came From

Freezer

Autoclave

Cutting

Layup
What is Coming

Hand-Layup

Advanced Forming

Additive Simulation

Automated Workcell
Advanced Materials at Autodesk

Design

Simulate

Make

Materials Database
Contact Info

• Massimiliano Moruzzi
  Massimiliano.Moruzzi@Autodesk.com