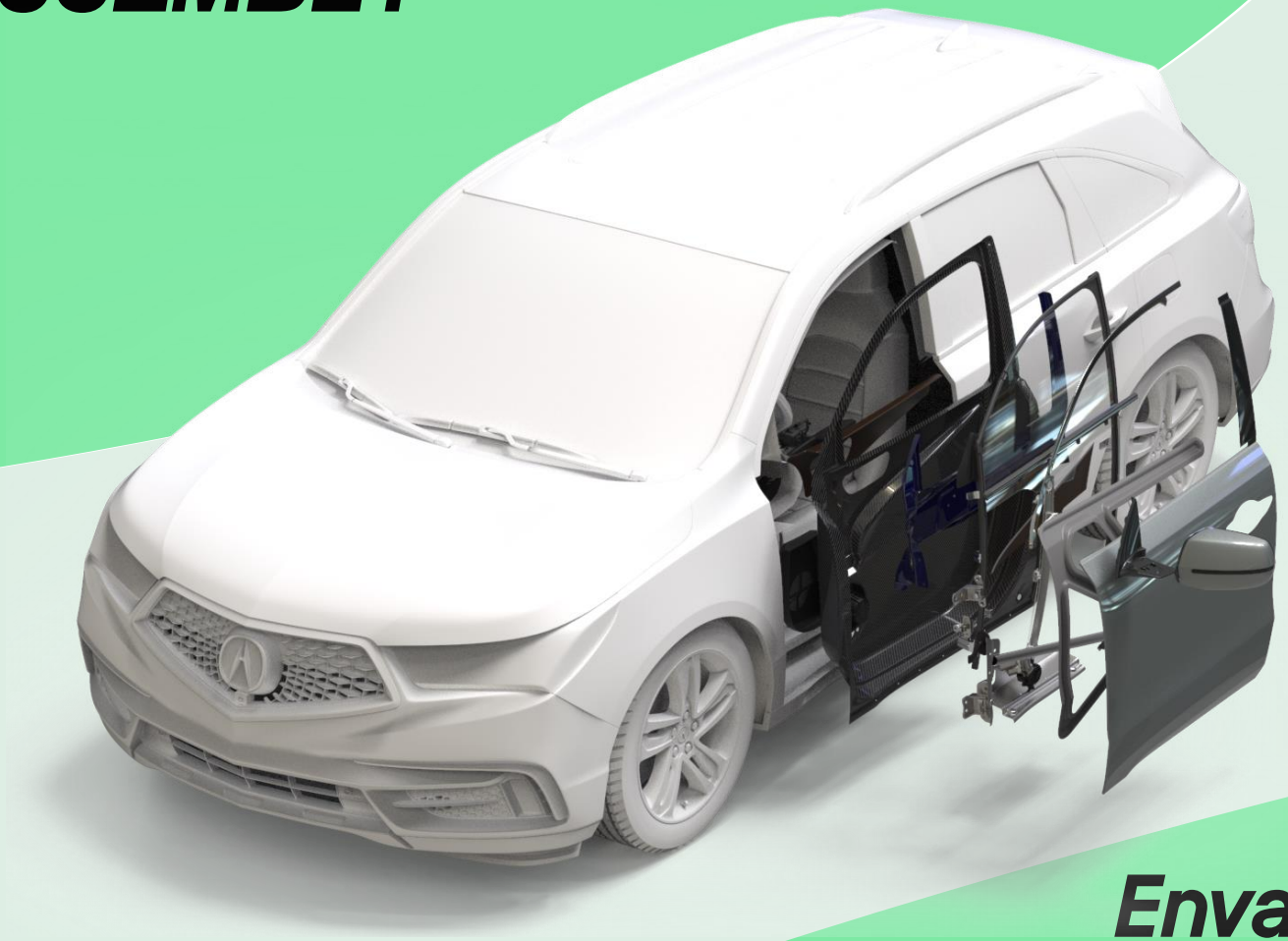
ADVANCED MANUFACTURING FOR LIGHTWEIGHT CONTINUOUS CARBON FIBER THERMOPLASTIC COMPOSITE DOOR ASSEMBLY

PAL SWAMINATHAN
SALES & BUSINESS DEVELOPMENT MANAGER
TEPEX THERMOPLASTIC COMPOSITES



UNIVERSITY OF DELAWARE CENTER FOR COMPOSITE MATERIALS Celebrating 50 Years
CLEMSON UNIVERSITY
HONDA
BOND LAMINATES Ein Unternehmen der LANXESS Gruppe

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ENVALIOR

A GLOBAL ENGINEERING MATERIALS COMPANY

BUILT ON A STRONG HERITAGE

LANXESS
High Performance Materials

+

DSM
Engineering Materials

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BOND-LAMINATES GMBH

THERMOPLASTIC COMPOSITE SOLUTIONS SINCE 1997

BOND LAMINATES

HIGHLIGHTS

2007:	Press Generation 2 = 900mm production width + 1st generation Water Jet Cutting
2011:	Press Generation 3 = 1300mm production width
2012:	100% new ownership: Incorporation to LANXESS' BU High Performance Materials
2014:	Demo Center including Hybrid Molding + IMD
2016:	Water Jet Cutting 2nd generation incl. optical control system
2019:	Facility expansion + 2 new production lines
2021:	Press Generation 4 incl. automated blank cutting
2023:	**Envalior**

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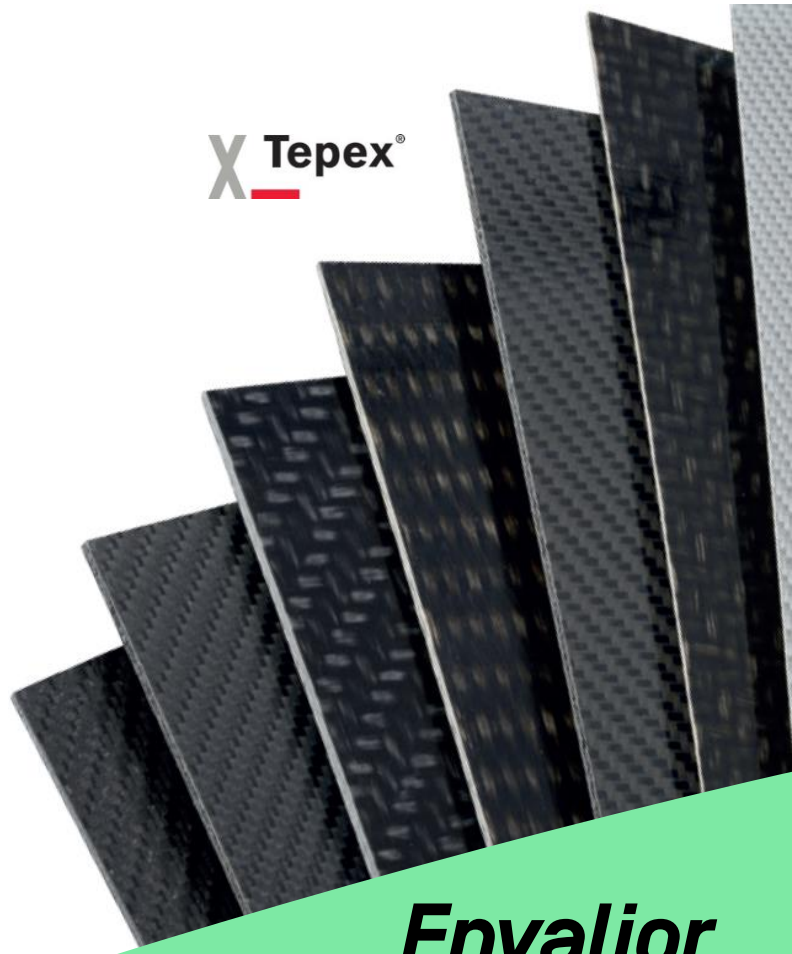
TEPEX®

THE REAL ORGANOSHEET

- Plain, semi-finished product (sheet) based on a thermoplastic polymer (matrix)
- Reinforcement is a fabric, or any kind of other continuous fiber made of glass or carbon
- Material is fully impregnated and consolidated, i.e.:
  - the fibers are completely coated with the polymer
  - there is no remaining air inside the material (<3%)

The material has already achieved its final mechanical properties and therefore only needs to be heated above the melt temperature and subsequently molded into parts within short cycle times (< 60 sec.).

During the manufacturing no chemical reaction occurs, a very reproducible process is obtained.



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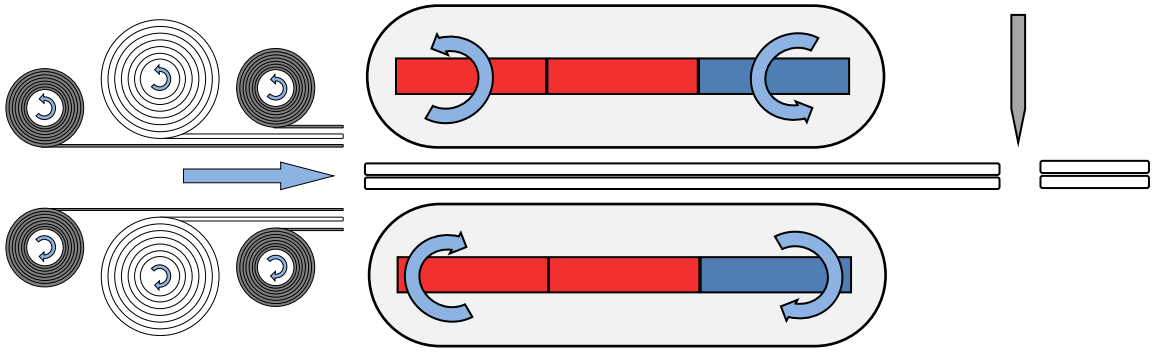
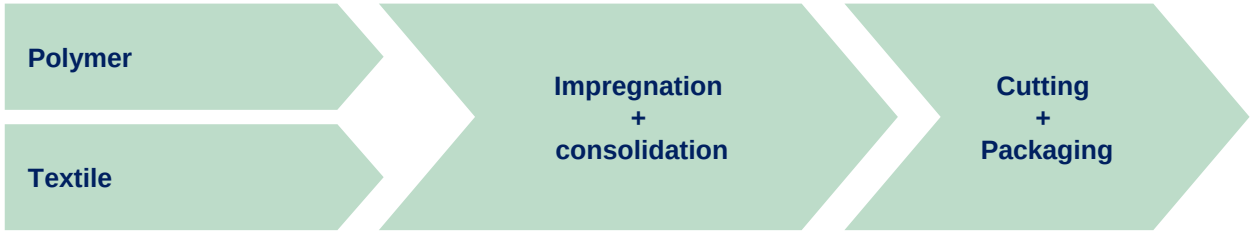
CONTINUOUS PRODUCTION OF TEPEX®

DOUBLE BELT PROCESS

production capacity > 4 million m^2/yr

ready for high volume mass production





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CUSTOMIZED MATERIAL LAY-UP

FULLY CUSTOMIZABLE

sheet thickness, fiber volume fraction, weave structure and water jet cutting

Width = up to 1240mm
Thickness = 0.5mm – 6mm (in steps of 0.5mm)
Fiber volume content = 45% - 55%

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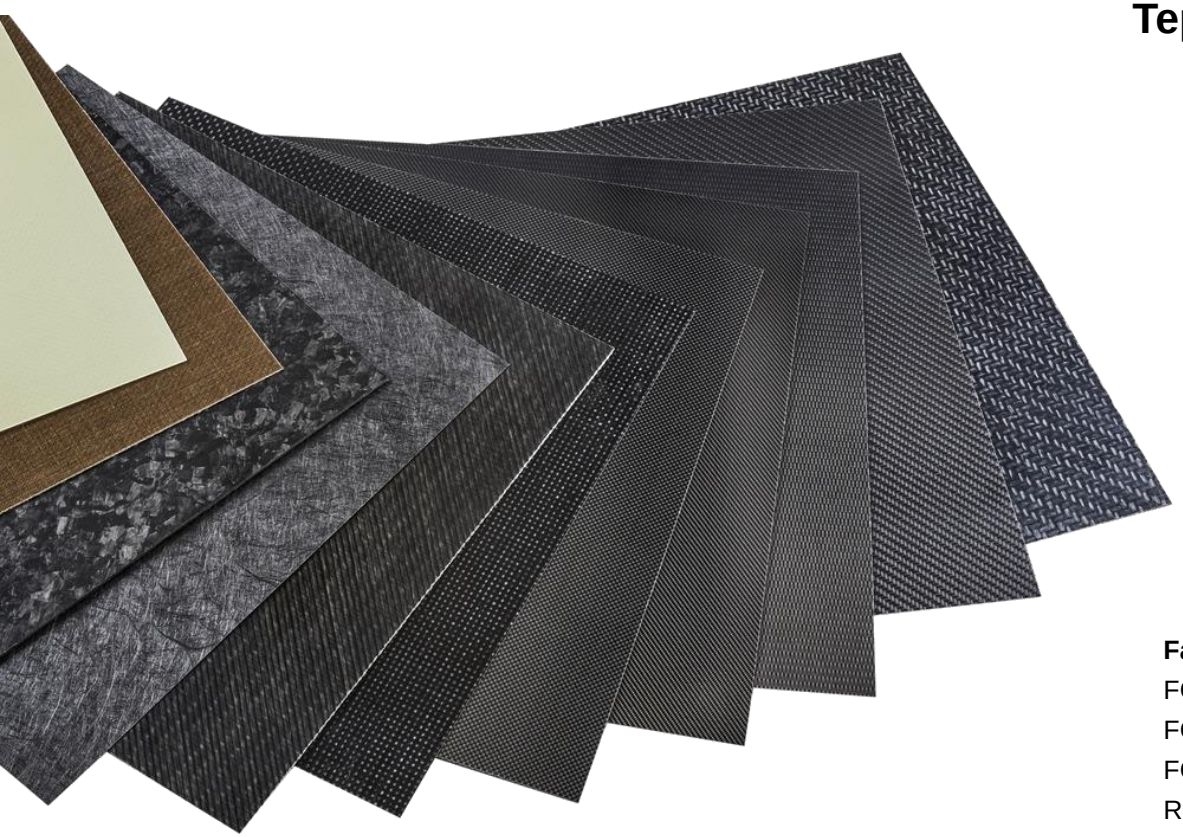
TEPEX® PORTFOLIO

OVERVIEW



Tepex® dynalite

1 02 – RG600 (4) / 47%

weaving style, textile area weight, no. of layers, fiber volume content

- 28 basic polymer-fiber combinations
- 18 basic weave types (Tepex® may contain more than one weave type!)

	Glass	Carbon	Aramid	Flax
PA66	■	■	■	■
PA6	■	■	■	■
PBT	■	■	■	■
PP	■	■	■	■
PA12	■	■	■	■
PPS	■	■	■	■
TPU	■	■	■	■
PC	■	■	■	■
HDPE	■	■	■	■
PLA	■	■	■	■

Fabric Code:

FG = Filament Glass
FGAL = FG Alu coated silver/anthracite
FGc = FG coloured
RG = Roving Glass
C = Carbon
CUD = C Uni-Directional
RGR = RG Random
RGUD= RG Uni-Directional
A = Aramid

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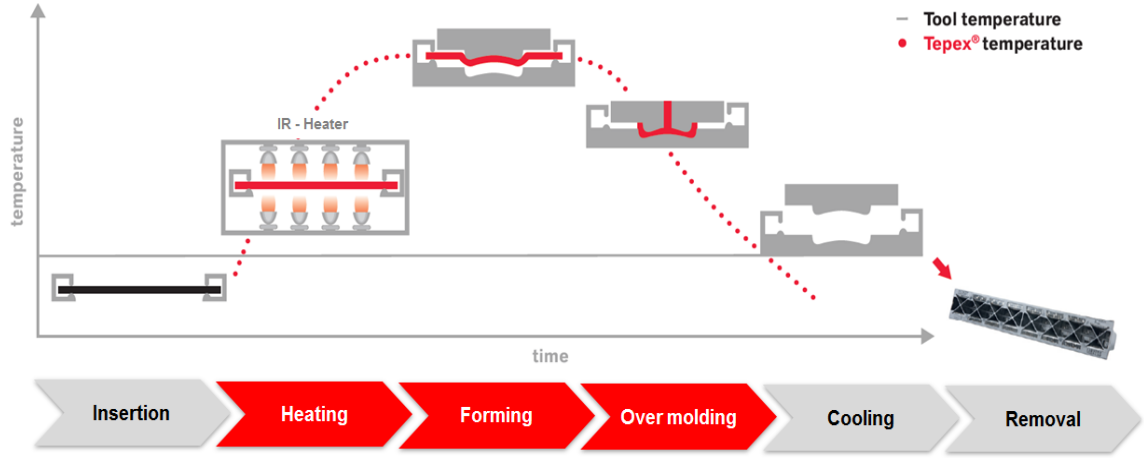
PROCESSING OF TEPEX® HYBRID PARTS

ONE SHOT HYBRID MOLDING PROCESS

Low cycle times <= 1minute



During the manufacturing no chemical reaction occurs, a very reproducible process is obtained

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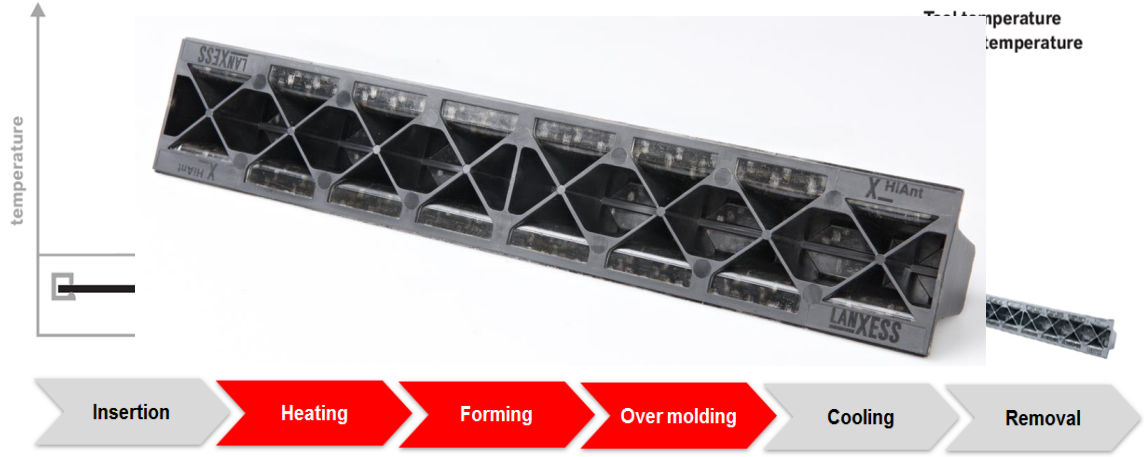

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Demo Cell, Brilon

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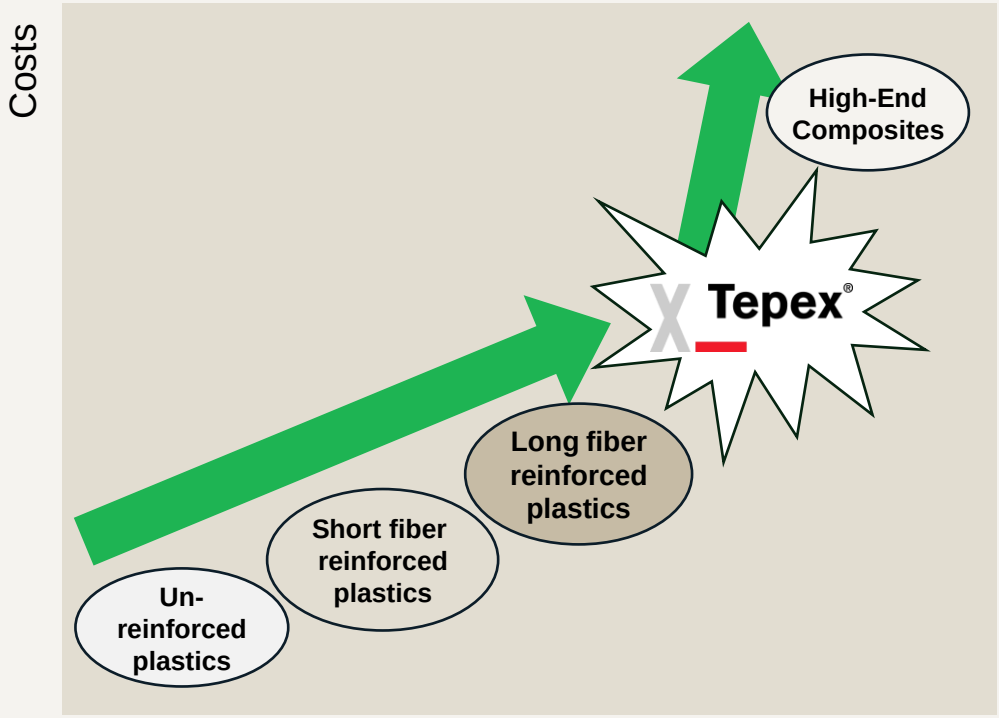
TEPEX® MATERIAL CHARACTERISTICS

INNOVATIVE MANUFACTURING PROCESS ENABLE AN ATTRACTIVE COST-PERFORMANCE RATIO FOR MASS PRODUCTION

ADVANTAGES

- Tailored fiber orientation
- Combination with injection & compression molding
- Hybrid molding / One-shot process
- Elimination of stamping tool
- No corrosion, no coating, no cleaning process for metal parts (Sustainable)
- Short part production cycle times (< 60 sec.)
- Recycling
- Unlimited shelf-life

Price-Performance Ratio



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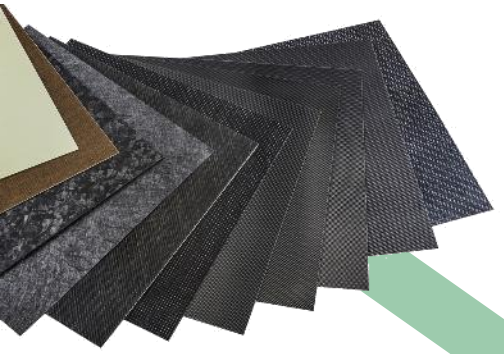
COMMERCIALLY ESTABLISHED RECYCLING LOOP

THERMOPLASTIC COMPOSITES SOLUTION FOR A SUSTAINABLE FUTURE



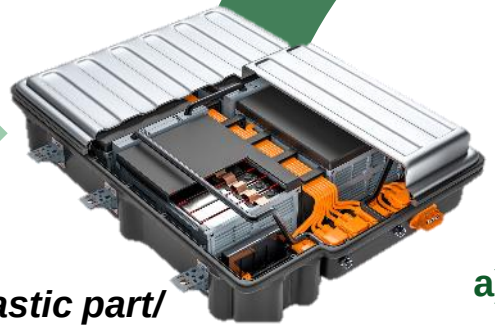
Tepex® sheet (continuous fiber)

(e.g.) **Hybrid molding**

Injection molding granulate (short fiber)

Alternative: LFT/D-LFT

Shredding



Full plastic part/ production scrap

Shredded flakes (short/long fiber)

a) Direct processing

b) Regranulation

Regranulate (short fiber)

Injection Molding

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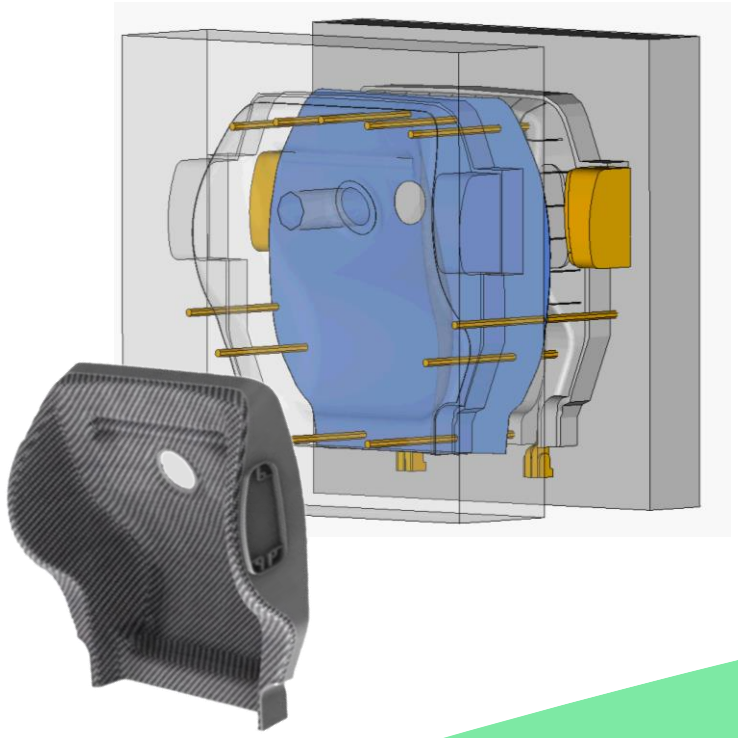
HI-ANT®

OUR VALUE PROPOSITION COMBINES HIGH-END MATERIALS AND HIGH-END ENGINEERING KNOW-HOW AT ITS BEST

More than 25 years of experience in application development

- Recommendation concerning materials, design and manufacturing
- Integrated in customer's design process (e.g. exchange of native files)
- Computer Aided Engineering
  - *Process simulation*
    - *–Injection molding, draping of Tepex*
  - *Optimization*
    - *–Thickness, rib structure*
  - *Conventional mechanical simulation (virtual testing)*
    - *–NVH, Crash, long-term/creep, durability*
  - *Integrative simulation*
    - *–In-house development based on micro mechanic theory*
    - *–Material data for simulation (internal/external)*
- Assessment of weight, cost and risks
- Cost/Performance optimization

Draping Analysis



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01

Manufacturing

Inner Panel

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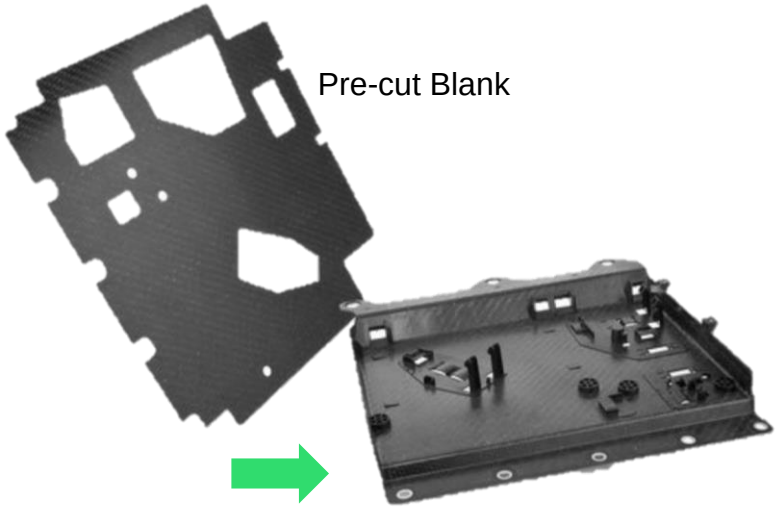
MANUFACTURING CHALLENGES

- Thermoforming only (no hybrid molding)
- Drapability
- Blank size
- Prototype Effort (robots, IR heater, automation)
- Part size, Geometric complexity
- Press (Platen) Size
- Heater (market availability, size, schedule)

HYBRID MOLDING VS. THERMOFORMING

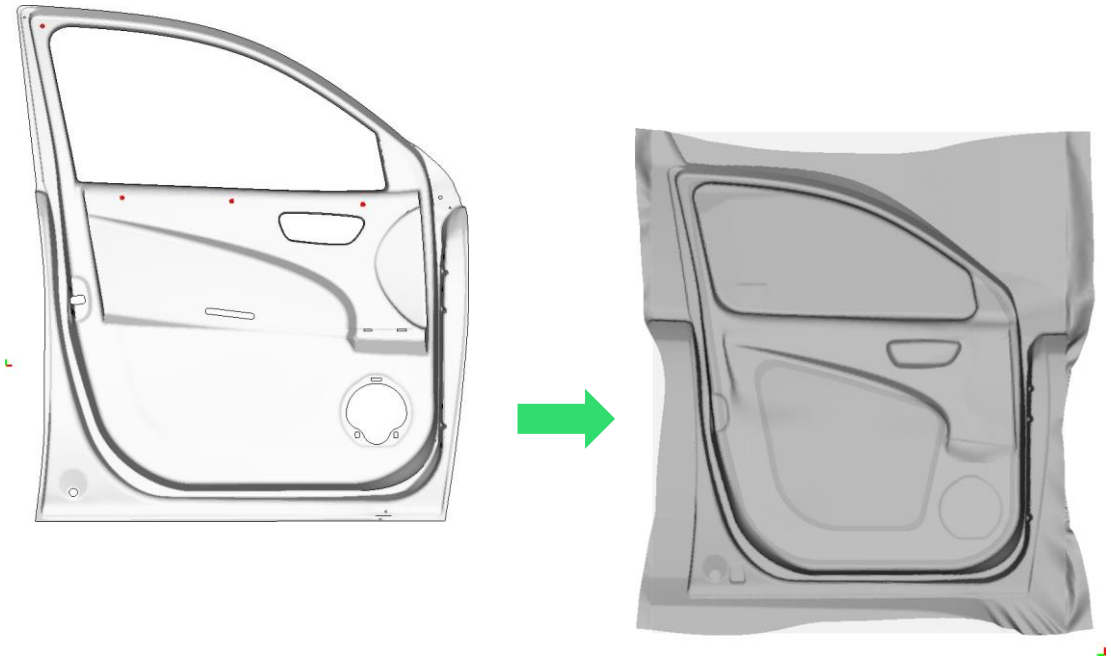
Hybrid Molding



Thermoforming with a pre-cut blank + Injection molding (in one step)

VS.

Thermoforming



Thermoforming with an oversized blank and post trim the featured holes/openings

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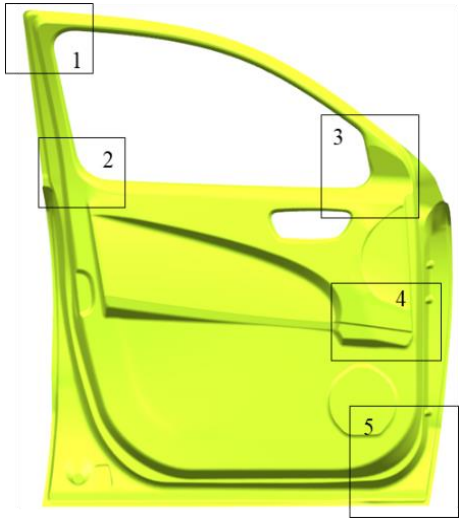
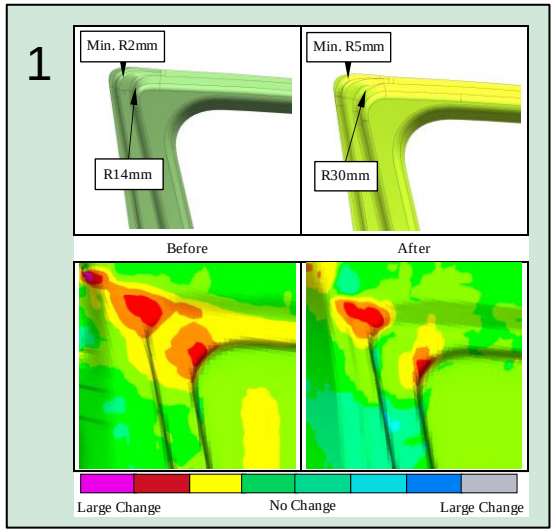
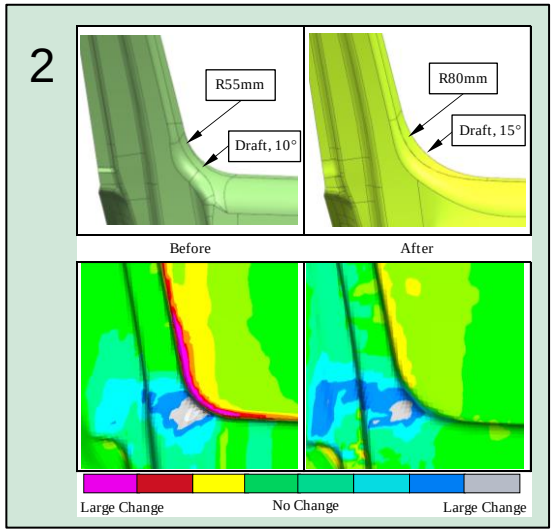
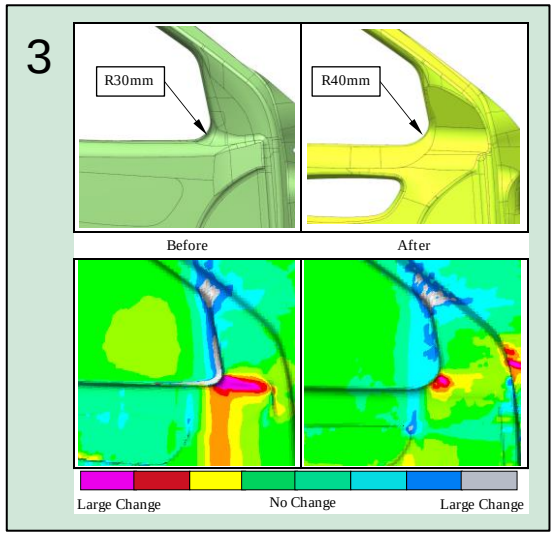
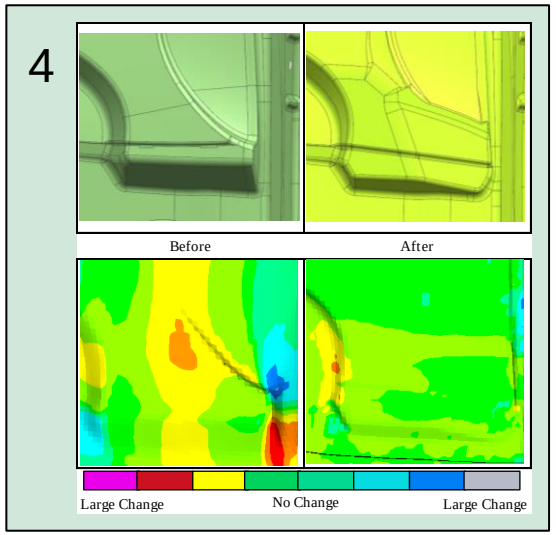
DRAPABILITY





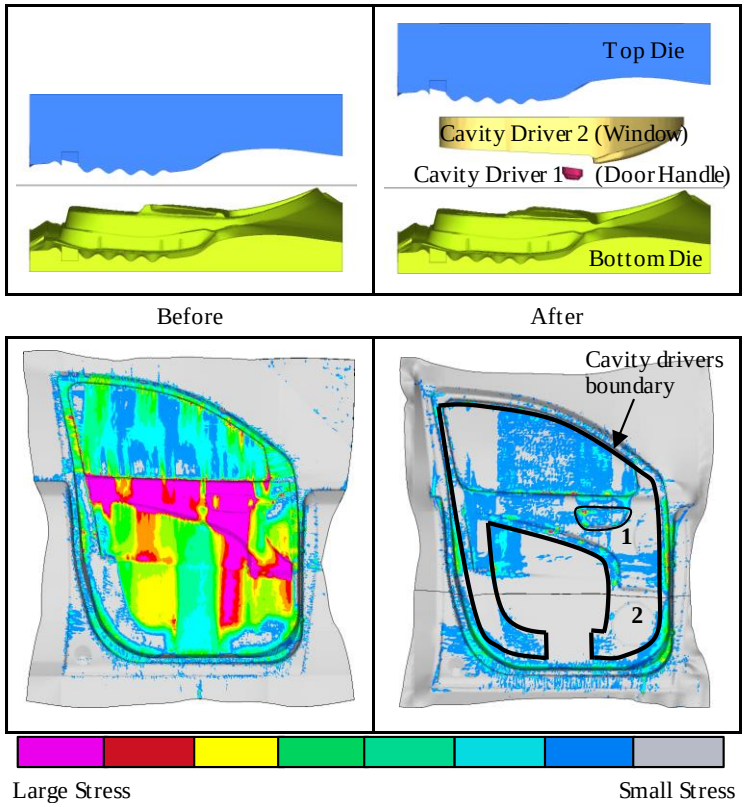






Issue: High shear angle at locations 1-4

Solution: Change in draft angle, radius of curvature, and depth-to-width ratio



Issue: Tearing observed
Solution: Cavity drivers to split single-stage forming into dual-stage forming

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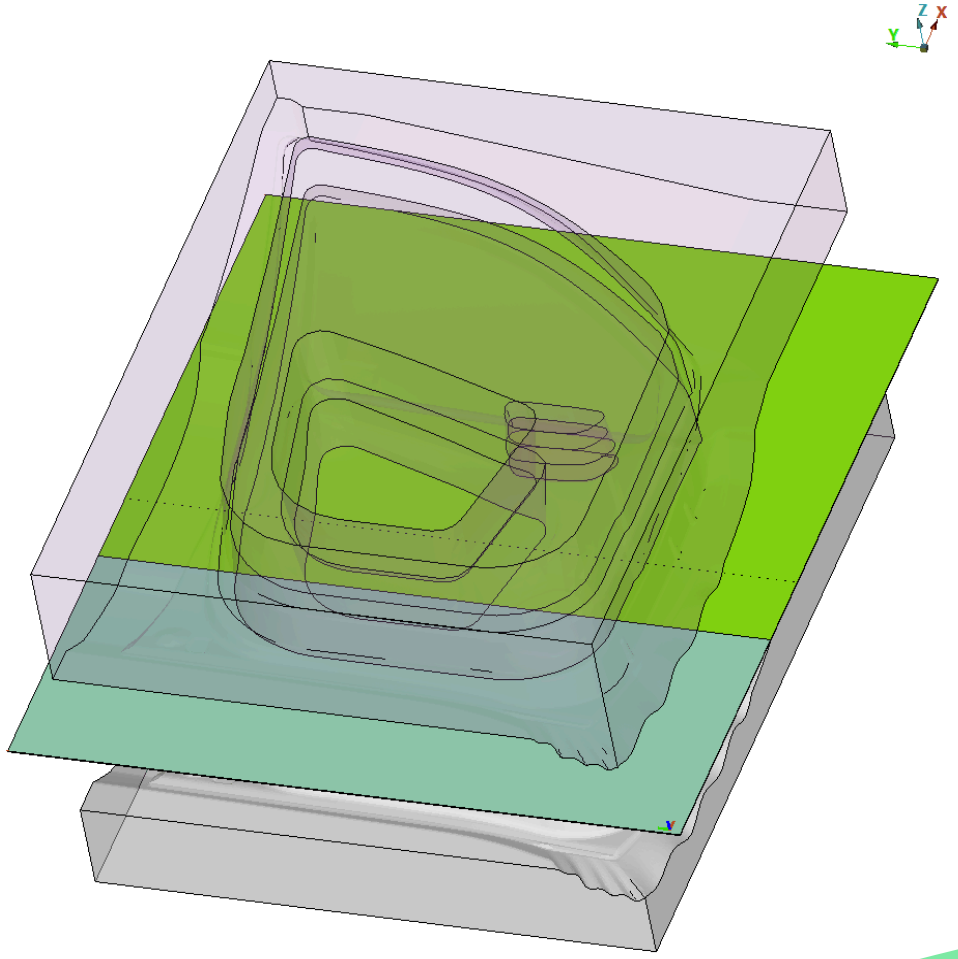
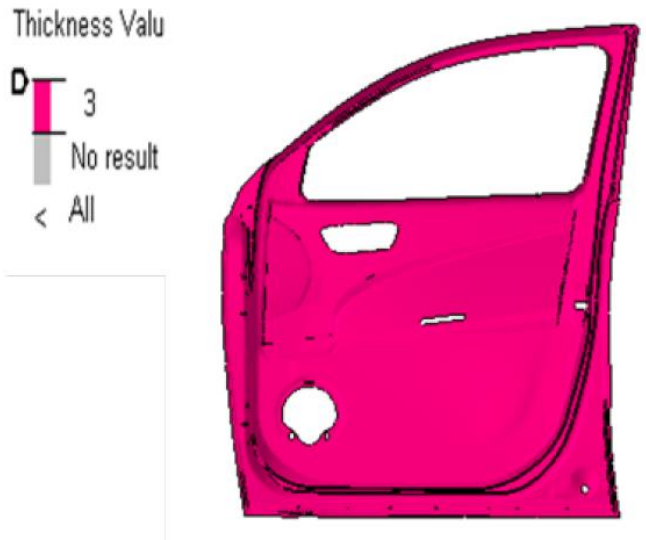
DRAPABILITY

- Window, sash formation through use of cavity driver
- Door handle region formation through use of a smaller cavity driver
- Adjustable slots to vary material holding locations
- A simple A-frame with needle gripers is being considered

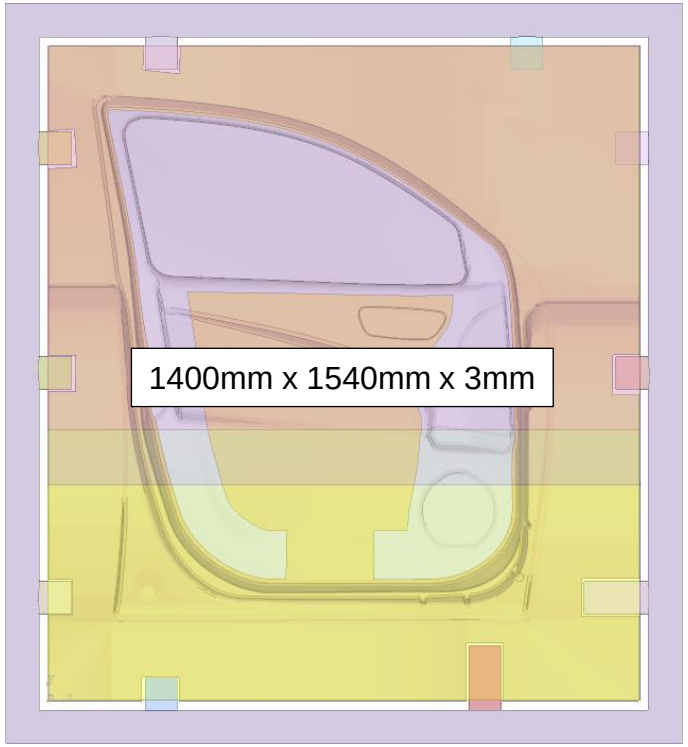


BLANK SIZE

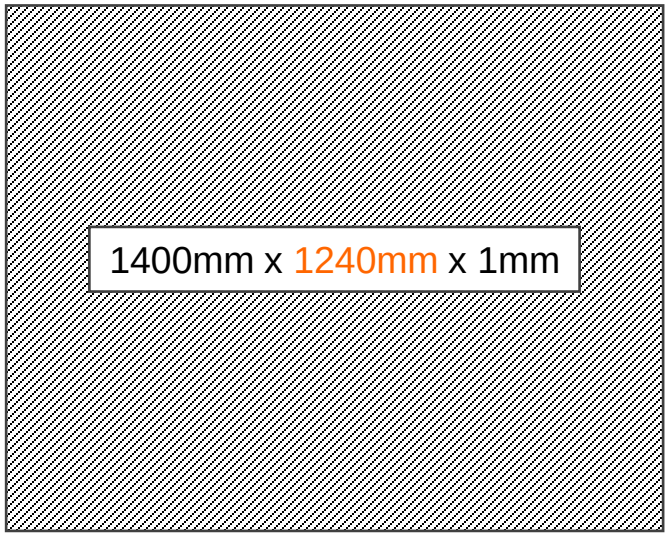
Inner Panel



Blank size needed for draping



Blank size to order



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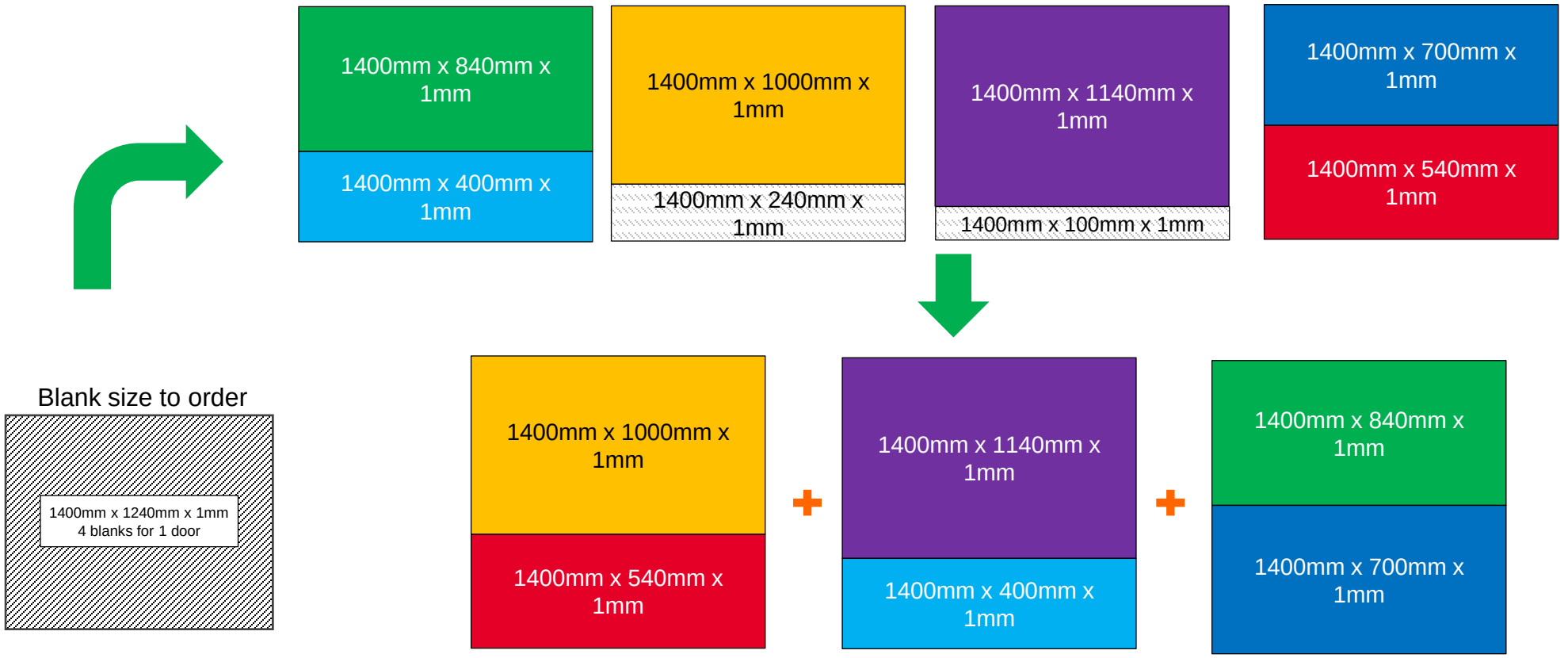
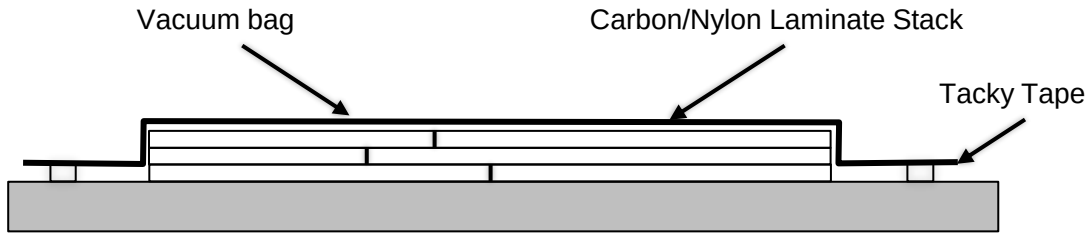
BLANK STRATEGY



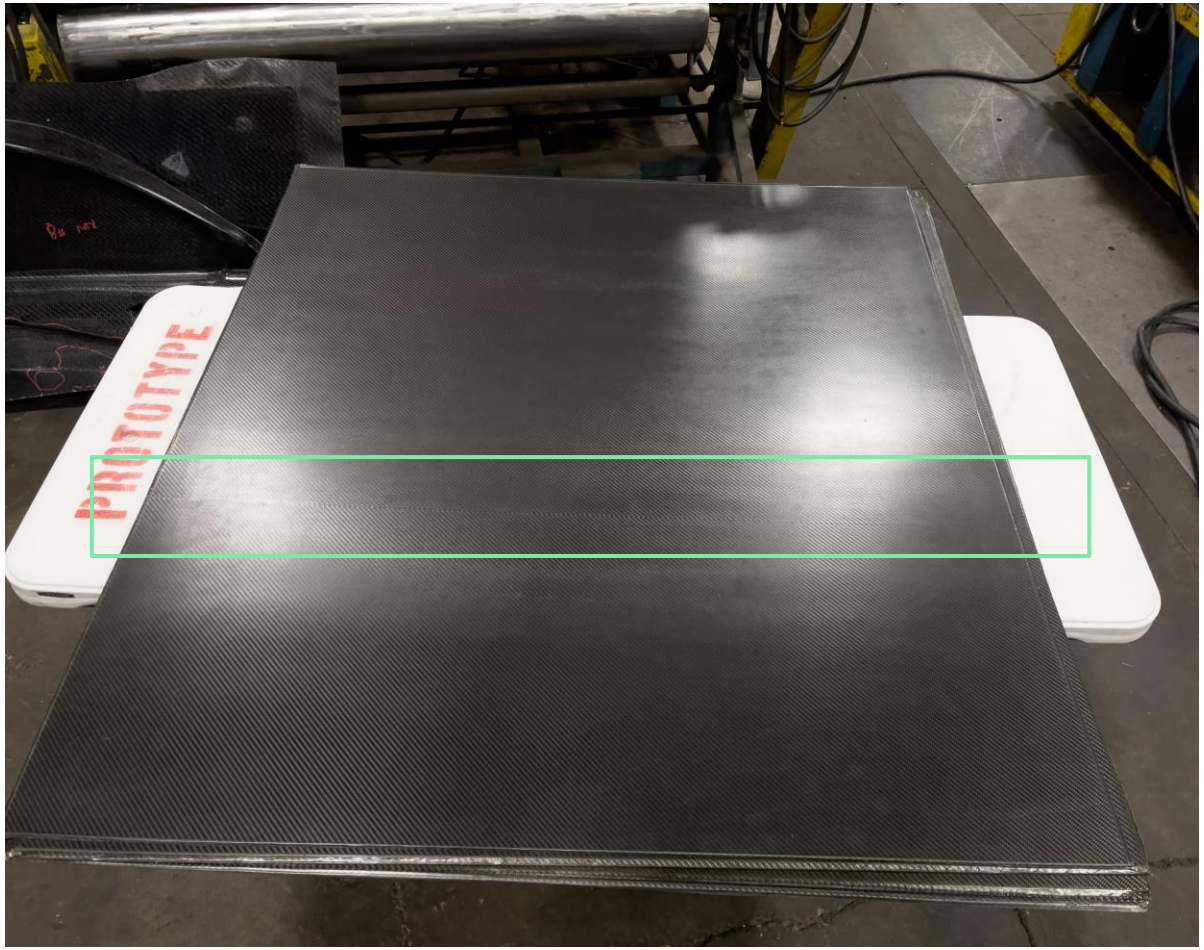
Reqd. Blank size 1400mm x 1540mm x 3mm; Blanks through the thickness (arranged in order from left)

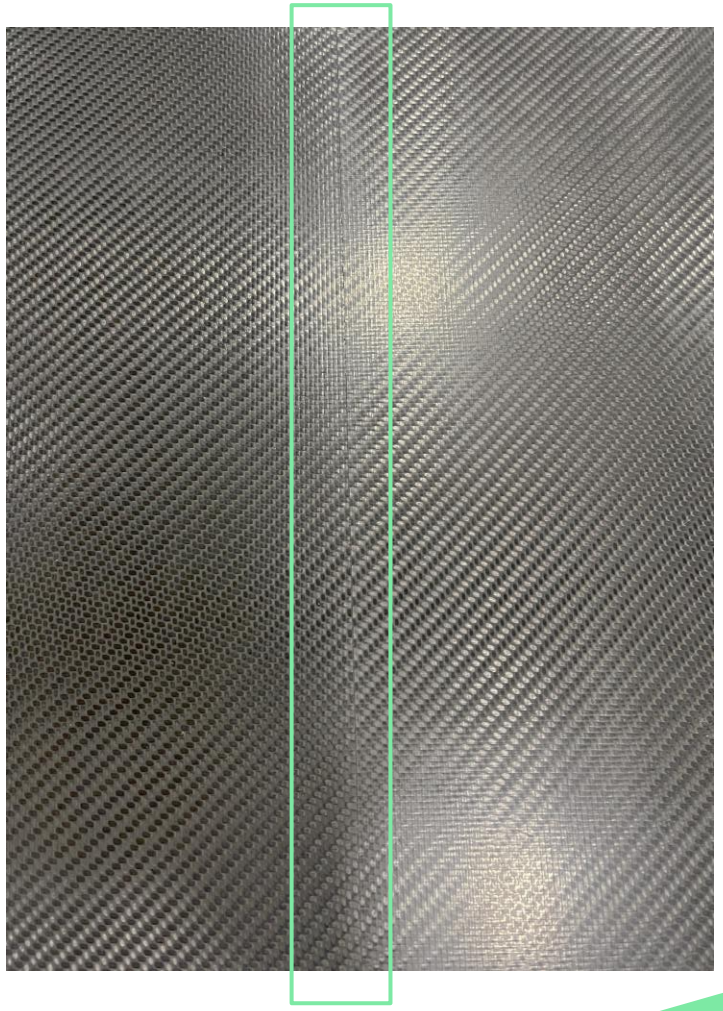
VACUUM FORMING (PRE-CONSOLIDATION)

- 3 Layer panel building block per specified geometry
  - Vacuum bagged
  - Temperature cycle based on prior work
    - PP : 350F (177C), 30 min hold at temperature
    - PA6: 480F (250C), 30 min hold at temperature
    - Vacuum pressure only



PRE CONSOLIDATED BLANK





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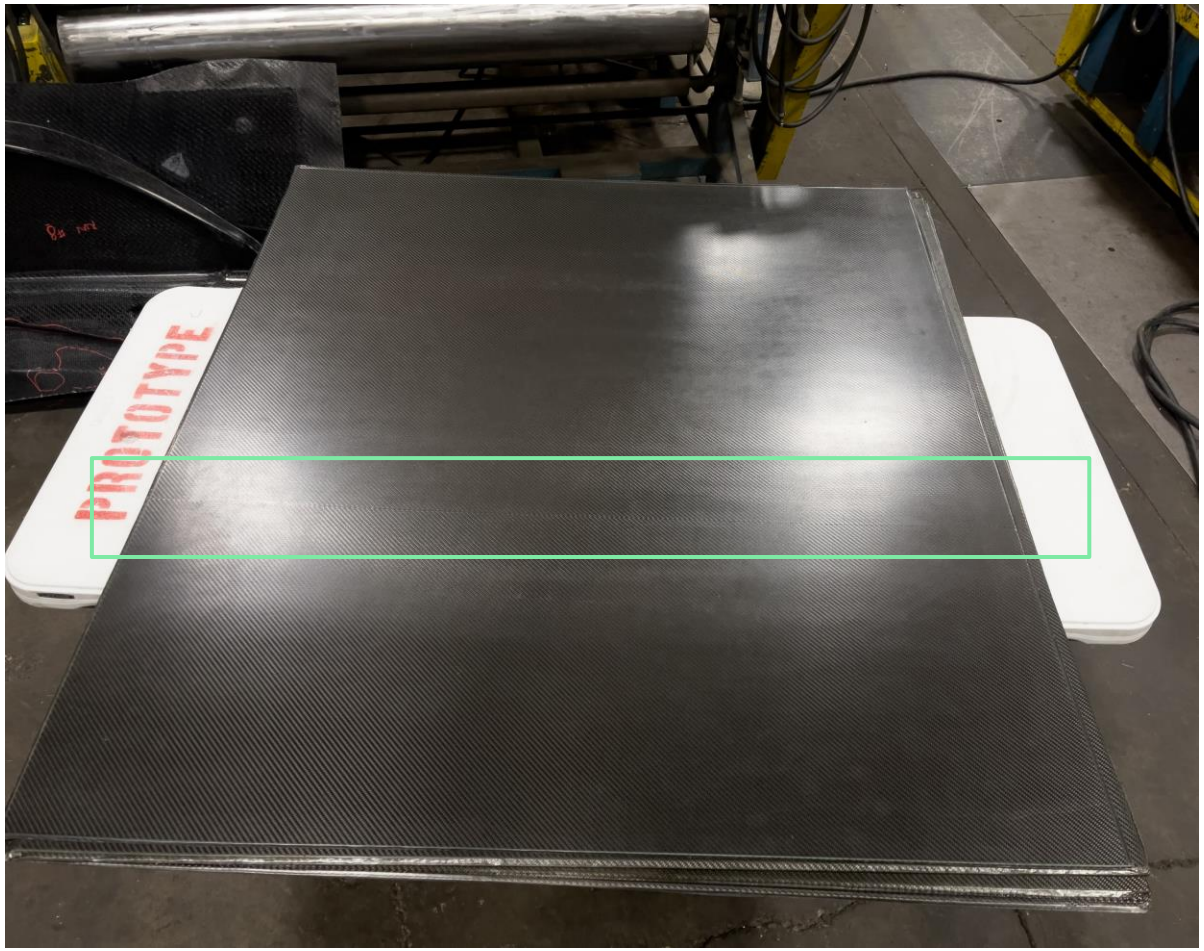
PRE CONSOLIDATED BLANK



- Blank weight = ~9.0 kg
- Handling in and out of the oven
- Transfer to the tool
- Repeatability of blank placement in the tool
- Time

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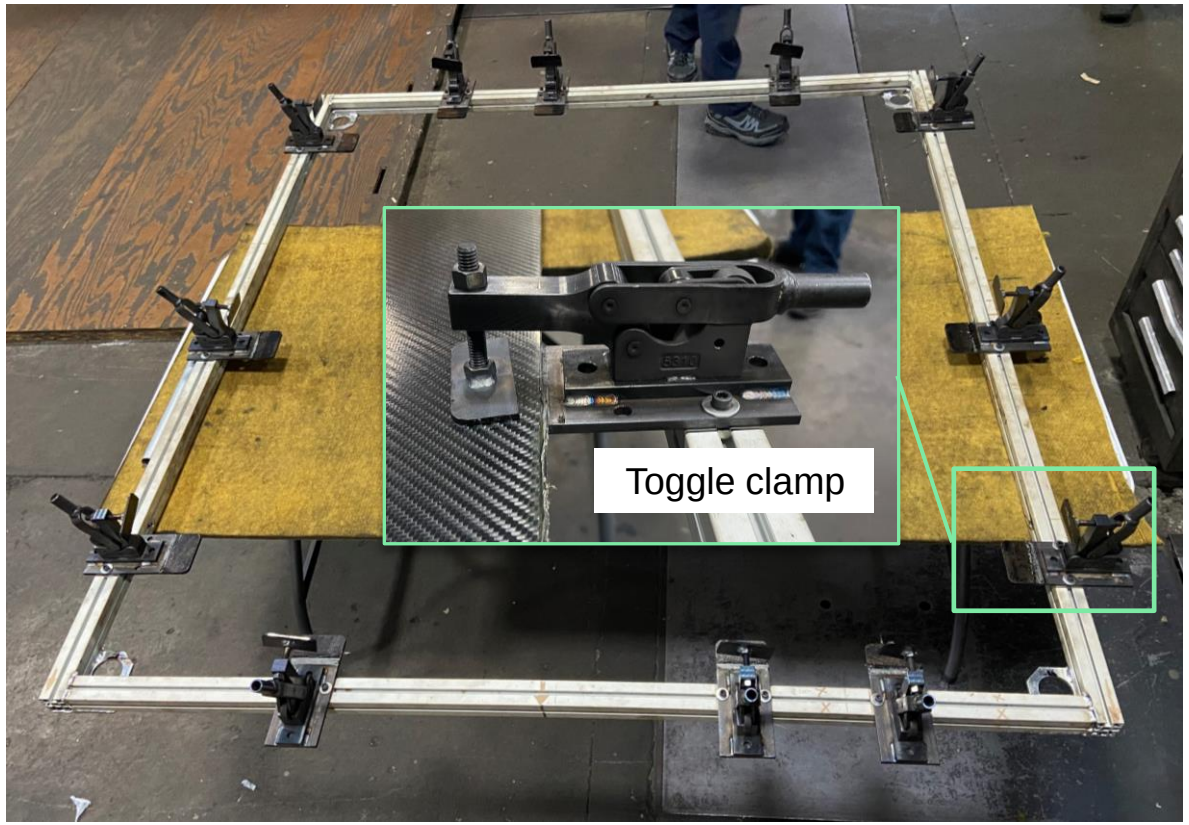
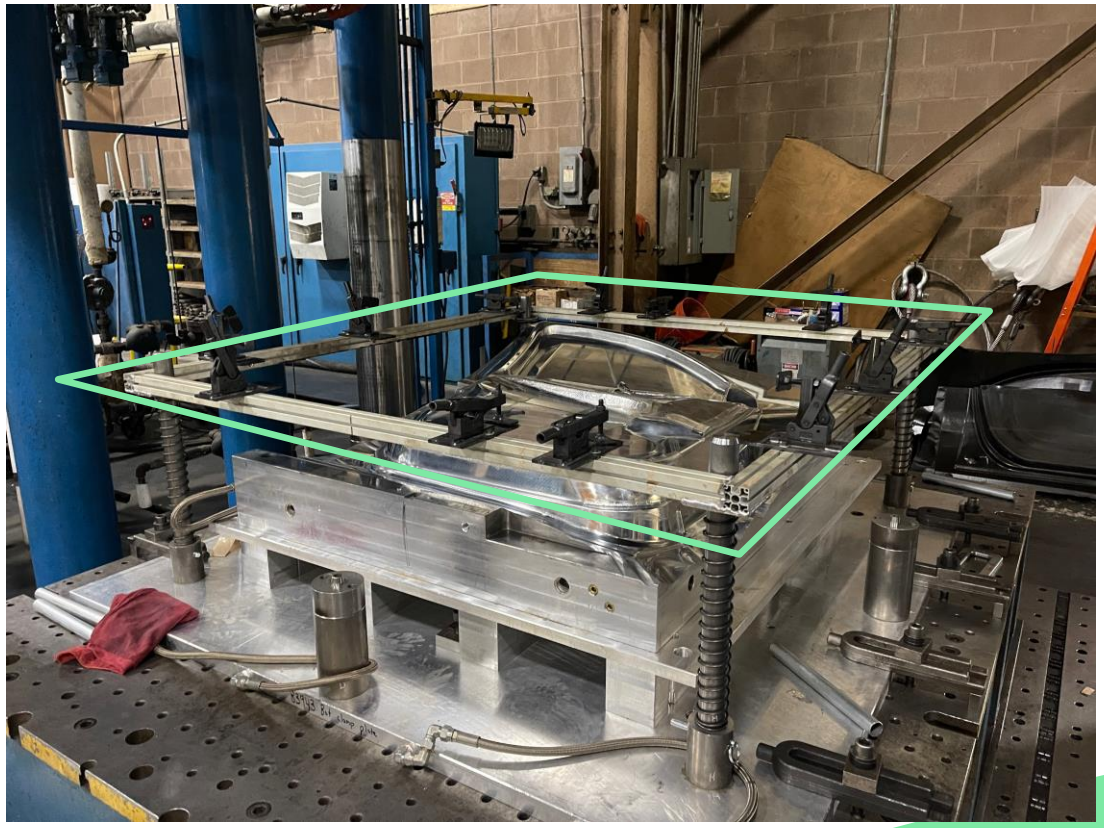
HANDLING SYSTEM

Handling system placed on 4 posts in the tool for blank placement (position repeatability)





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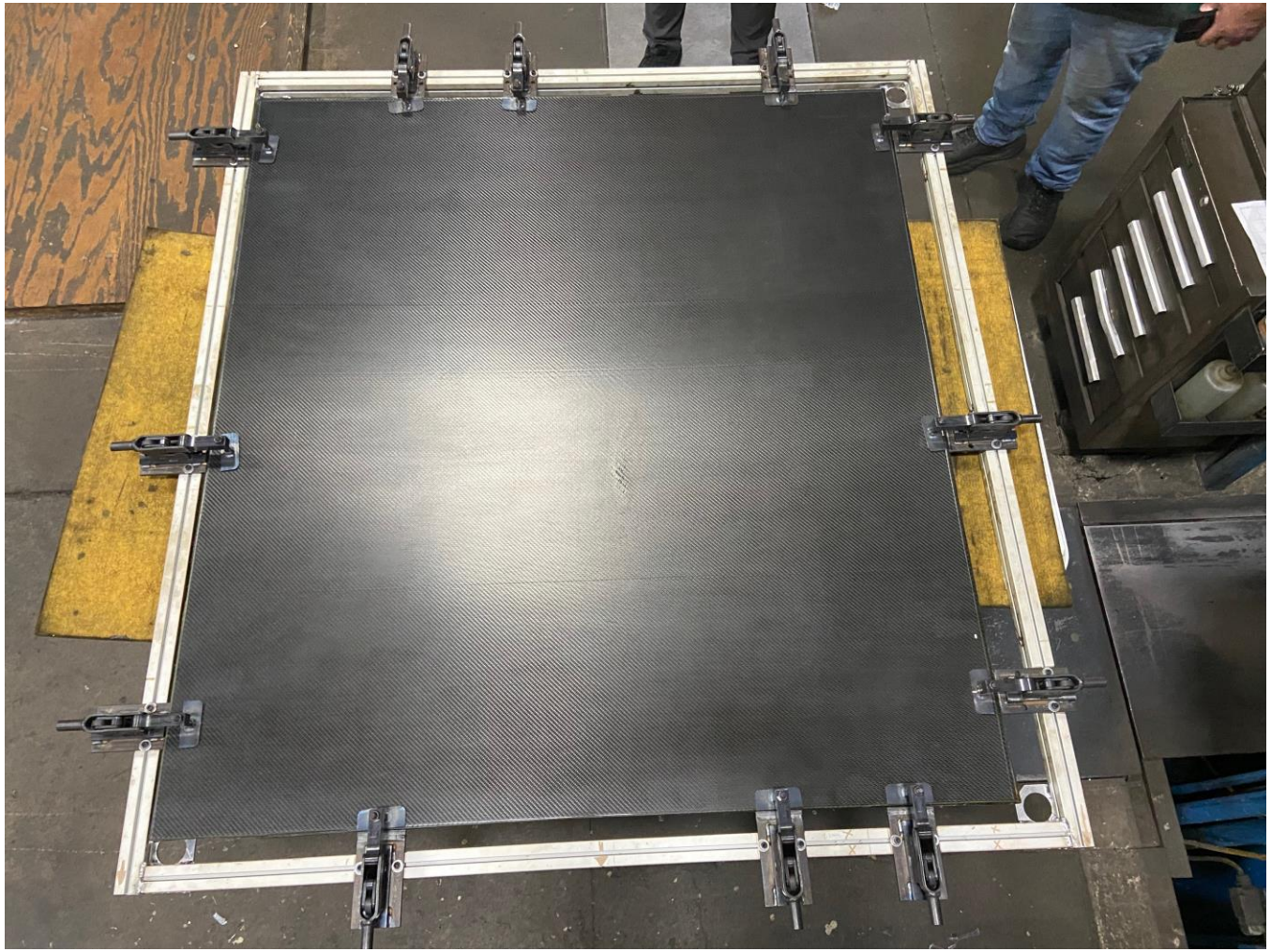
BLANK SETUP ON HANDLING SYSTEM



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CART DESIGN

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Ultra-lightweight Carbon Fiber Reinforced Thermoplastic Composite Door Assembly

Sai Aditya Pradeep, Aditya Yerra, Anmol Kothari, , Madhura Limaye, Alireza Zarei, Amit M Deshpande, Gang Li, and Srikanth Pilla

Pal Swaminathan

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Ryan Hahnlen and Duane Detwiler

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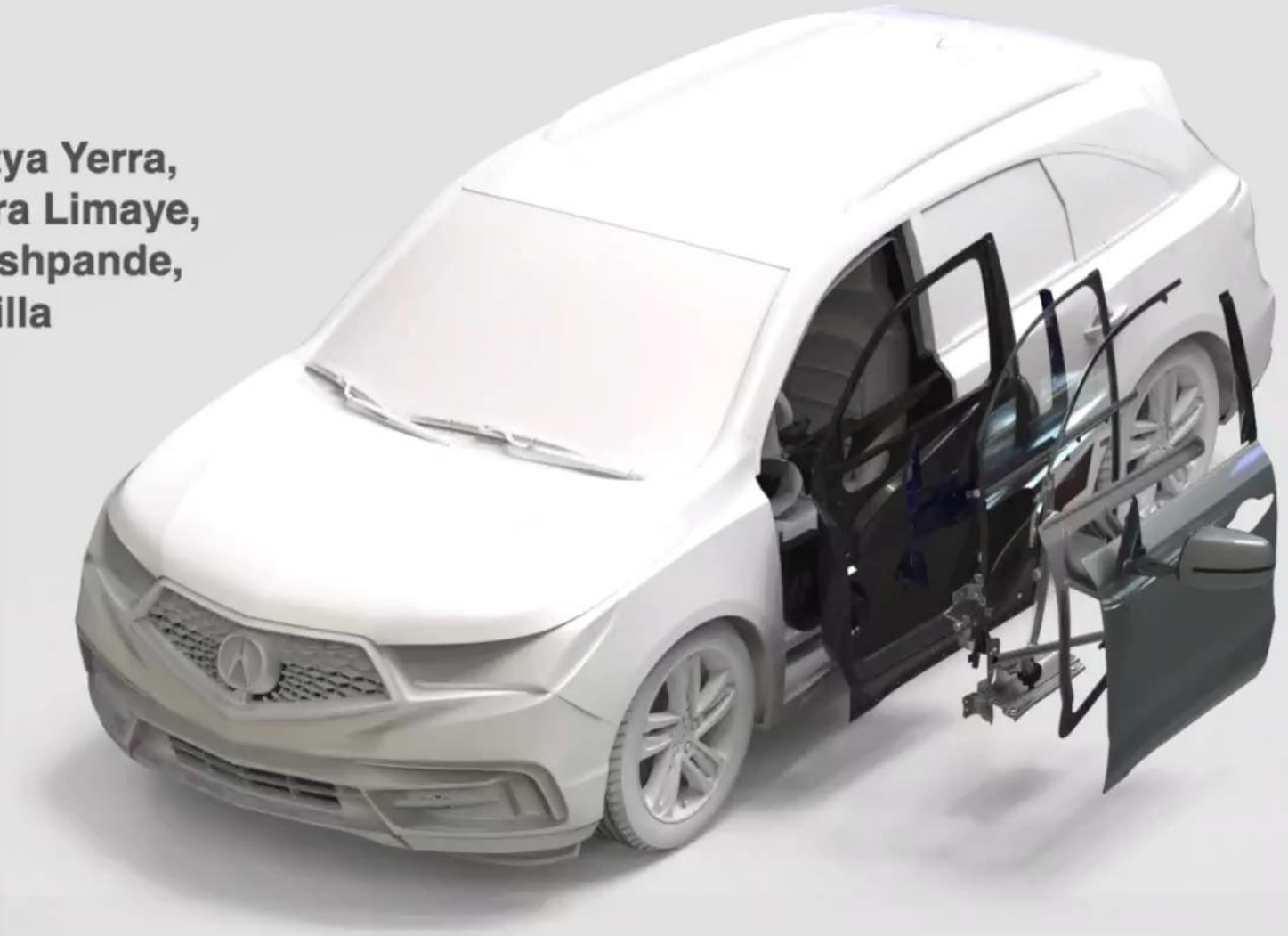

CYCLE TIME STUDY

- Heating time : 30 mins (driven by convection heater, cart and handling system) => Oxidation of material
- **IR Heating (Estimated): ~3 mins**
- Team was able to optimize manual handling time to be under 40 sec
- Automated handling could drive this down to under 10 sec

Automation can help to keep the cycle time < 5 mins (estimated)

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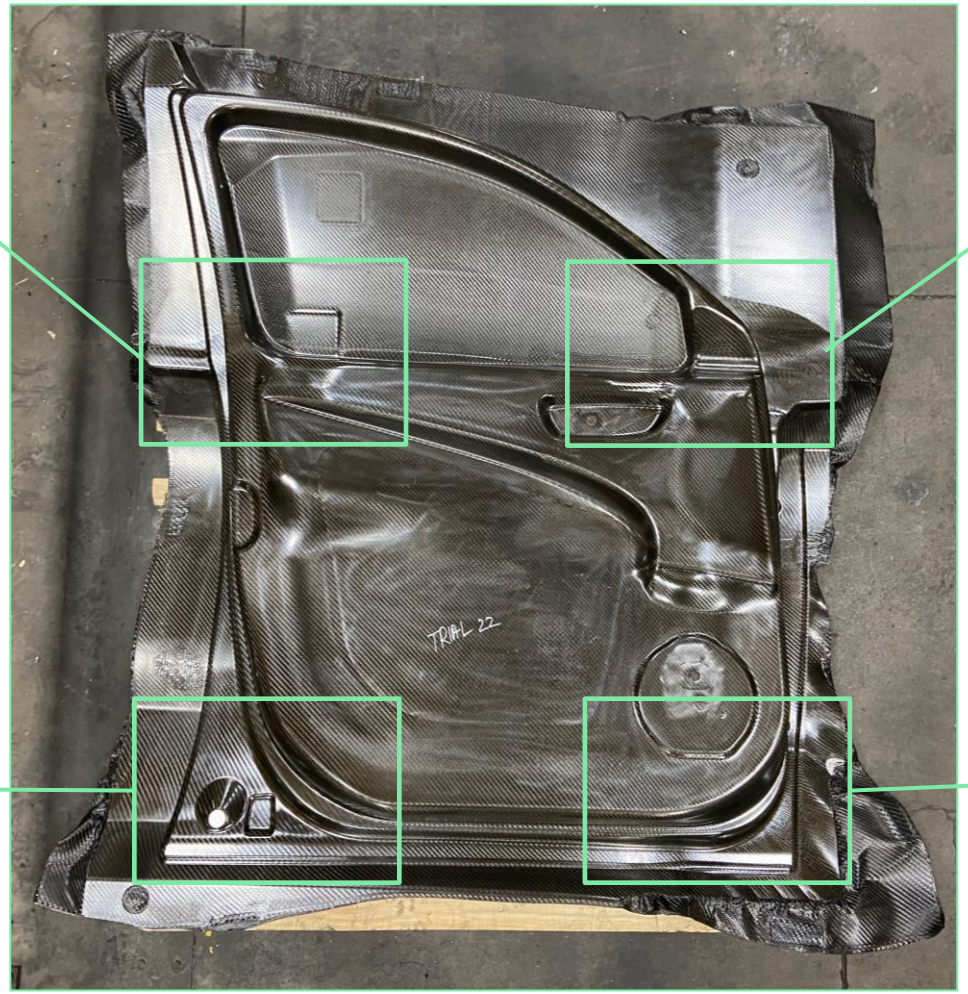
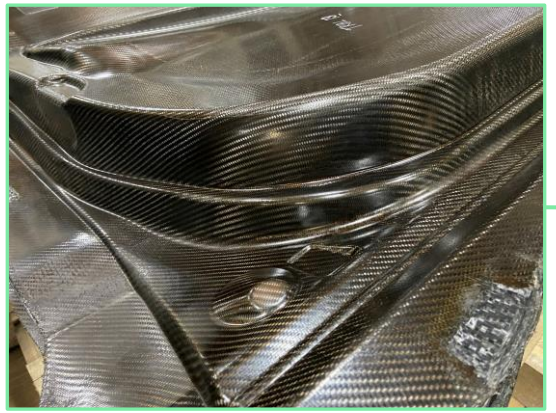
FINISHED PART

FINISHED PART





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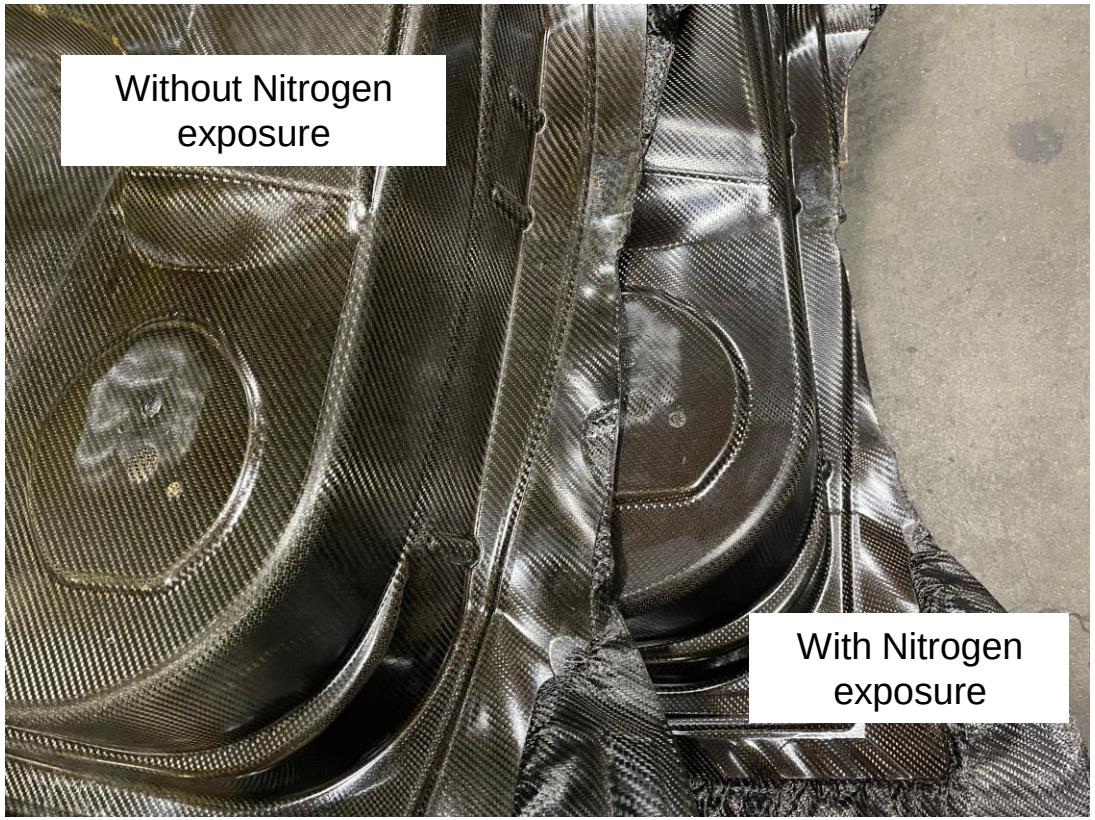
OXIDATION ISSUES

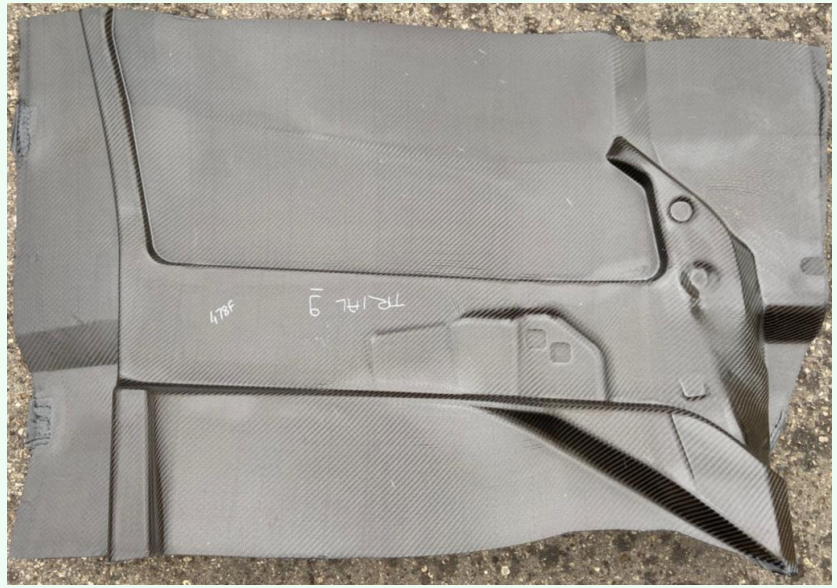


The addition of Nitrogen increased the heating time

02

Manufacturing

Belt Line Stiffener



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HANDLING SYSTEM

Ultra-lightweight Carbon Fiber Reinforced Thermoplastic Composite Door Assembly

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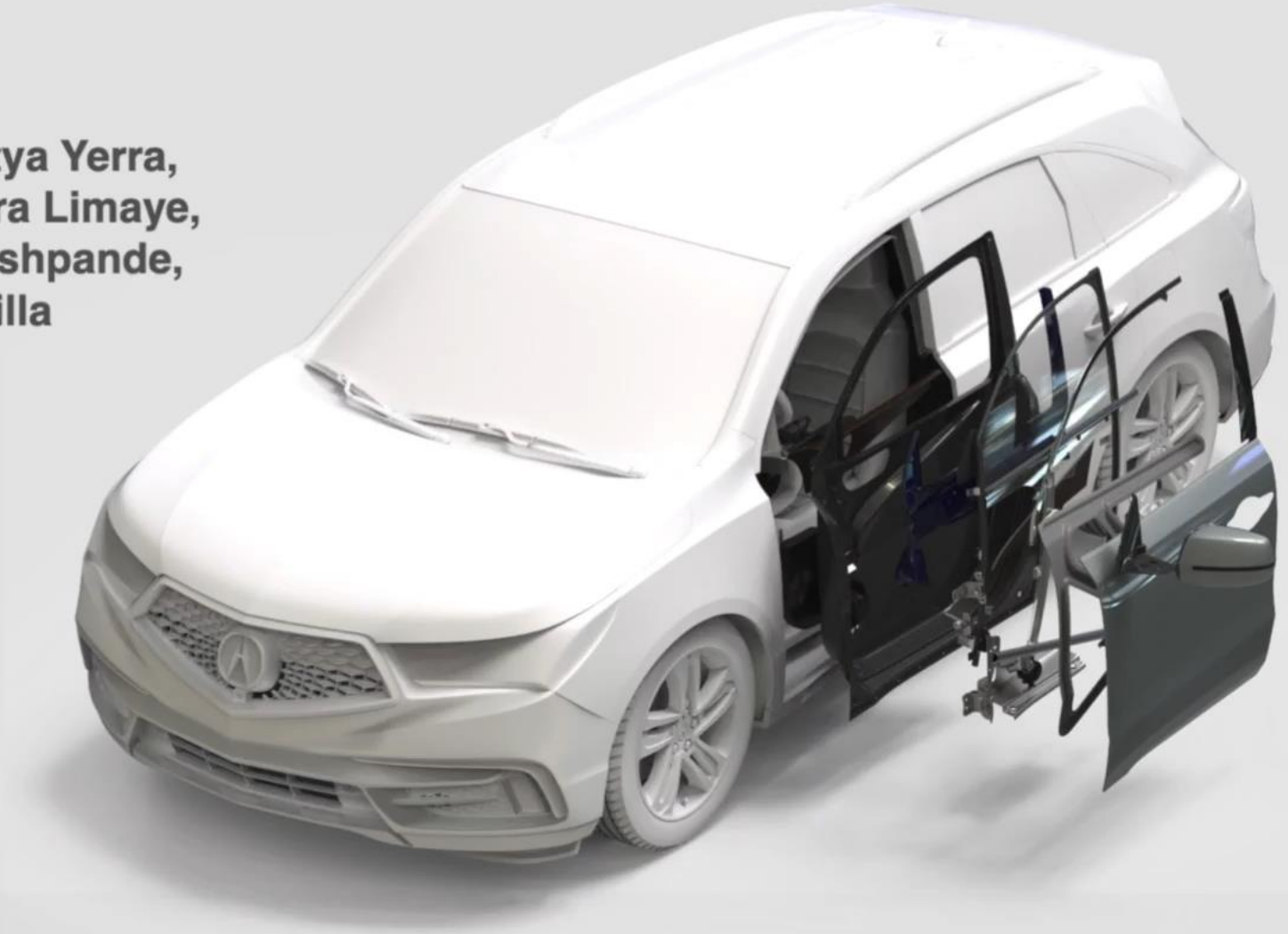

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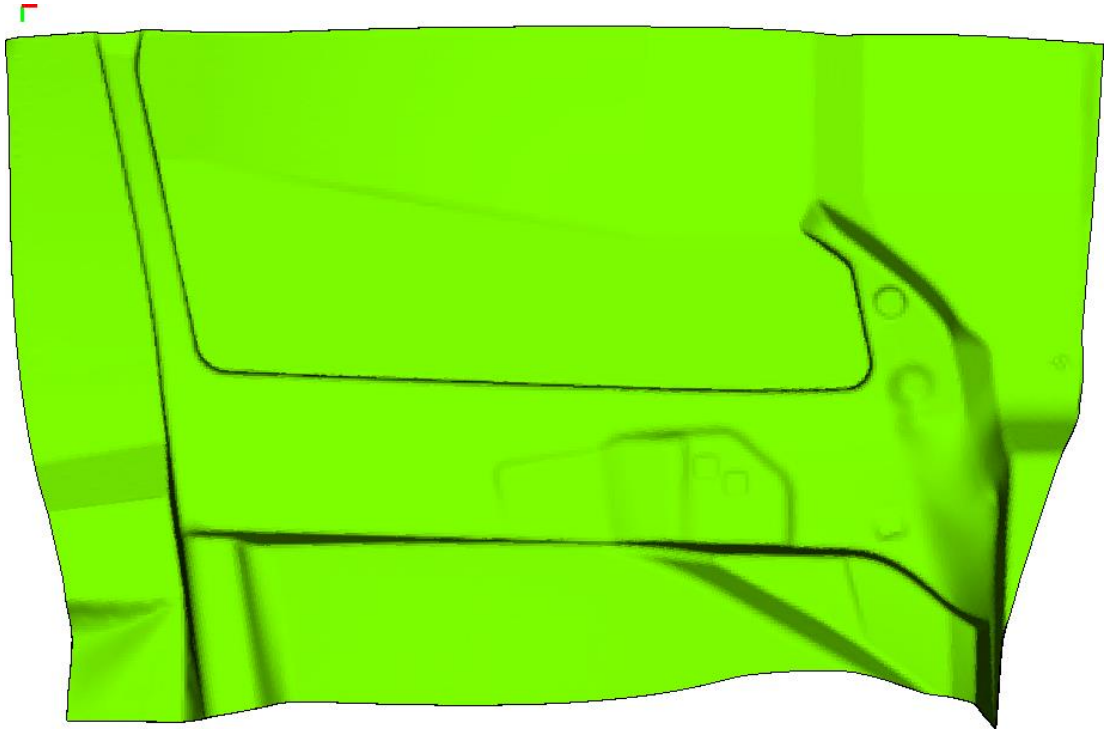
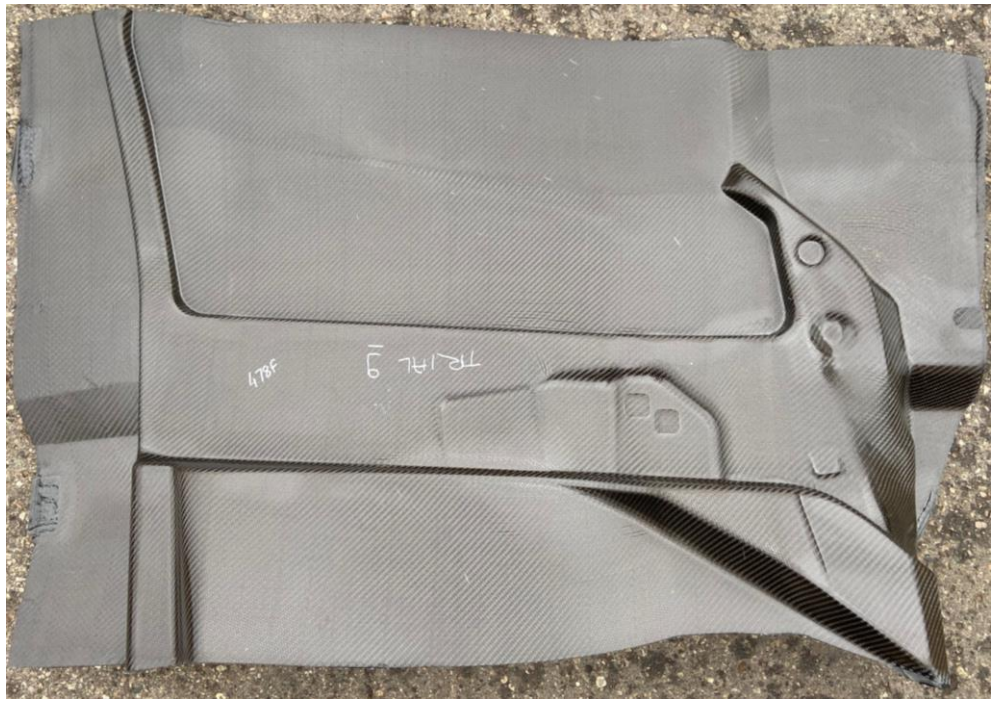
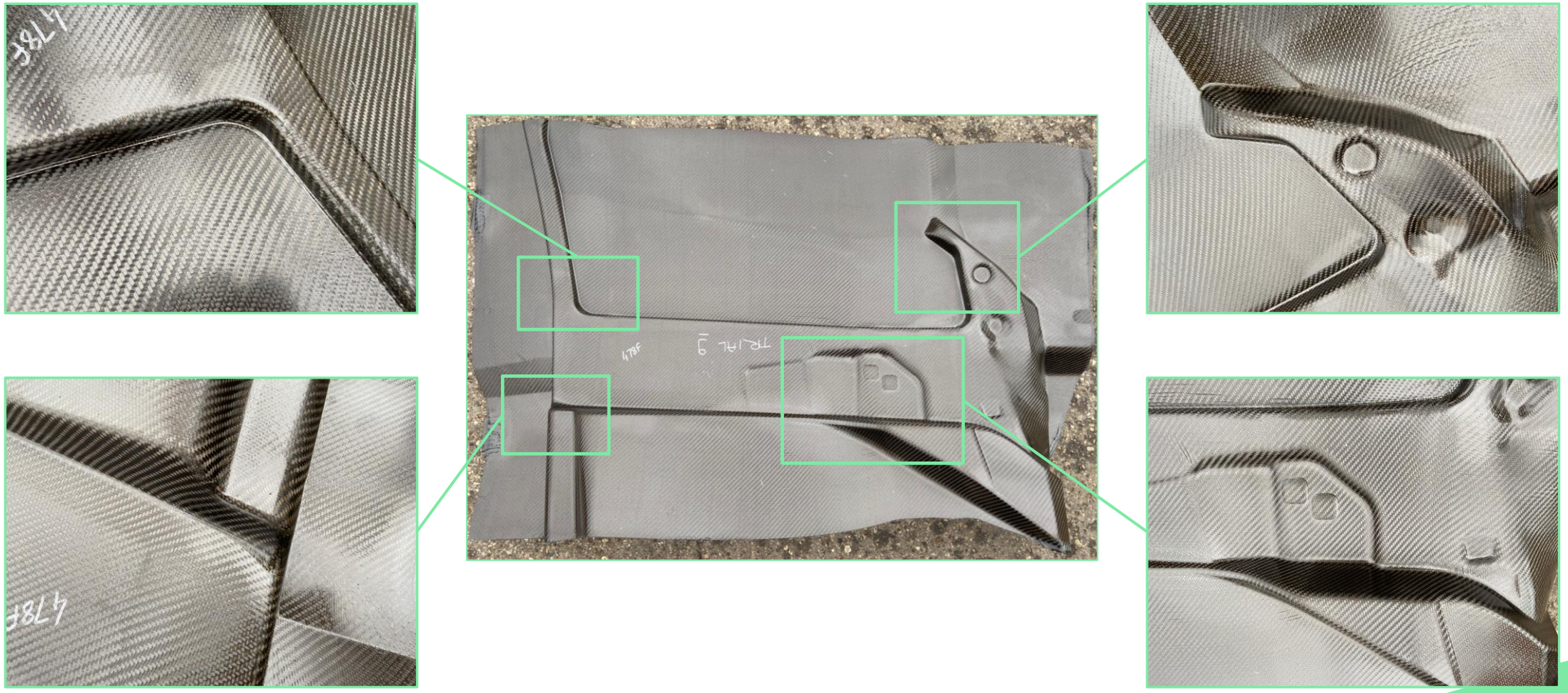




FINISHED PART



TEAM WORK – THANK YOU

Clemson Composites Center
Sai Aditya Pradeep (Research Professional)
Aditya Yerra, Amit Deshpande, Alireza (PhD Students)
Sushil, Ashir, Senthil, Akash (Masters Students)
David Kirk, Rick Martin, Gary Mathis, Megha Patel (Staff)

Clemson Mechanical
Dr. Gang Li (Faculty)
Istemi Ozoy (Staff)
Anmol Kothari, Madhura Limaye (PhD Students)
Pardhvi Shah, Gaurav Dalal (Master's Students)

Center for Composite Materials
Dr. Shridhar Yarlagadda (Research Professional)
Bazle Haque, Laxmanan, Edward and Nick (Staff)
Lukas Fussel (PhD Student)

ENVALIOR (BOND-LAMINATES)
Pal Swaminathan

Proper Tooling
Bruno Mariani, Mike Tabbert (Partner)
Dave, Rob, Mike (Hourly)

Honda
Duane Detwiler (Chief Engineer)
Skye Malcolm, Ryan Hahnlen (Principal Engineers)

Department of Energy
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