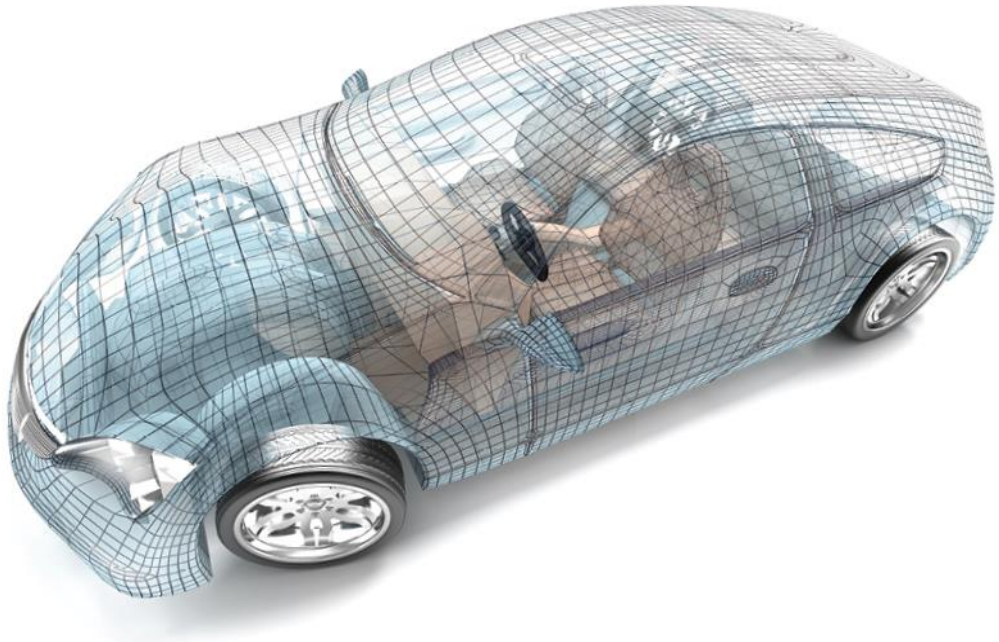
TCC 2020
THERMOPLASTIC COMPOSITES CONFERENCE

A VIRTUAL EVENT
APRIL 29 – MAY 1, 2020



# Advances in Understanding the Properties of Thermoplastic Composites

**Presented By: Daniel Leeser**
**Technology Manager, Thermoplastics**
**Toray Advanced Composites**

**Toray International**

- Manufacture of Carbon Fibers
- Leader in Composite Materials

**Toray Advanced Composites (TAC)**

- Thermoset prepregs and ancillary materials
- Thermoplastic prepregs and ancillary materials
- Compression Molded Parts

'TORAY'
Toray Advanced Composites

**Thermoplastic Composites**

- Uni-directional tapes
  - PEEK
  - PEKK
  - LMPAEK
  - PPS
  - PEI
  - Nylon
  - Polypropylene
  - Polyethylene
  - PET
- Fabric based prepregs
  - PEEK
  - PEKK
  - LMPAEK
  - PPS
  - PEI
  - Polycarbonate

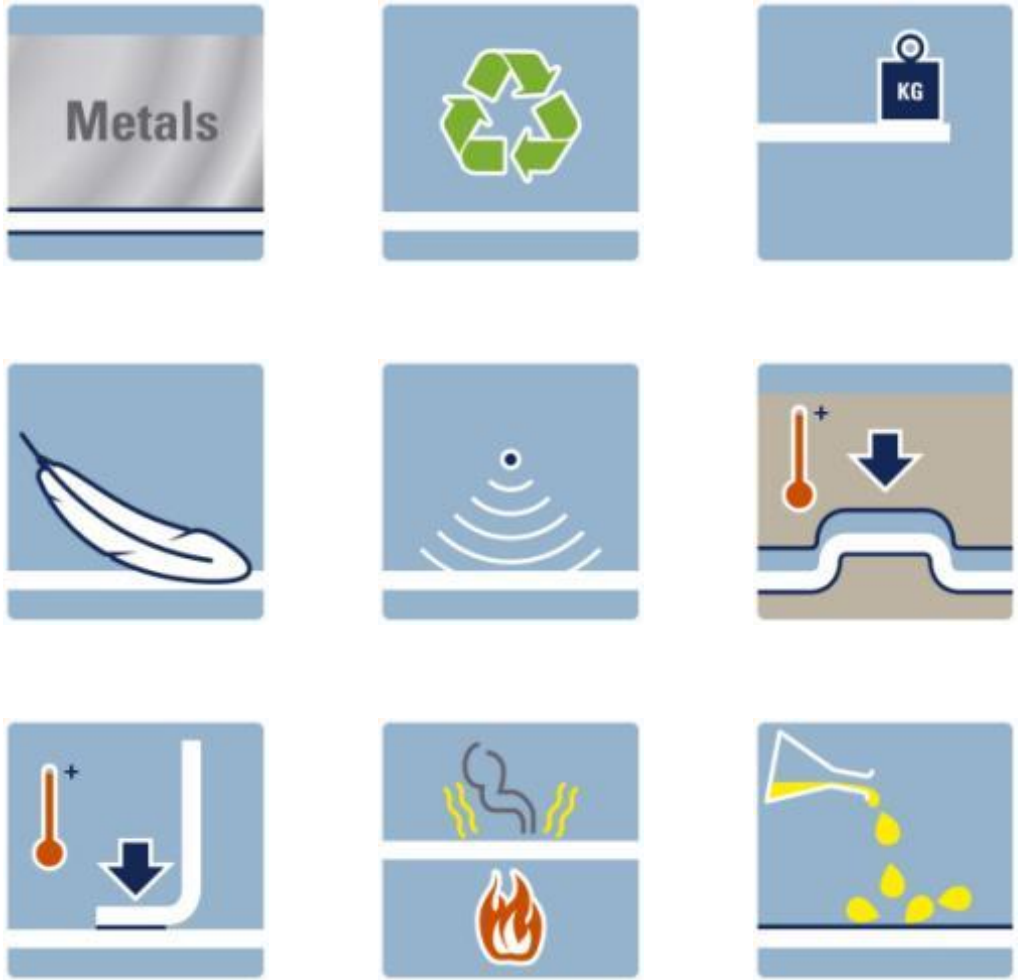
# Advantages of Thermoplastics

**Properties**

- High Fracture Toughness & CAI
- Excellent Mechanical Properties
- Recyclability
- Low Flame, Smoke & Toxicity
- Room Temp Storage
- Reformable

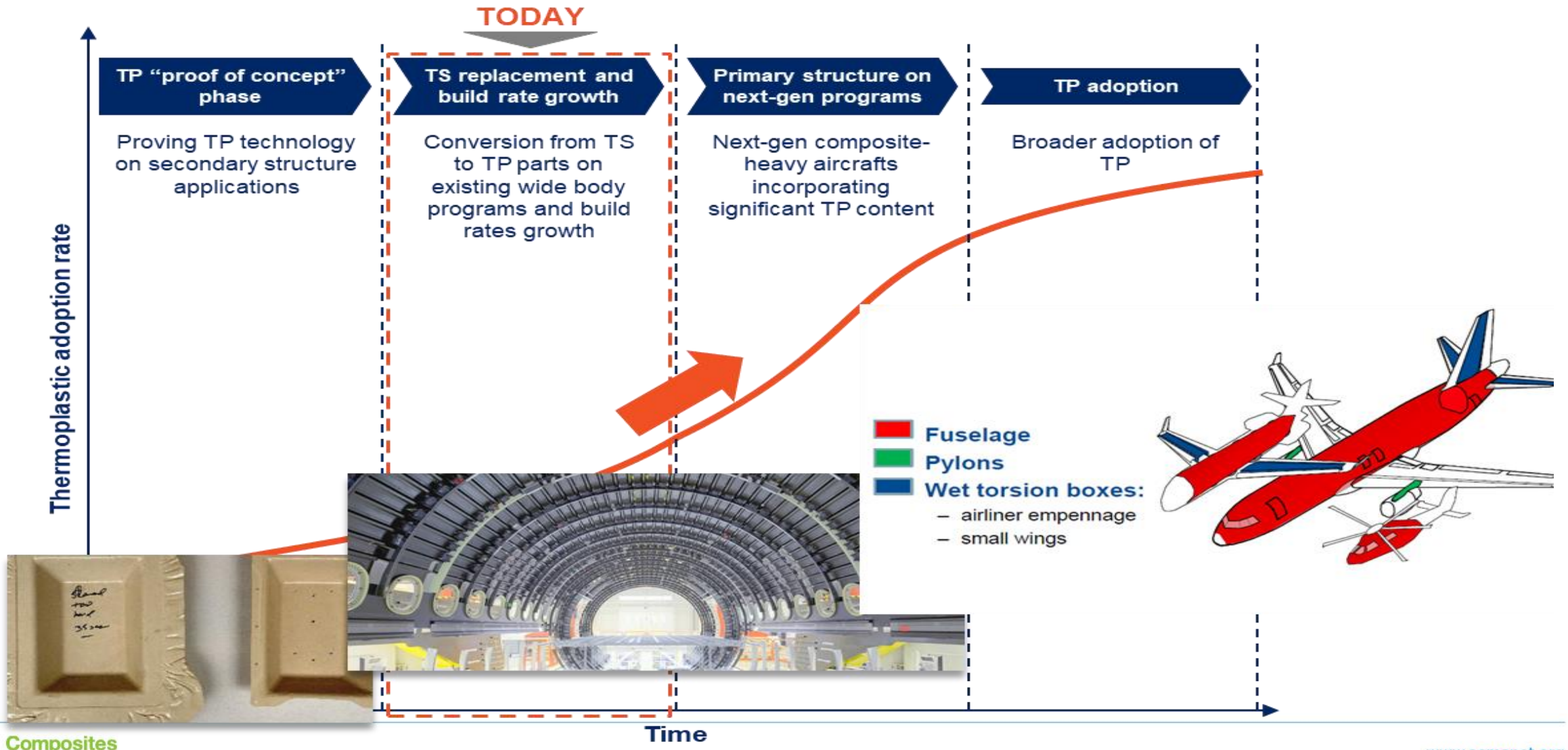
**Low Cost Manufacturing**

- Able to make parts quickly
  - Thermoforming
  - Press
  - CCM
  - Advanced Fiber Placement (AFP)
- Able to join parts quickly
  - Welding
  - Unitized Structures



# Towards cost effective and weight optimized structures

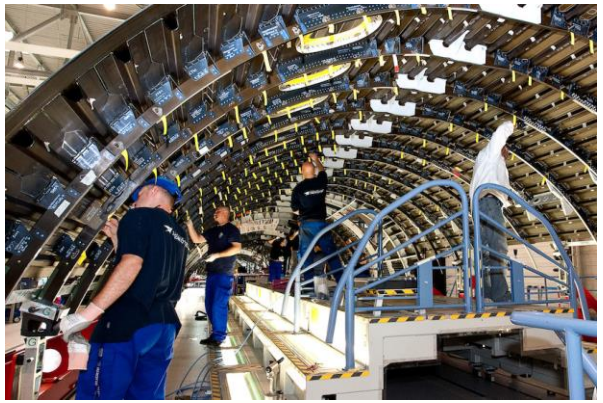
## Use of TP composites in commercial aviation is poised to accelerate



# Applications for Thermoplastic Materials

**Current**

- Clips and Brackets
- Galleys
- Leading Edges
- Vertical Stabilizers
- Window Frames
- Stow Bin Latch Covers
- Aircraft Seats
- Riblets
- Wing Tips
- Environmental Control System Components

**Future**

- Fuselage
- Wing Skins
- Floor Beams
- Radomes

# What Processes are Currently Used to Make Aerospace Parts

**Primary Processes**

- Automated Fiber Placement (AFP)
- Advanced Tape Laying (ATL)
- Continuous Compression Molding
- Presses
- Autoclaves
- Vacuum Forming
- Thermoforming/Stamp Forming
- Vacuum Bag Only (VBO)

**Secondary Processes**

- Injection Overmolding
- Bonding
- Welding
- Painting

## Automated Fiber Placement

Courtesy of Coriolis Composites

## Continuous Compression Molding

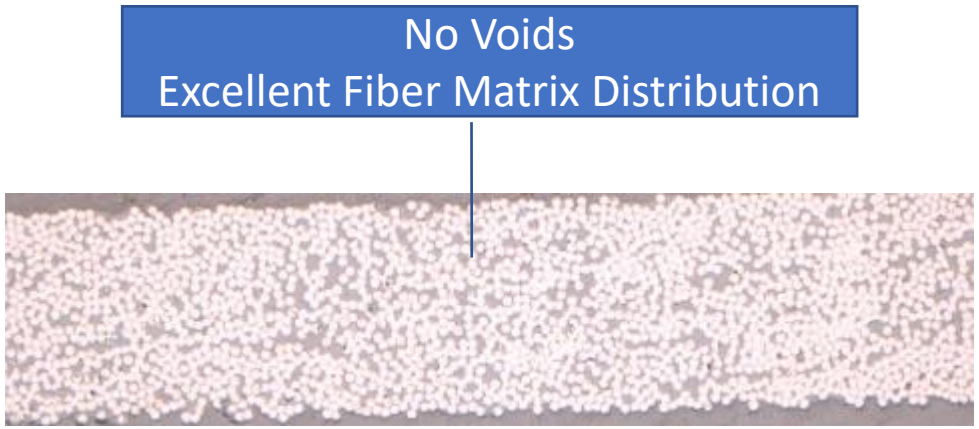
Courtesy of ATC Manufacturing

## Thermoforming


Courtesy of TPRC

# What Material Properties are Important

- **Polymer Choice**
  - Processing Temperatures
  - Mechanical Properties
  - Solvent Resistance
    - Crystallization Kinetics
  - Polymer Viscosity
    - Trade off between Toughness and Flow
      - TC1225 (LMPAEK) Shows Lower Melt Viscosity with Excellent Toughness
- **Prepreg Quality**
  - Good Fiber/Matrix Distribution
  - Consistent Thickness across Width
  - Low voids




**Photomicrograph of Toray TC1225 T700 Prepreg**

## What is Automated Fiber Placement (AFP)

- An automated process to place prepreg on to a tool in the desired fiber orientation and lay-up
- AFP for Thermoplastics
  - In-Situ Consolidation
    - Part comes off the tool fully consolidated
  - Partial Consolidation
    - A secondary consolidation process is required to remove voids from the part
      - Complex parts
      - Parts with ply drops
  - Heating Sources
    - Hot gas
    - Laser
    - UV/IR Light Sources

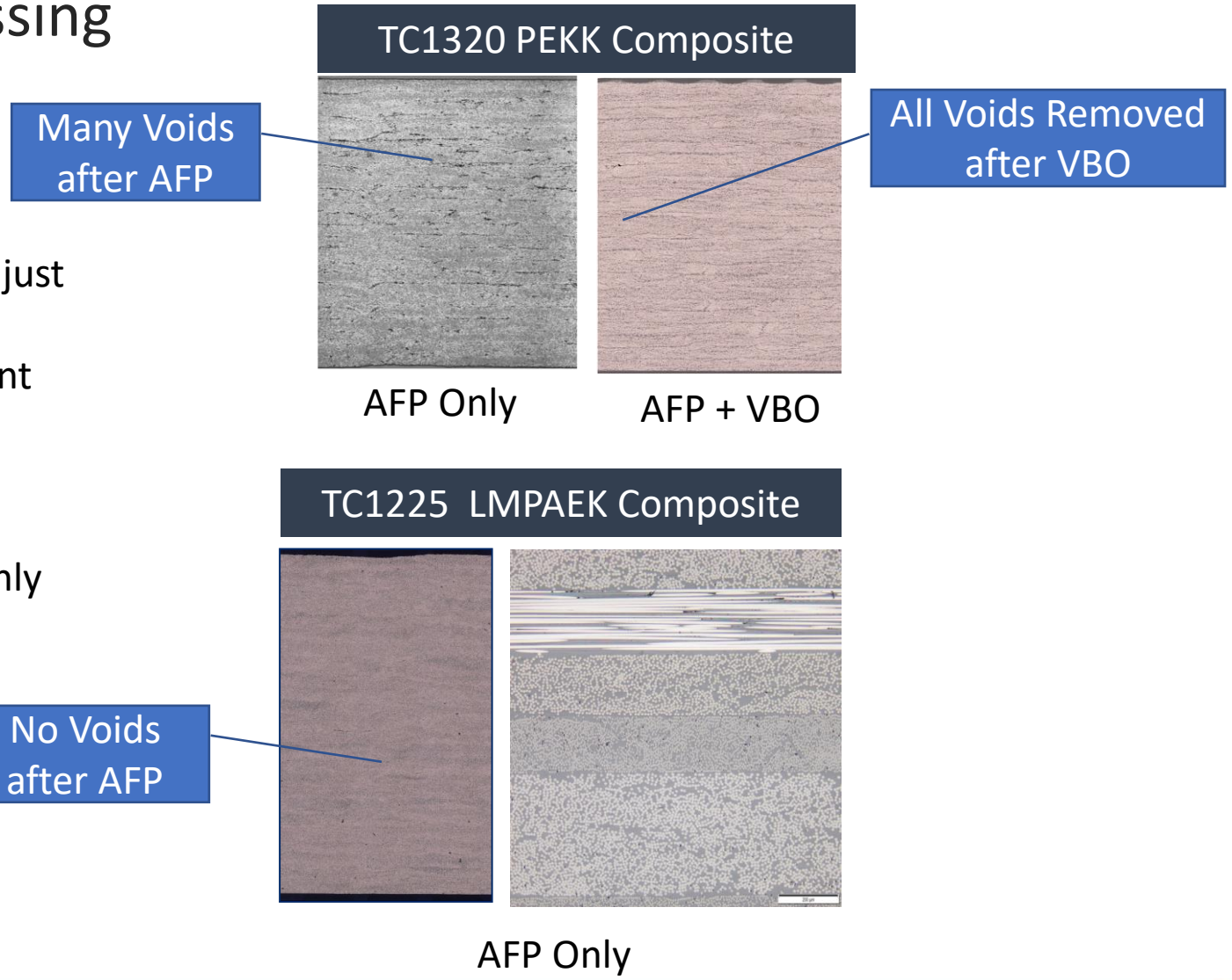

**Video Courtesy of NLR**
Recorded in 2016 for Tapas 2 Pylon Project

# How Polymer Choice affects Processing

**AFP**

- TC1320 (PEKK)
  - Difficult to make laminates without voids just using AFP process
  - After Vacuum Bag consolidation – Excellent looking laminate

- TC1225 (LMPAEK)
  - Good Panel can be Produced using AFP only
  - Main Reason
    - TC1225 which has a lower polymer viscosity



## Material: Toray TC1225 (LMPAEK) T700GC

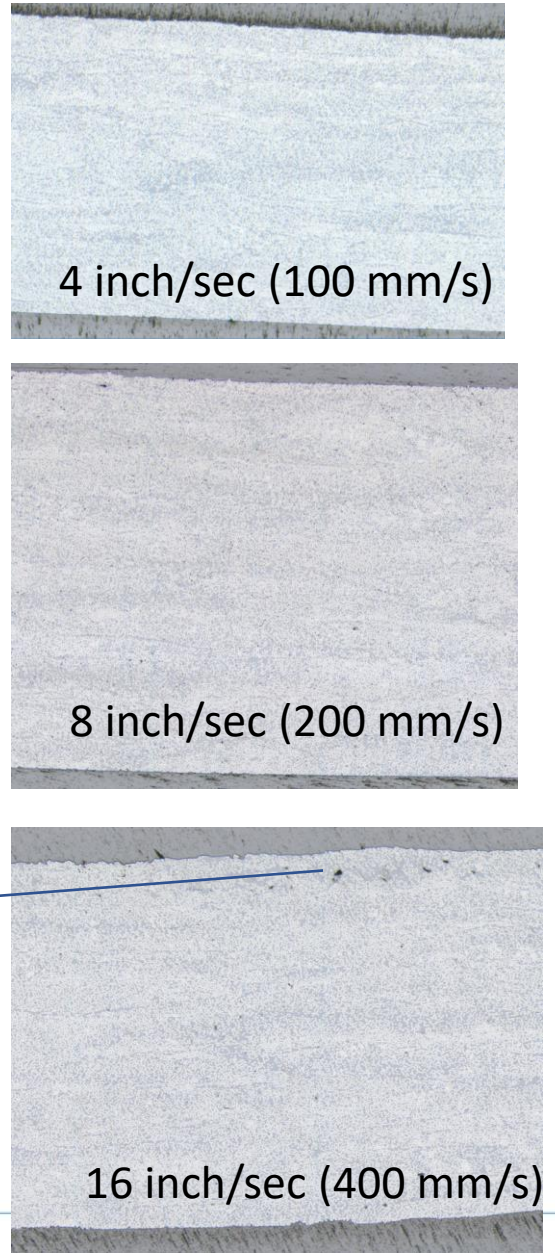
### Evaluation of Tape Placement at Different Speeds

- Investigated three laydown speeds
  - 4 inch/sec (100 mm/s)
  - 8 inch/sec (200 mm/s)
  - 16 inch/sec (400 mm/s)
- Good consolidation quality up to 400 mm/s
  - Robot speed and laser power limited going faster
  - Some porosity development at 400 mm/s in last ply

### Investegated Effect of Tool Temperature

(16 inch/sec – 400 mm/s laydown rate)

- Room Temperature Tool
  - Crystallinity - Low
  - Consolidation - Excellent
- 210°F (100°C) Tool Temperature
  - Crystallinity - Increased
  - Consolidation - Excellent
- 390°F (200°C) Tool Temperature
  - Crystallinity - Full
  - Voids Due to Deconsolidation
- Room Temperature Tool + Annealing
  - Full Crystallinity
  - Excellent Consolidation



**Material: Toray TC1225 (LMPAEK) T700GC**

**Investigated Effect on Last Ply**
(16 inch/sec (400 mm/s)

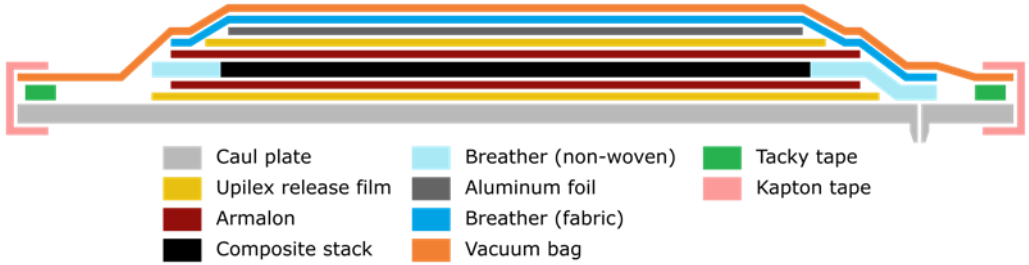
- Voids formed on Outer Ply
- Second pass of Roller Over Last Ply
  - Eliminated Porosity
- Conclusion
  - Roller Consolidates Multiple Plies

Panel Outer Ply – One Pass of Roller

Panel Outer Ply – After Second Pass of Roller

## What is Vacuum Bag Only Process (VBO)?

- VBO is an Out of Autoclave (OOA) solution
- Uses Vacuum Pressure and Heat to Consolidate Laminate
- Advantages
  - No autoclave or other high cost capital equipment required
    - Typically just an oven
  - One sided tool
  - Size limited to Oven or Heating System Available
- Disadvantages
  - Relatively long consolidation cycles
  - Cost of consumables



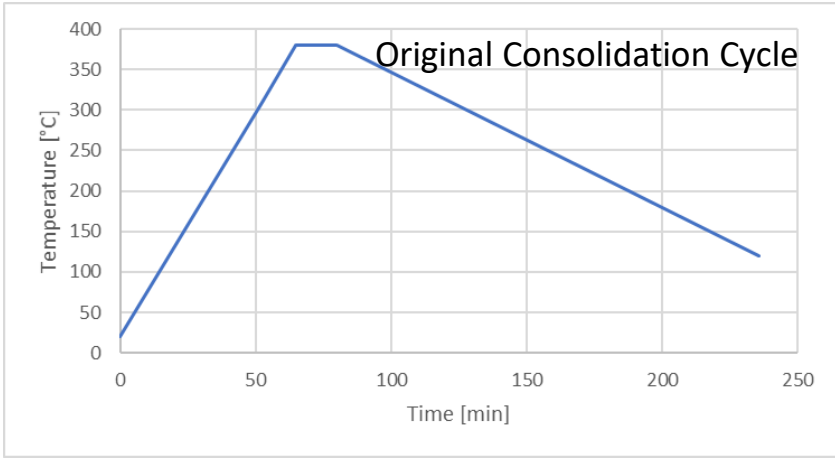

Typical Bagging Sequence for VBO

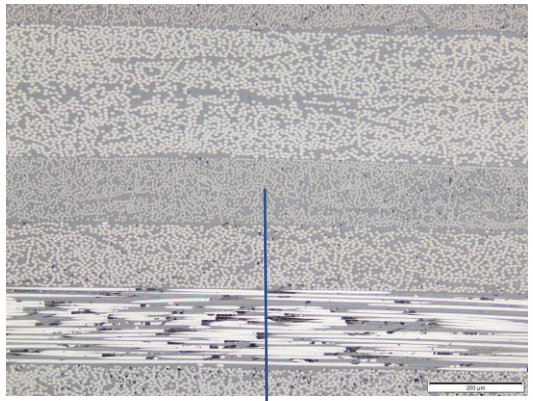
Courtesy of Wisconsin Ovens

**Material: Toray TC1225 (LMPAEK) T700GC**

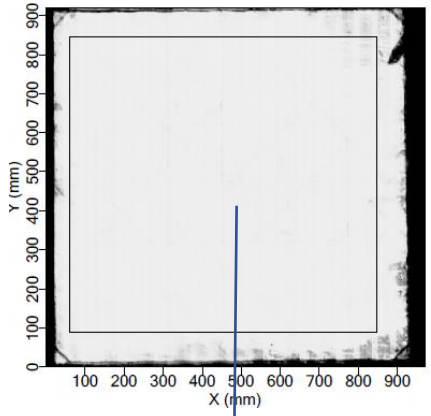
**Vacuum Bag Only (VBO) after Tape Placement**

- In some instances in-situ consolidation of part is not practicle
  - Complex shapes
  - Ply Drops
- VBO/Oven consolidation is a Good Option
  - Relieves stresses
  - Improves crystalline content
  - Mechanical performance on par with autoclave consolidation and press consolidation



No Voids



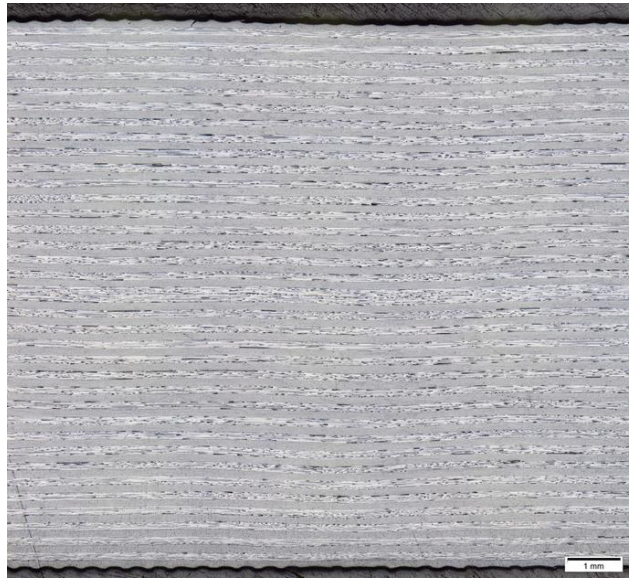

Great C-Scan

# How Polymer Choice affects Processing

**VBO Investigations**

- Study Performed on TC1225 (LMPAEK)
- Goal
  - Thick Laminates
    - Successful at 72 plies 3/8 inch (10 mm)
      - 12 inch by 12 inch (300 mm x 300 mm)
  - Short Consolidation Cycle
    - Low Maximum Temperature - 625°F (330°C)
    - 9°F/min (5°C/min) Heating Rate
    - 5°F/min (3°C/min) Cooling Rate
    - No Dwell
    - 3 Hours Total Time
  - Reduced Consumables

- Result
  - Excellent Laminate



**Photomicrograph Showing No Voids in Laminate**

(Dark areas are 90° Fibers – Not voids)

# Conclusion

**Adoption of Thermoplastic Composites**

- Wide Spread Across Aerospace Platforms
- Will increase in the Future
  - Increased Processing Options
  - Improved Composite Materials
  - Expanding Infrastructure
  - Increased Technologies to Produce parts and Create Assemblies

Dan Leeser
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