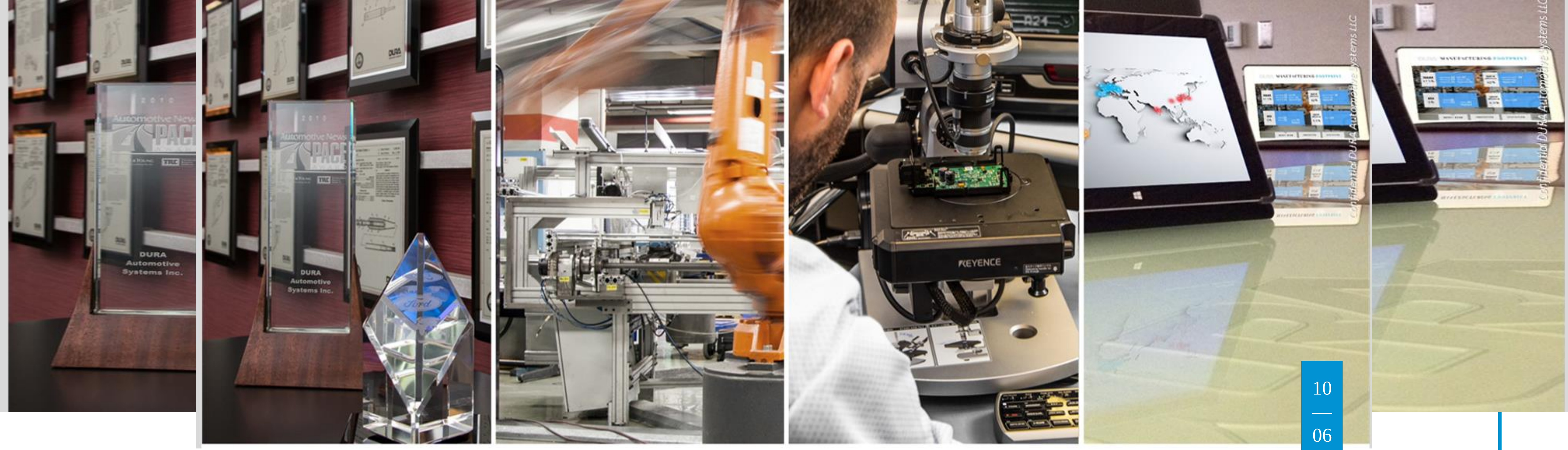

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Project 3.9 High Speed Layup and Forming of Automotive Composite Components

Indraneel Page representing the 3.9Project Team

DURA · BASF We create chemistry · Ford · The Composites iacmi Institute · Purdue University

OUTLINE

- Project Statement.
- Project Description & Team Members.
- Key Tasks.
- Integration of Performance - Manufacturing Design and Costing.
- Design Optimization
- Process Flow Optimization
- Project Relevance and Impact.

Project Statement

- 60 Second Layup, Forming, and Trimming of a Continuous Fiber Automotive Component for the Mainstream Market.

- **Challenge:**
  Current available tape layup systems cannot support high volume automotive manufacturing.

- **Approach:**
  Utilize an automotive component design that meets strength and torsional targets (structural requirement’s) as a surrogate to collaborate and prove out equipment supplier’s concepts to produce a tape lay-up in cycle times of less than 60s via continuous fiber tape lay-up.

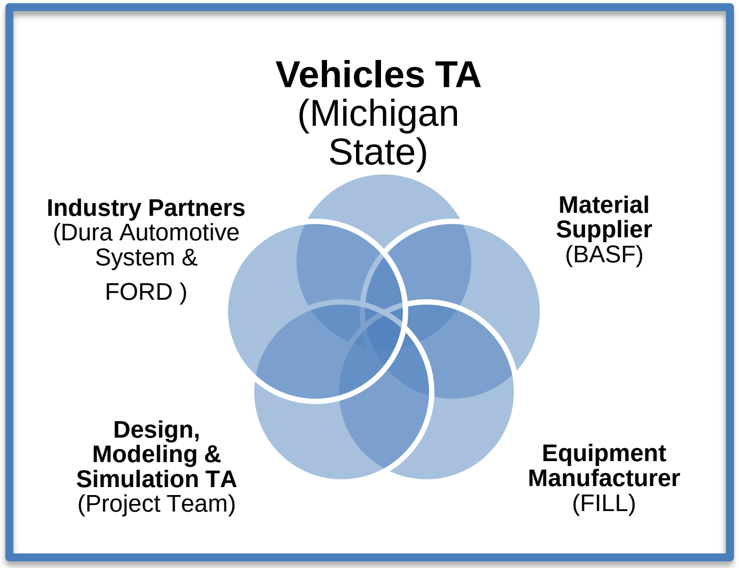
- **Impact**:
  Enables continuous fiber tape layup technology at automotive volumes to achieve Light weight and energy saving (Fuel efficiency).

Project Description & Team Members

- This project is based on a automotive component that meets strength requirement's for passenger vehicles (Sedan, SUV) using high speed tape lay-up equipment at a cycle time ~ 60 seconds (APV >100K.)
- The automotive component is a large component with composite tape layup utilized strategically to meet strength requirements.
- It will consist of 6 - 14 composite layers in different fiber orientation's (0/90/45/60 etc.)
- Component also includes forming, overmolding and trimming operations.

Project Team:

Dura Automotive Systems: Bhanumurthy Veeragandham, Indraneel Page
FORD: Patrick Maloney, Sangram Tamhankar
BASF: Mohamed Bouguetteya, Kipp Grumm
MSU IACMI SuRF: Ray Boeman, Doug Bradley.
Purdue University: Jonathan Goodsell, Michael Bogdanor.



Key Tasks

- Optimize component design based on cost and performance.
- Define scalable layup and consolidation process and produce 2D preforms on prototype equipment.
- Purchase and install tape layup equipment at IACMI/MSU SuRF based on prototype studies, cost, and functionality for future IACMI projects.
- Lay-up, Mold and Trim 20+ Prototype Composite parts at rate (~60s).
- Assemble Composite part and perform static vehicle testing at OEM.

Product Design and Finalization:

Product Design & Validation:
Industry partners identified 2 pilot projects to demonstrate the high volume composite insert molding process and cost evaluation.

Project A: Rear Package Shelf

- Structure, Safety, environmental and packaging functional component
- Component designed to align with current manufacturing process so that it would be a drop in place for OEM assembly.
- Component not selected as it wasn't able to meet the Cost/ Weight targets selected for the project.

Project B: Composite Seat Design (Ford)

- Project is to conceptualize and engineer a lightweight 1st row seat structure and mechanisms having equivalent performance and accommodations as current traditional 30-way FGen2 seat.
- Structural optimization with unique load path management and cost efficiency are key deliverables for this project.

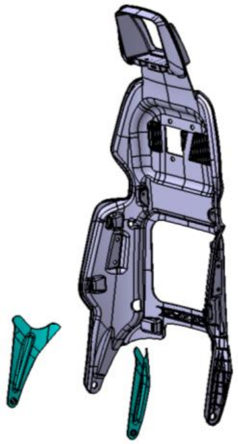
Composite Seat Components

- FORD Featherweight design was used in Project 3.9 as a joint development between Ford Product Development and DURA, BASF and MSU IACMI research organizations.

- Some key highlights vs traditional 30-way seat include
  - 29% Weight Save
  - 28% Part reduction
  - Overall Cost neutral

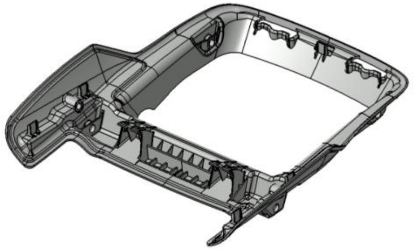
- For Project 3.9, the components of interest are the composite back structure and cushion pan.
  (Seat back inner & outer, Seat Cushion Inner & outer)

- Material used for these structures is BASF Ultratape®and Ultramid® B3ZG10 CR.
  (50 % Glass fiber reinforced PA 6 resin)

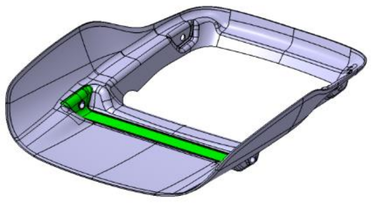


Seat Back Inner

Seat Back Outer



Seat Pan Inner

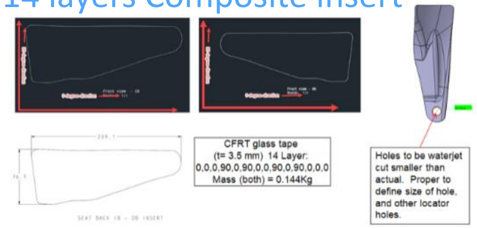


Seat Pan Outer

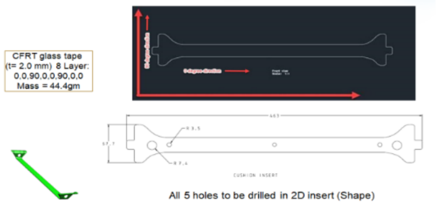
Design Optimization

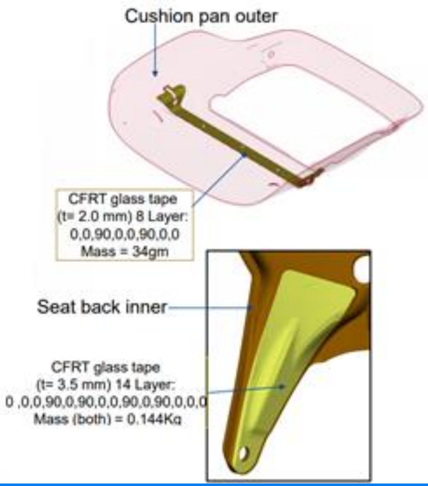
Insert Design Optimization

14 layers Composite insert



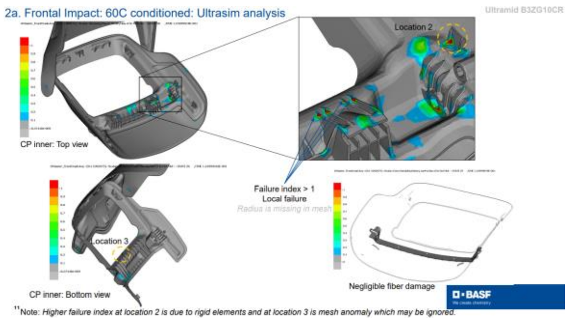
8 Layers Composite insert

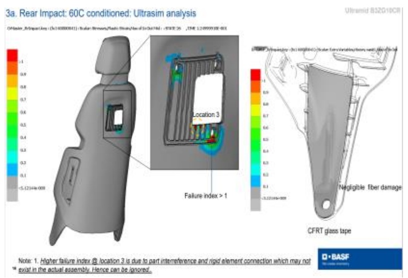


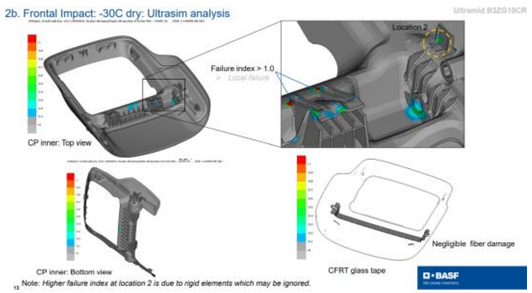


FEA/ CAE Optimization

- FEA analysis was completed at -40°, 23°, 60° C
- Structural cases such as Luggage Retention, Front and Rear Impact were evaluated when comparing to base design.
- Software including LS-DYNA, Moldflow and BASF propriety software Ultrasim® were utilized for analysis







High Speed Layup Equipment selection

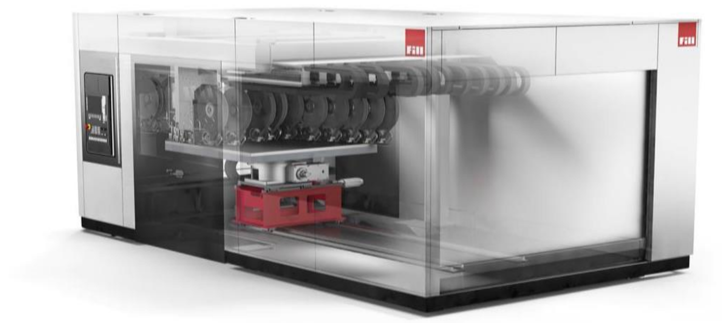
- Primary Goal: Selection of High speed multi layer equipment which meets the 60 second cycle time as defined in the project charter.

- Project team went through the exercise of identifying major equipment manufactures in NA and EU.

- Suppliers that had the advanced technology required were down selected, visited, and prototypes produced to understand each technology in detail

- After detailed evaluation FILL was selected as the supplier of choice based on their technical, sales and support capabilities.

- IACMI has purchased the first FILL layup equipment in NA and it is installed in the MSU SuRF Corktown facility in Detroit MI.



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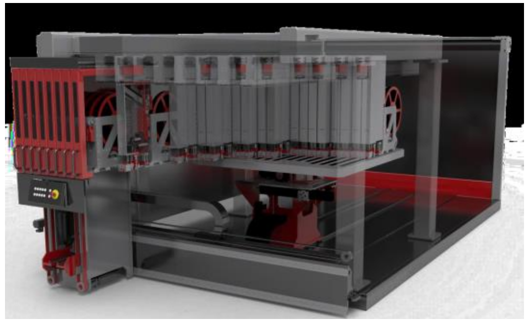
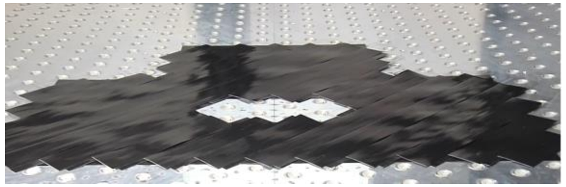
Criteria		Description	Weighting	Ranking	Score	Ranking	Score	Ranking	Score
General	US company	HQ in the United States. Manufacturing in the US.	0.01	3	0.03	1	0.010	1	0.01
	US content		0.01	3	0.03	1	0.010	1	0.01
	Financial stability	Strong books; little risk of default	0.12	4	0.48	4	0.480	2	0.24
	Value-added contribution	Does the supplier bring process expertise beyond the basic technical specifications?	0.06	2	0.12	5	0.300	3	0.18
	Manufacturing capability/reputation	In house or contracted, overall impression of manufacturing capability	0.06	2	0.12	5	0.300	2	0.12
	Confidence in meeting project timing	Based on meeting requested timing for samples and quotes	0.05	1	0.05	3	0.150	3	0.15
	Probability of equipment upgrades	Confidence that the supplier continue to upgrade equipment to improve process	0.03	3	0.09	4	0.120	3	0.09
	Demonstrated prototype in existence	Has manufacturer built and demonstrated full-scale Prototype (1=no, 2=partial or subscale, 5=full-scale)	0.05	1	0.05	2	0.100	2	0.10
	Service and support	How strong is the service/support package	0.01	3	0.03	2	0.020	1	0.01
					1.00		1.49		0.91
Technical	Cycle time	Ability to support high volume (300K ABY) with single machine (e.g. 60s per 6 layer preform)	0.07	1	0.07	2	0.140	2	0.14
	Multiple lay-up angles	Infinite angles are preferred	0.07	2	0.14	4	0.280	2	0.14
	Ability to produce 3D preforms	e.g additional "pad-ups"	0.07	1	0.07	4	0.28	1	0.07
	Ability to produce preforms of varying siz	up to 48"X48"	0.07	2	0.14	4	0.280	3	0.21
	Beneficial technical features	Are there features of the equipment not explicitly required by the specification that make the press especially attrac	0.04	2	0.08	4	0.160	2	0.08
	Data system and software capabilities	Ease of quickly programming dissimilar lay-ups (ply book and size)	0.05	2	0.10	4	0.200	2	0.10
	Automation and system control	Is the level of automation and control sufficient to meet high volume applications (300K ABY)	0.05	3	0.15	5	0.250	3	0.15
	Demonstration of spec. compliance	Buy-off plan that shows what testing will be performed to demonstrate compliance to specification parameters?	0.03	1	0.03	3	0.090	1	0.03
	Near net-shape capability	Does the equipment have the capability to reduce scrap for non-rectangular shapes or shapes with	0.05	1	0.05	3	0.150	1	0.05
	Overall quality of prototype equipment	Impressions from observing prototype equipment during evaluation process.	0.05	2	0.10	5	0.250	3	0.15
					0.93		2.08		1.12
Commercial	Lead time	Lead time from order to installed.- Level of detail of project plan. Is it believeable?	0.04	2	0.08	3	0.120	2	0.08
	"Retail" machine cost	Would the equipment be affordable to US producers?	0.02	4	0.08	2	0.040	2	0.04
	Installation costs	Are there additional costs required (e.g. ventilation, air handling) 5= no additional costs	0.05	3	0.15	5	0.250	3	0.15
	Input material cost	Does material require additional processing (e.g. slitting) 5= no addditional processing	0.02	4	0.08	2	0.040	5	0.10
	Cost share	How much cost share is the supplier willing to offer?	0.05	1	0.05	3	0.150	1	0.05
	Warranty	Does the warranty meet or exceed the minimum requirements	0.01	3	0.03	3	0.030	3	0.03
	Footprint	Relative square footage required (1= largest and 5 = smallest of candidate systems)	0.02	1	0.02	5	0.100	2	0.04
	Terms and Conditions	Are the terms and conditions of sale acceptable?	0.03	3	0.09	3	0.090	3	0.09
					0.58		0.82		0.58
		Grand Totals	1.19		2.51		4.39		2.61

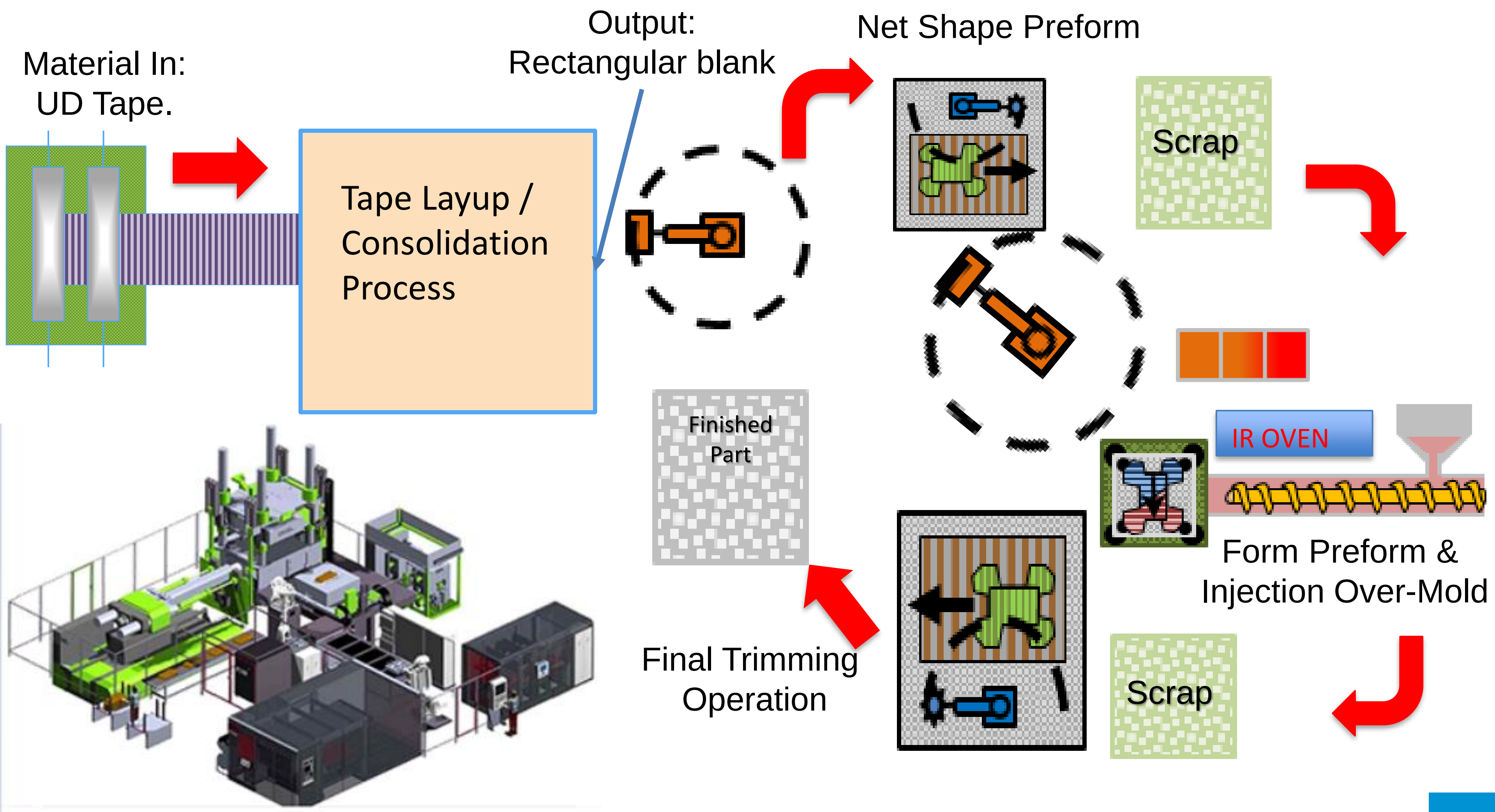
FILL Layup Equipment



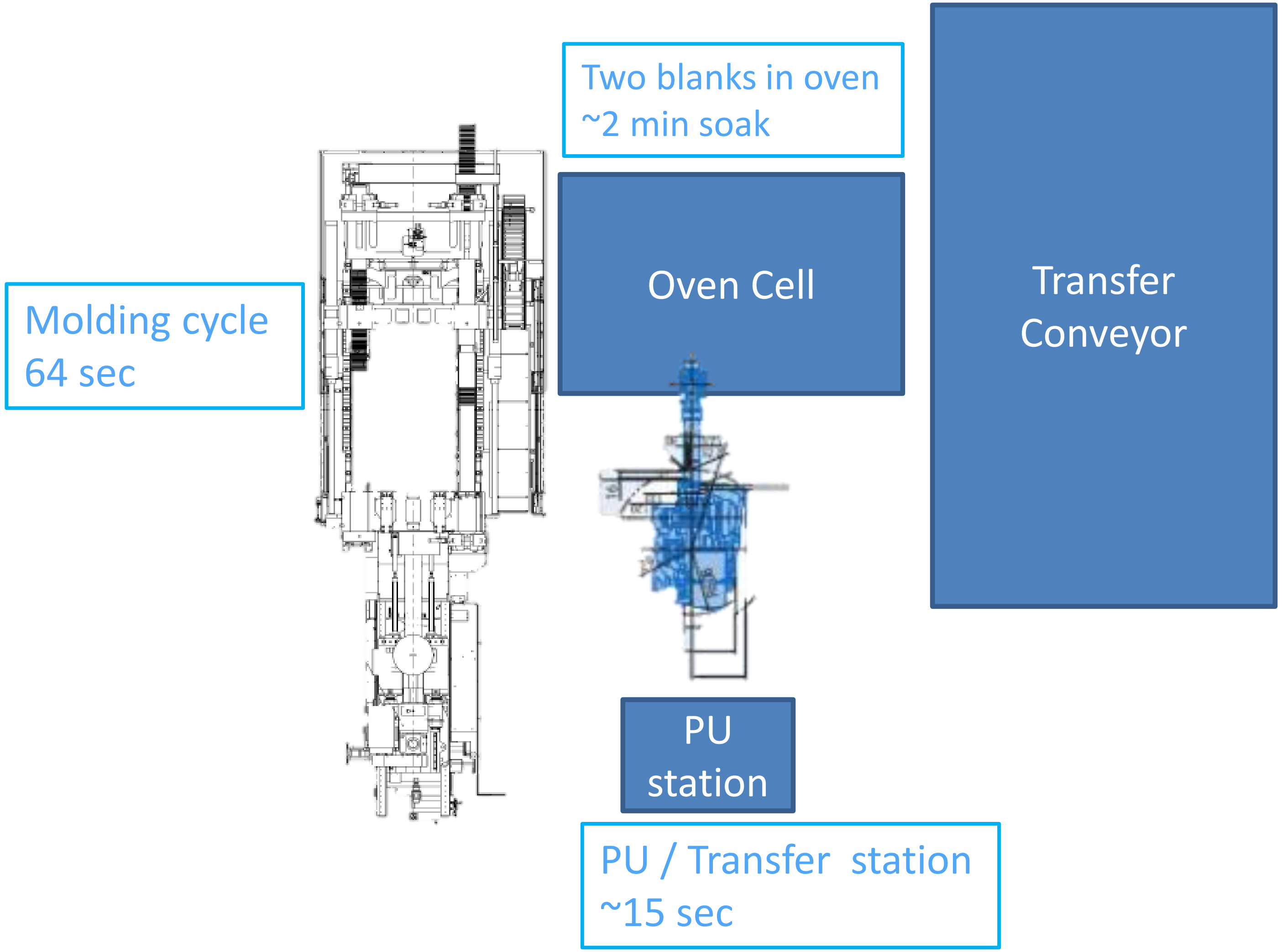


Material: BASF Ultratape®
Laid up on IACMI machine @ Fill parameters
Consolidated: Double belt Press
(**Meyer** Maschinenfabrik)

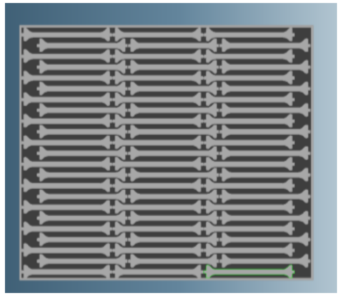
Process flow optimization

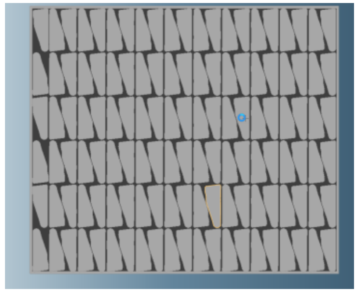


SurF floor layout



Prototyping: Water Jet Cutting and 3D Forming





Water Jet Cutting

3D Printed Insert Pre-forming Tools

- Molds 3D-printed at Ford AMC.
- Material: Ultem 1010

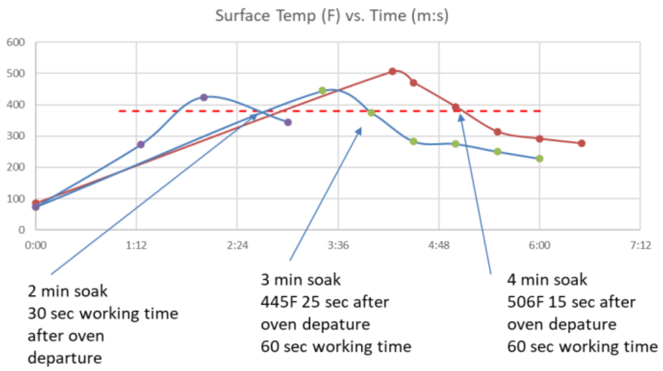
Untrimmed preforms

3D Forming

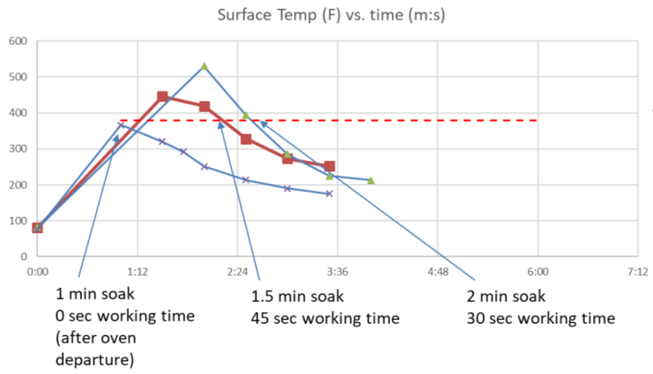
Prototyping: Injection Molding Trials

Material & Process Analysis

3.5 mm tape

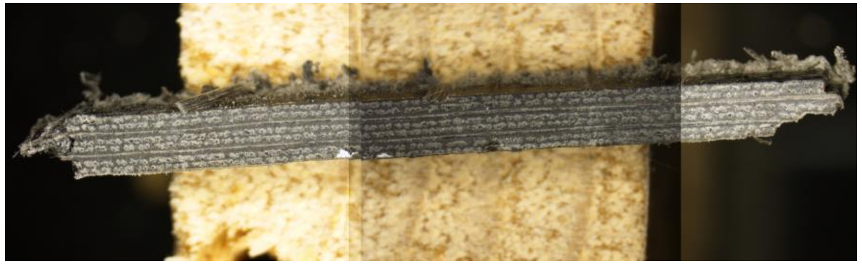


2.0 mm tape



Material:
BASF Ultratape®
Oven: FORD Oven
550F Radiant Heat.

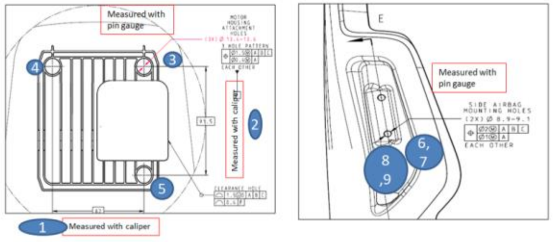
Heat & Soak Analysis



Micrograph Analysis of 8 ply & 14 ply tape

Nominal — Put in part identifier from trials

	Dimension Measured	Dimension	Tolerance +	Tolerance -	Part 44	Part 41/15	Part 45	Part 42	Part 5	Part 32	Part 37	Part 38	Part33	Part 39	Median	Upper Limit	Lower Limit
1	istance - Horizontal between Motor Suppo	82	0.4	0.4	82.04	81.95	81.97	82.02	82.09	82.02	82.00	82.00	81.99	82.00	82.00	0.09	0.05
2	Distance - Vertical between Motor Support	91.5	0.4	0.4	92.22	92.14	91.90	92.25	92.37	92.05	92.07	92.34	92.34	92.33	92.23	0.14	0.33
3	Diamter - Hole 1	13.5	0.1	0.1	13.31	13.39	13.34	13.39	13.41	13.34	13.36	13.36	13.39	13.39	13.37	0.04	0.06
4	Diameter- Hole 2	13.5	0.1	0.1	13.39	13.39	13.41	13.28	13.36	13.39	13.36	13.41	13.41	13.39	13.39	0.03	0.10
5	Diameter Hole 3	13.5	0.1	0.1	13.36	13.34	13.39	13.34	13.36	13.36	13.34	13.36	13.34	13.36	13.36	0.03	0.03
6	Diameter - Side Air Bag Hole 1	9	0.1	0.1	8.92	8.84	8.99	8.94	8.99	9.02	9.02	9.07	9.02	9.04	9.00	0.06	0.17
7	Diameter - Side Air Bag Hole 2	9	0.1	0.1	8.92	8.84	8.94	8.94	8.97	8.99	8.99	9.09	9.07	9.09	8.98	0.11	0.14
8	Diameter - Side Air Bag Hole 3	9	0.1	0.1	8.99	8.89	8.94	8.99	8.99	9.02	9.02	9.12	9.09	9.07	9.00	0.11	0.11
9	Diameter - Side Air Bag Hole 4	9	0.1	0.1	8.99	8.94	8.94	8.99	8.99	9.04	9.04	9.12	9.07	9.12	9.02	0.10	0.08



Dimensional Measurements

Confidential DURA Automotive Systems LLC

FORD Bonding and Physical Test

Bonding Activity

- Adhesive selection: Acrylic based developmental adhesive (3M)
- Fixtures with clamps at critical locations were designed and developed at FORD.
- Manual application of adhesive on injection molded inscribed lines

Bonding Tear Down Activity

- Rough teardown activity conducted at FORD
- Brut force used to separate bonded parts
- Adhesive Failure observed as expected.

Physical Testing

- FORD has internally developed 4 physical tests for the bonded assemblies and will conduct testing at FORD.
- A Test fixture has been built by FORD to execute the planned tests as per FORD standards and includes Quasi-static loading.
- CAE Analysis and physical testing correlation activity planned for final confirmation of product.

Summary and Next Steps

Summary:

- Project Team 3.9 achieved all outlined project objectives
  - Design and performance of product.
  - Cost Neutral to current base design.
  - Selection & acquisition of High Speed Tape layup equipment supplier.
  - TAKT time: Achieved 60s layup target.
  - Injection overmolding.
  - Assembly (Bonding) of component assembly.

Project Impact:

Commercialization: This project aims to be the catalyst of integrating composite components in mainstream automobiles.

Outcome: Technology for structural composite part is ready for production on a high volume vehicle platform.

Next Steps

- Complete additional Injection molding trials (2D preform) @ MSU IACMI SuRF location.
- FORD Internal Quasi-static testing.
- Correlation between CAE and Testing.
- Identify additional structural applications for technology.

THANK YOU