Application and Case Studies of four potential Wind Blade Manufacturing Process Improvements

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Topics of Presentation

- A Quick Refresher on Project 4.6/Phase 1
- Project 4.8/Phase 2 Objectives & Demo Project Selection
- The Four Case Studies
- Process Trials

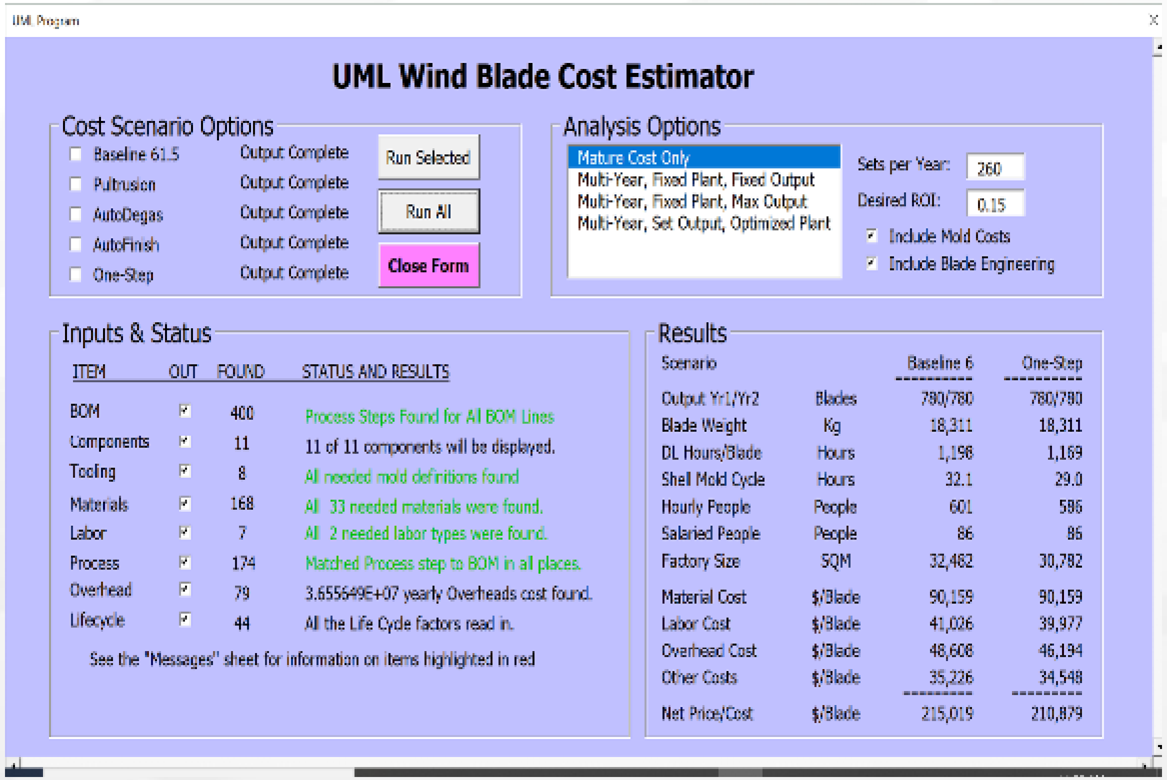
IACMI 4.6/Phase 1

Two Key Deliverables

1. A comprehensive techno-economic model on wind blade manufacturing.
2. A DELMIA full factory visual discrete event simulation

Techno-Economic Model as Delivered

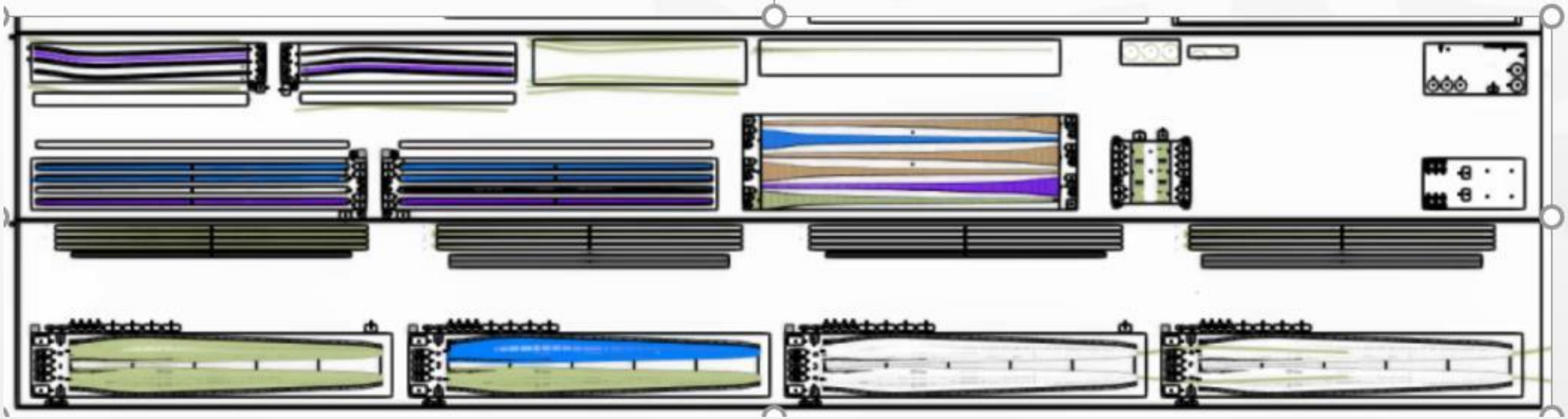
- Easy Excel input/output
- Visual Basic to handle complexity
- Design linked to manufacturing
- Multiple scenario capability
- Parametric process models.
- Detailed overhead costs
- Multi-year operation
- Full product lifecycle impacts
- Balance sheet & Cash flows



Dassault DELMIA Integration

Discrete Event Simulation with Visualization

- Identifies bottleneck and opportunities
- Add statistical variability to the modeling



IACMI Project 4.8 Objectives

Use the tools developed in Project 4.6/Phase 1 to

- Analyze potential process improvements for blade making
- Select a project for an actual process trial
- Generate additional process detail and engineering
- Run process trials
- Compare results for trials against model predictions.

Project Down Selection

IDEA LIST
Automated Resource Tracking & Analytics
Elimination of Shear Web Fixtures
Pultrusion replacements
Material Kitting & Scheduling
Automated Resin Degas and Delivery
Laser Projection
Reconfigurable Shear Web Fixture
Replace Epoxy with PU or PE
Automated Blade Finishing (Edge Trimming & s
Large scale preforming with vacuum & heat
Bond Shells outside of molds
Automated large-scale adhesive for close
Pixelated mold heating and cooling
Automated fabric lay down
Automated gel coating

			Idea Scoring			
		Weight	Auto Finish	Auto Degas	Pultruded	One Step
1	Time Scale	8	5	7	3	7
2	Blade Cost Impact	8	6	3	5	5
3	Model Validatation	8	8	5	5	8
4	Team Participation	8	7	2	4	9
5	Budget	5	3	8	6	5
6	Easy or Hard to Do	8	5	8	4	4
			Weighted Scoring			
			Auto Finish	Auto Degas	Pultruded	One Step
1	Time Scale		40	56	24	56
2	Blade Cost Impact		48	24	40	40
3	Model Validatation		64	40	40	64
4	Team Participation		56	16	32	72
5	Budget		15	40	30	25
6	Easy or Hard to Do		40	64	32	32
	Net Score		263	240	198	289

15 Initial Ideas ➔ 4 Ideas ➔ 1 Idea to Demonstrate

Baseline Blade & Modeling

- NREL 61.5m Blade with carbon spars used in all case studies
- Four shell mold factory making 780 blades per year.
- Standard blade process except:
  - No root prefabrication
  - Prepreg assumption for spars

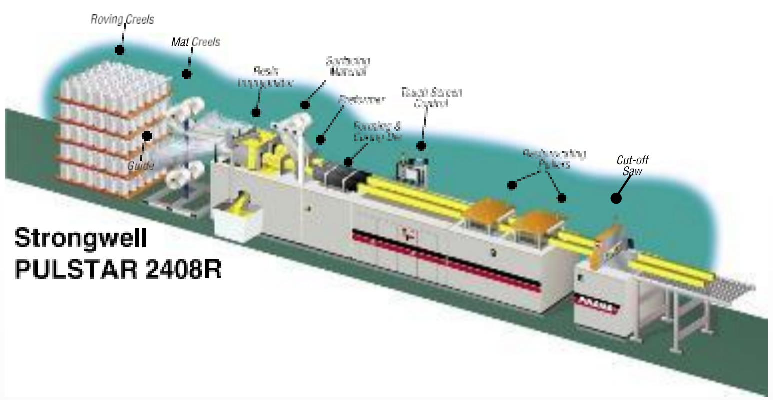
Metrics		
Blade Weight	18,311	Kg
Direct Labor	1,198	Hours
Shell Mold Cycle	32.1	Hours
Factory Space	32,482	Sqm
Costs		
Material	90,159	$
Labor (Direct)	41,026	$
Overheads	48,608	$
Business	35,226	$
Total Cost/Price	215,019	$

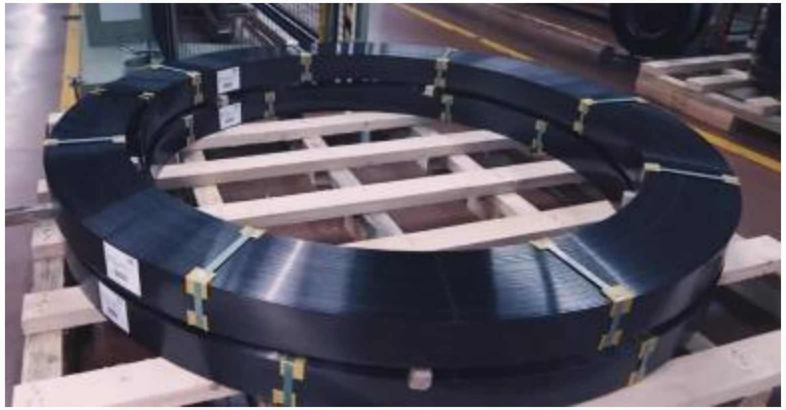
Case 1 – Automated Degas

- Resin needs degassing before infusion in order to minimize porosity
- Old method uses vacuum tanks, is a batch process, and takes time.
- Automated degas delivers instantaneously, and right at the mold, but needs CAPEX

TEM Model Predicted $298 (0.1%) Savings per Blade

Case 2 – Pultrusions for Spar Caps





- Carbon and prepreg more complex to use in spar manufacturing than glass fabric.
- Increasing glass spars thicknesses driving unacceptable exothermic peaks.
- Pultrusions solve problems for both, at expense of pultruding cost.
- Enables elimination of spar molds altogether.

TEM Model Predicts $6,000 (3%) Savings per Blade

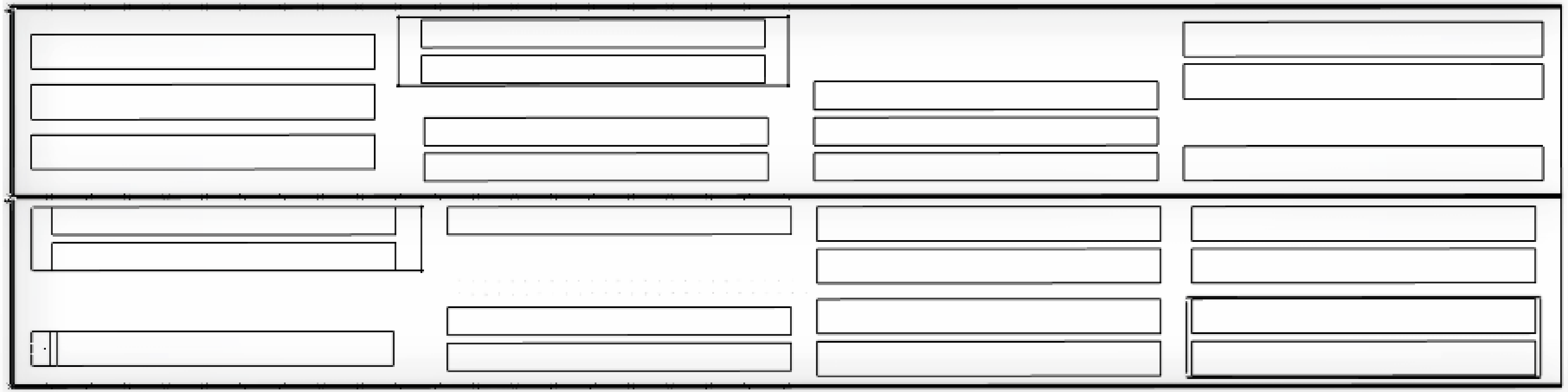
Case 3 - Automated Finishing

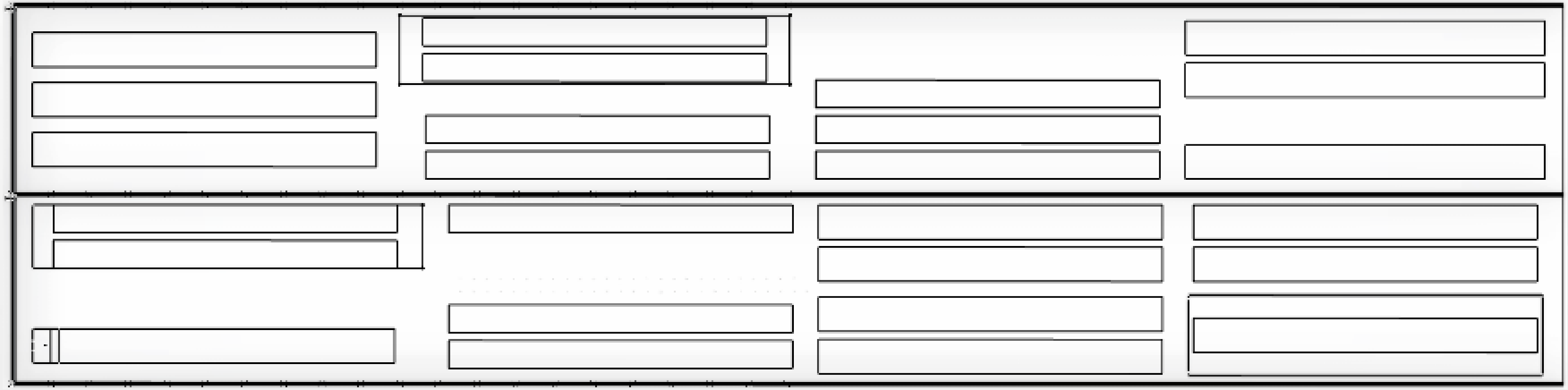
- Manual surface prep for painting takes 90 man-hours (7% of Total)
- Multiple stages: Leading/trailing edge trim and prep, main surface, root drilling
- Dirty, dust generating operations.
- Automation developed and available for these operations.

TEM Model Predicts $3,631 (1.7%) Savings per Blade

Case 3 - Automated Finishing

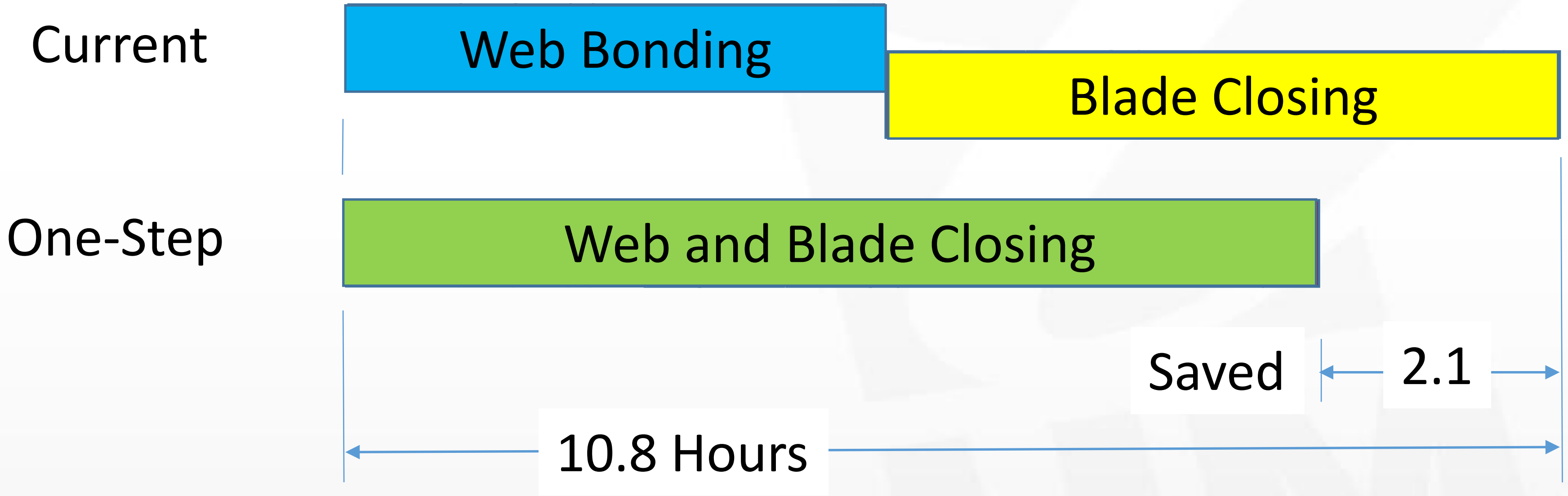
Standard Finishing Bays





Automated Finishing Added

Case 4 – "One-Step" Close



- Immediate Close after setting the shear webs saves >2 hours shell cycle
- Eliminates dispersal and reassembly of work crew while web cure takes place.
- Potentially increases factory output by 10%

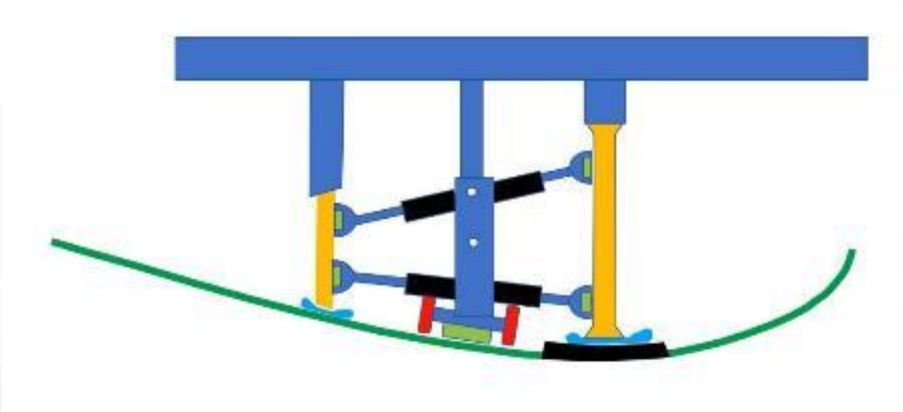
TEM Model Predicts $4,140 (1.9%) Savings per Blade

But, How to make “One-Step” work?

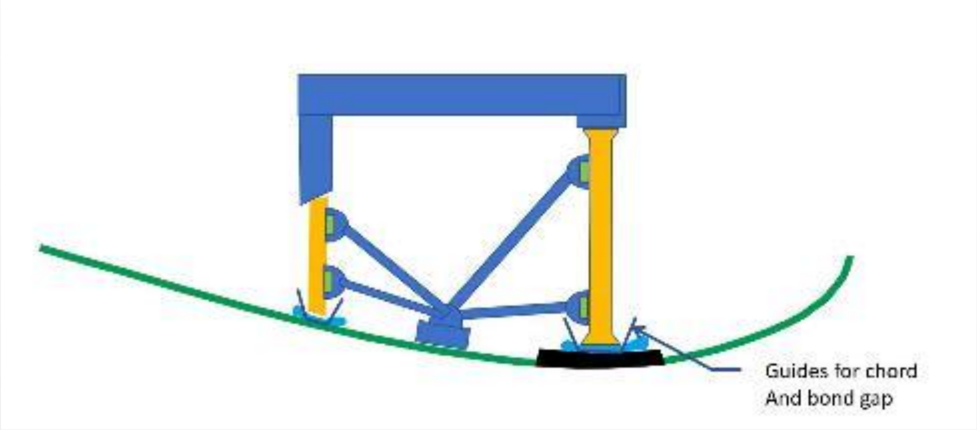
Two Problems to Overcome:

1. How to locate the webs
2. How to hold them while the adhesive cures

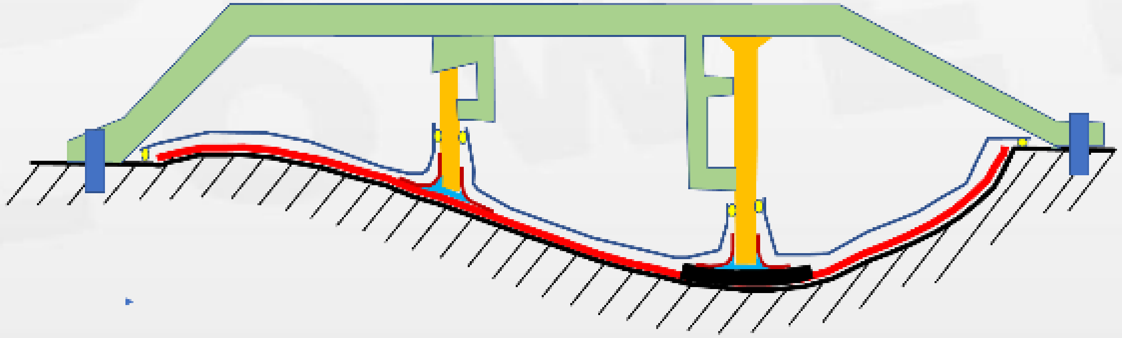
Gantry to locate webs



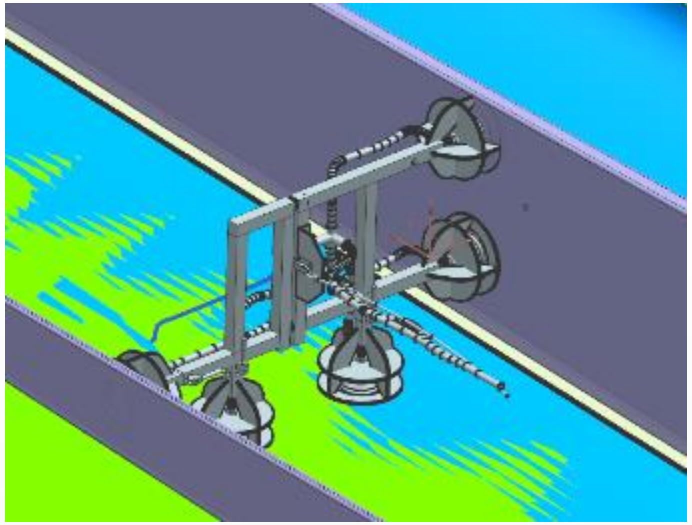
Wedges locate webs



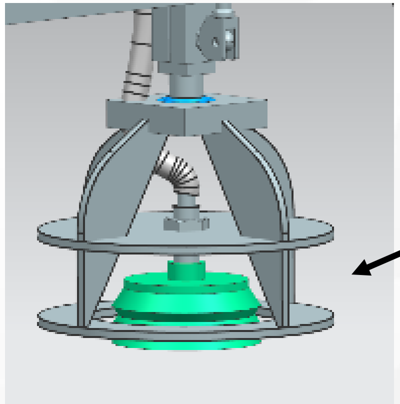
Co-infused Web



Team Brainstorming & Janicki Engineering



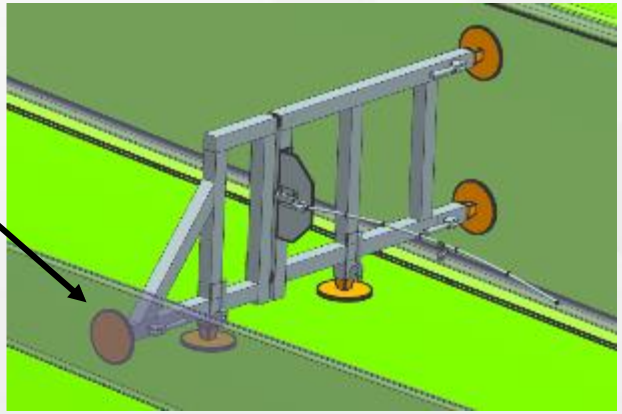
Vacuum Cup Based Attachment

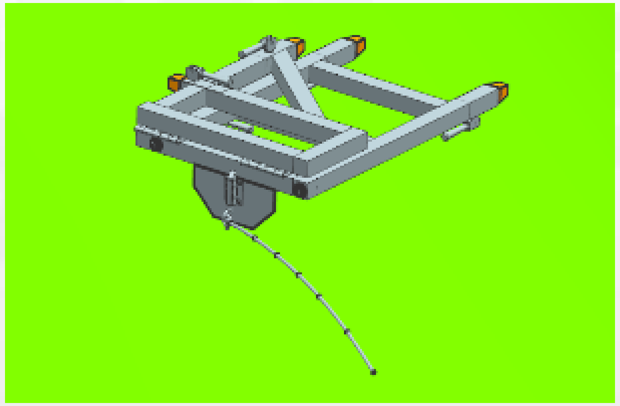


Protective enclosures take loads and prevent damage – cups merely secure the metal against lateral slip

Frangible Tip Based Attachment

Frangible foam sized to breakoff when fixture is unlatched and pulled





Trials at TPI Warren, RI facility

Process and Fixture Testing at TPI's Advanced Transportation and Composites Center included:

- Fixture holding power
- Vacuum cup vs. Frangible
- Simulation and ability to pull fixtures out of closed blade.
- Set webs with "gantry" or
- Set webs with fixtures
- Fixture improvement needs

Trials at NREL COMET facility

Manufacture of three blade tips at the NREL COMET facility enabled:

- Fixture capability
- Fixture functionality
- Co-infusion process validation
  - ✓ Shear web height repeatability
  - ✓ Web bond quality
  - ✓ Incremental time
  - ✓ Incremental consumables

Case 4 - Conclusions

- The TEM Model predicted significant savings
- Technical challenges were overcome with multiple solutions
- Demonstration of the process change
  - ✓ Enabled validation of process improvement
  - ✓ Allowed testing of technical variations
  - ✓ Showed potential further improvements

Demo project validated potential savings and technical viability.

Thanks to our IACMI Project 4.6/4.8 Partners

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