AERLYTE

Thermopastic structural composites for sustainable weight reduction of automotive components

Automotive Composite Conference & Exhibition

Chris Johnston, Prof. Dr.-Ing. Frank Henning

Novi, Michigan

September 6 - 8th, 2023

Agenda

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Material performance
Applications

02. Thermoplastic Skid Plate Development

Development Goals

Global Technology Award

Virtual design

Automated Manufacturing

03. Multi-piece hybrid truck box

Enabling innovation through shared expertise–Team

Development of structural floor panel

04. Virtual Design & Testing

Water absorption

Mechanical test of floor panel

05. Summary & Outlook

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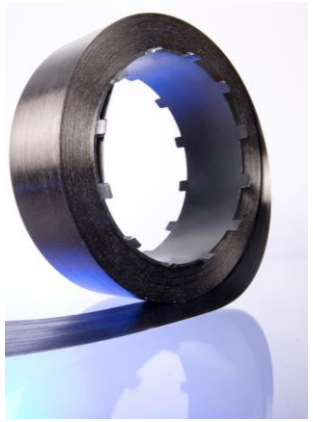
Aerlyte‘s Mission

Enabling the evolution of advanced polymer composite materials and systems through the introduction of **low-cost sustainable thermoplastic composite tapes and technologies** for their economical and ecological manufacture and conversion into parts.



Why Thermoplastics ?

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- Higher elongation at break and toughness than thermosets
- Recyclable for a circular economy
- Less knowledge about the chemical reactions required
- Semi-finished products can be stored unlimited time in a suitable environment
- Clean, easy, low-emission and fast processing
- Tack-free handling of material compared to reactive thermosets
- Suitable for robust mass production
- Weldable

Why Composite Tape - Glass

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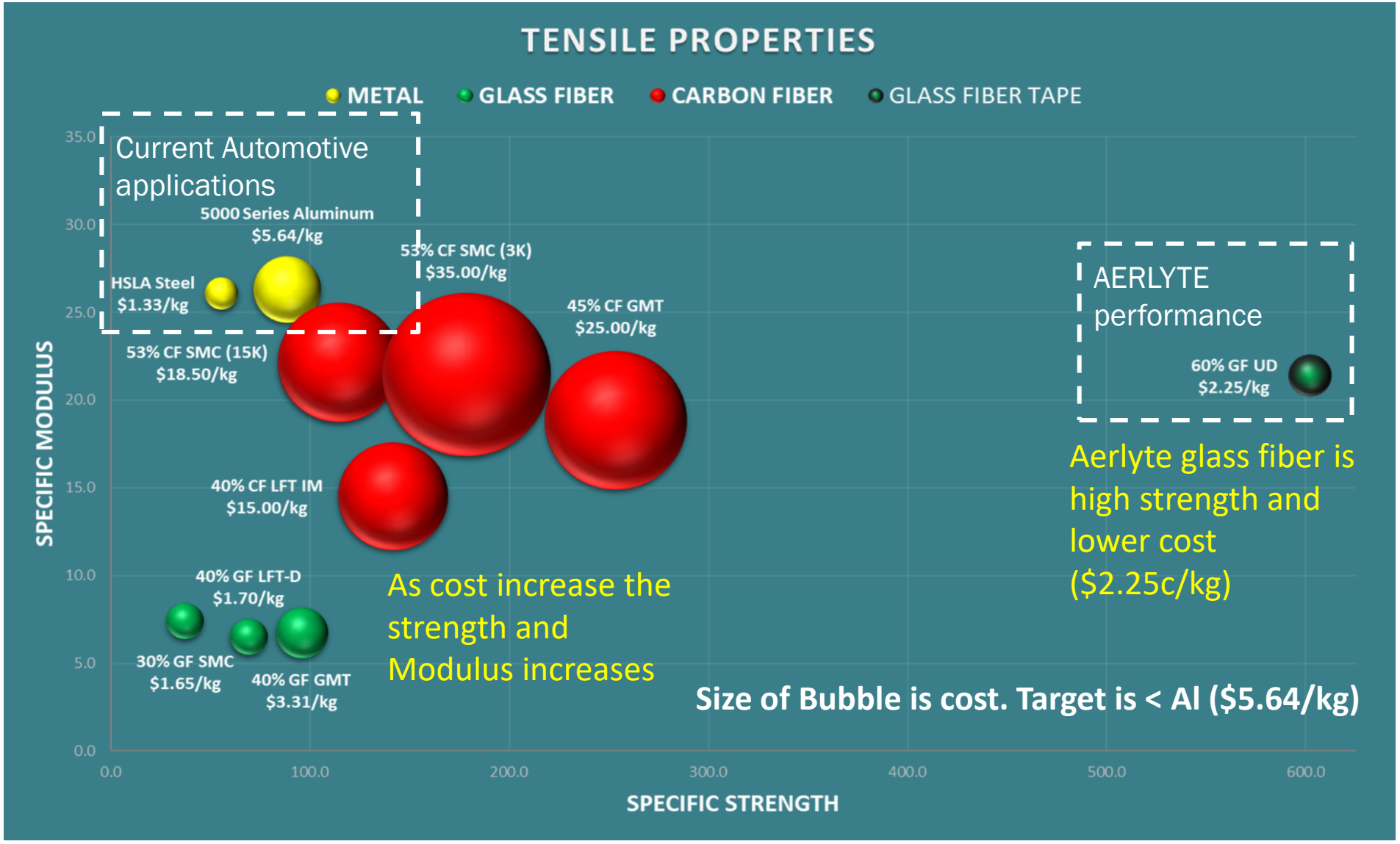
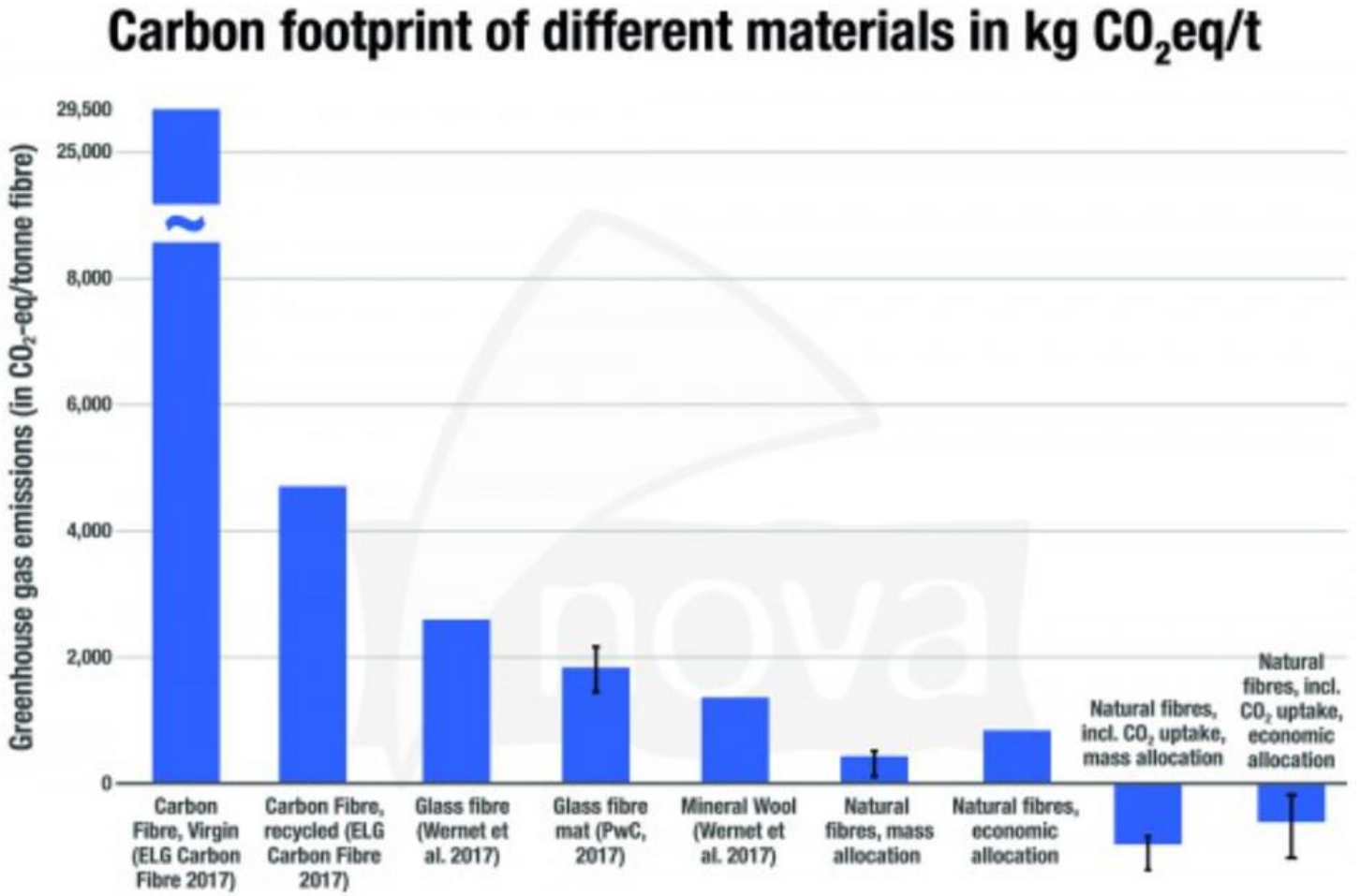


PERFORMANCE - Emission reduction

93% Emission reduction.

The production of 1kg of carbon fibres has a carbon footprint of about 29.5 kg CO2-eq per kg of fibre, whereas glass fibre only have a carbon footprint of about 1.7-2.5 kg CO2-eq per kg of fiber

(Reference - Steel - 2.75 kg of CO2 is emitted, aluminum, 8 kg of CO2)



Why Composite Tape - Carbon

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Applications

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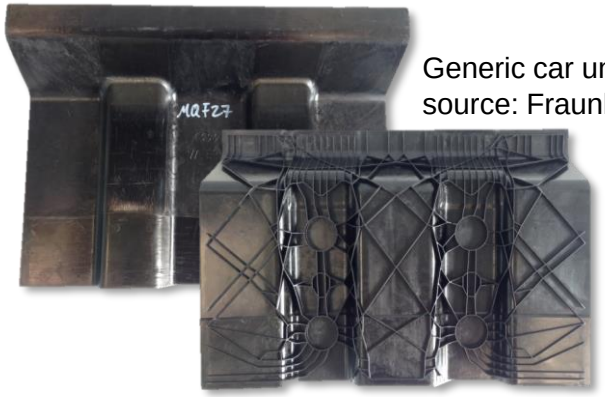

Generic car underbody floor
source: Fraunhofer ICT / MAI qFast

Bracket
source: Tri-Mack

Door module
source: Brose

Seat structure
source: Fraunhofer ICT / MoPaHyb

Side-member
source: Faurecia/Fraunhofer ICT

Hybrid car underbody floor
source: Fraunhofer ICT / Smile

Door module
source: Fraunhofer ICT /
EU ForTape

Latest Developments

Thermoplastic Skid Plate

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Continuous Fiber Reinforced Thermoplastic Skid Plate for Toyota Tundra

Achievements

- Reduce Weight
- Save Space
- Improve Performance
- Reduce Cost
- Reduce Components
- Improve Fuel Efficiency
- Reduce CO2 Emissions

- Solution: utilizing best-of-class materials for the application
- Composites can provide these optimizations

Global Technology Award

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Global First Application For A Continuous Fiber Thermoplastic Laminate For The Skid Plate and the recipient of a Global Technology award from Toyota

Original Skid Plate assembly consisted of 9 steel components stamped, welded and E-coated weighing 4,350g

Continuous Fiber Tape based Thermoplastic Laminate

superior impact performance compared to steel, aluminum, GMT, and SMC < 750g net weight

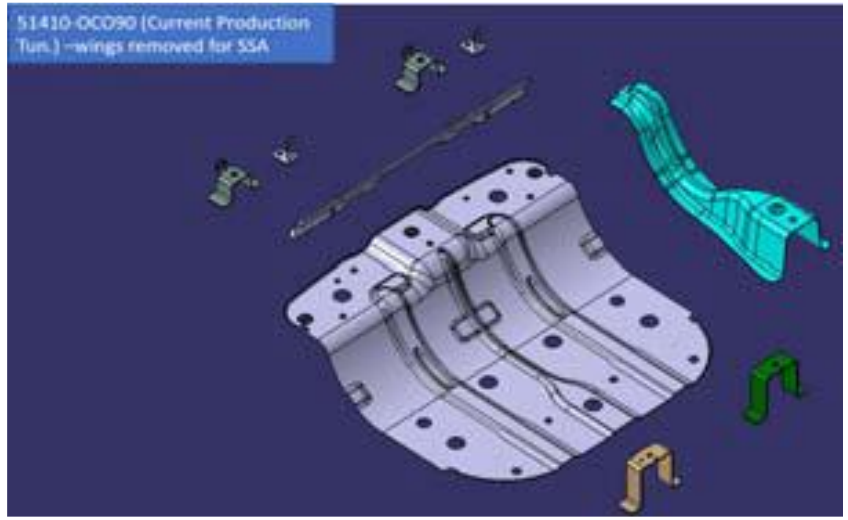
capability to achieve < 45s cycle time

Developed a Unique Thermoforming method that delivers a cosmetically pleasing surface in a completely automated process.

Corrosion and dent resistant

Marwood and Aerlyte collaborated to launch a commercial scale, high volume automated production line

The part was redesigned to 5 components: 1 main thermoformed skid plate, 4 collars



TOYOTA

MARWOOD

Virtual design for manufacturing

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Simutence Support

- Utilizing a standardized process for the virtual design of thermoforming processes with tape laminates
- Application to the undercover protection (skid plate)

Project partners

TOYOTA

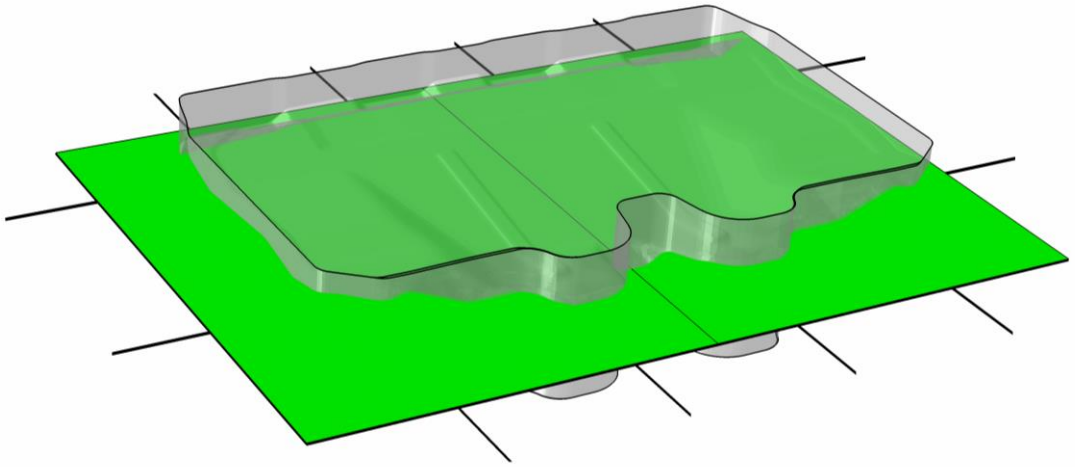
SIMUTENCE
Digital Composites Engineering

AERLYTE

Western UNIVERSITY · CANADA

in cooperation with Fraunhofer

SIMUTENCE
Digital Composites Engineering



Thermoforming simulation of an undercover protection (skid plate)

Virtual design of thermoforming process

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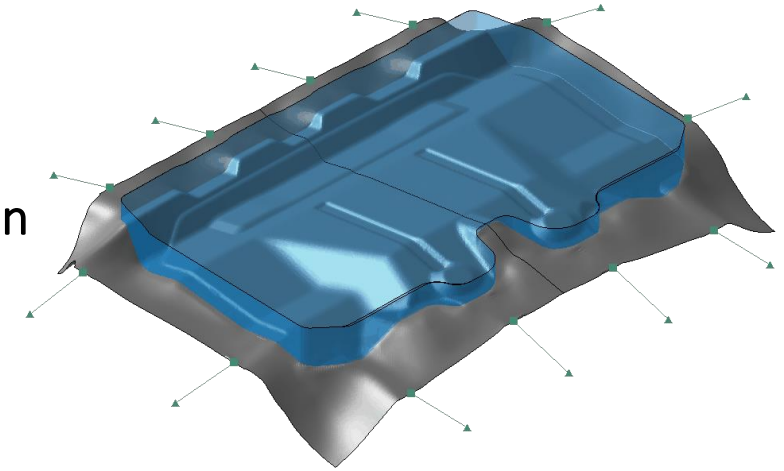
Preparation

SIMUTENCE
Digital Composites Engineering

1 Materials characterization and analysis
- Shearing, bending, slipping
- Thermal and kinetical behavior

2 Part analysis & tool definition
- CAD | Part-as-molded
- Analysis | Tip angle & center of gravity
- CAD | Tool concept and surfaces for forming simulation
- Analysis | Laminate loading plane

Iterative execution



3 Forming simulation & optimization
- FEM | Model setup, test, and optimization
- FEM | Analysis of manufacturability and optimization of processing parameters
- Analysis | Tailored blank size & maximum mold block size

4 Reporting & closing
- Standardized reporting
- Transfer of CAD (part as-molded & gripper setup)

Finalization

Automated Manufacturing

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Marwood has high level of experience in the metal stamping and hot forming processes

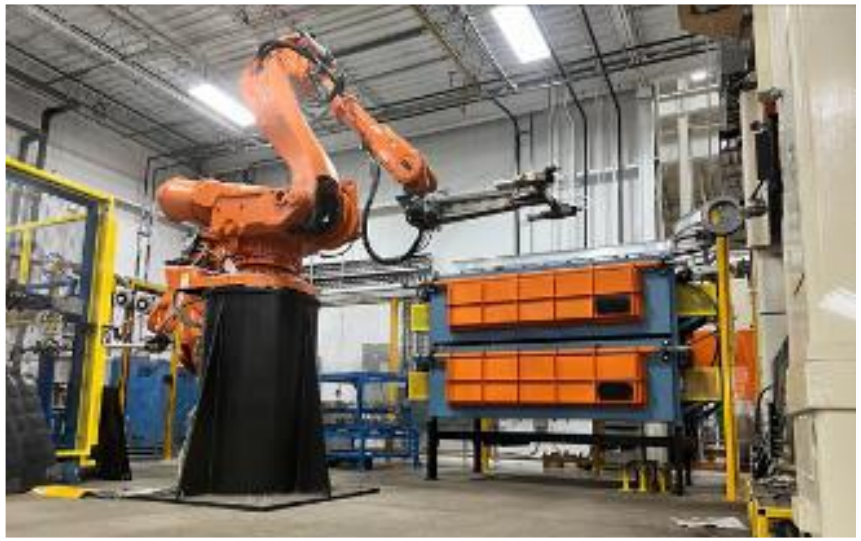
Additionally, Marwood has in-house press and automation capabilities

High-speed heating and composite thermoforming cell for converting pre-laminated sheets into formed components

Processes steps:

- Loading of pre-laminated sheets
- Single laminate picked up and transferred into oven
- Heating laminate above melt temperature
- Rapid robotic transfer from oven to mold
- Fast closing of mold, forming of part and cooling < 45 s
- Part removed and laser QR code etched into part for complete traceability anywhere using a proprietary Marwood App installed on a phone

MARWOOD



Stiffness by Smart Engineering - Joining Innovation

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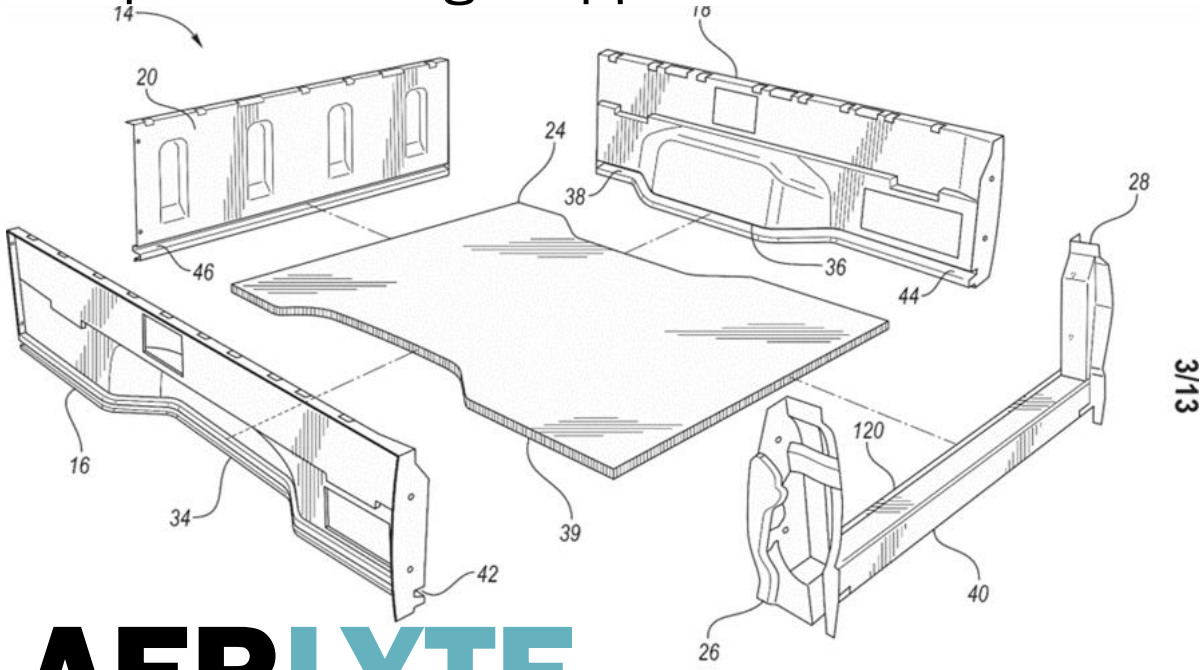
Patented Multi-Piece-Hybrid Truck Box

AERLYTE expands to larger Applications



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Prototype on display at the booth of our material partner, Johns Manville, at the April 2023 JEC World composites expo in Paris

Enabling innovation through shared expertise

Providing proprietary Neomera high performance organosheet materials, testing and expertise

Providing proprietary Covalent Intermediate Bond technology, sandwich construction and product testing

Providing proprietary Multi-Piece-Hybrid Truck Box concept – design and engineering

CAE for Assembly

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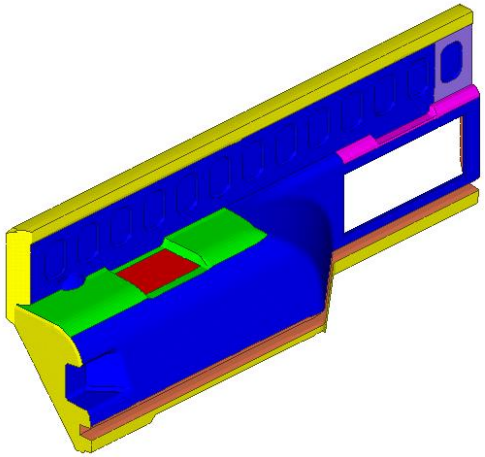
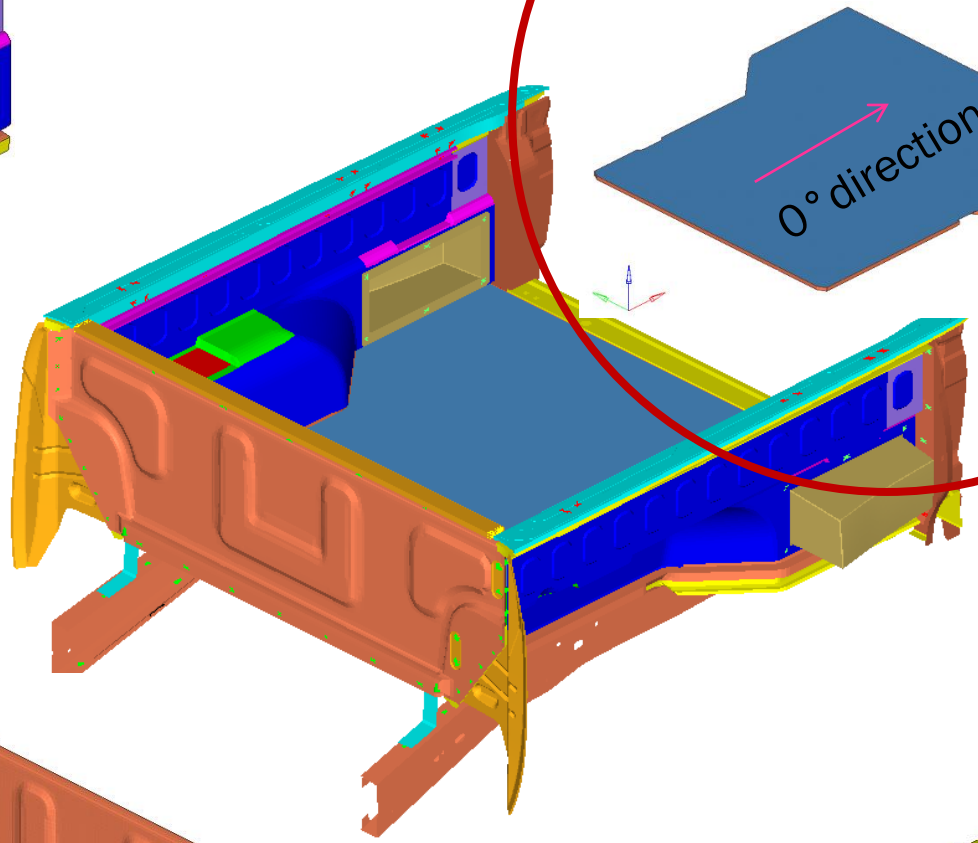
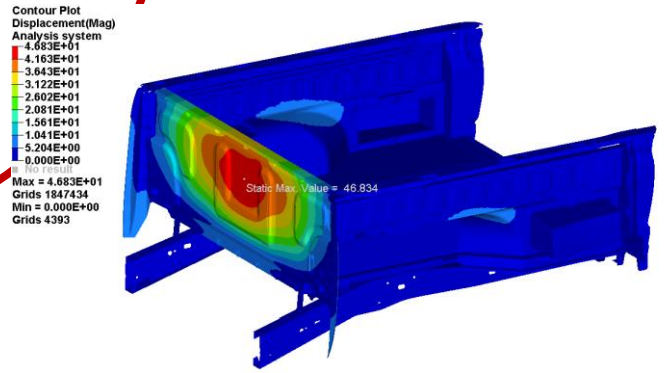
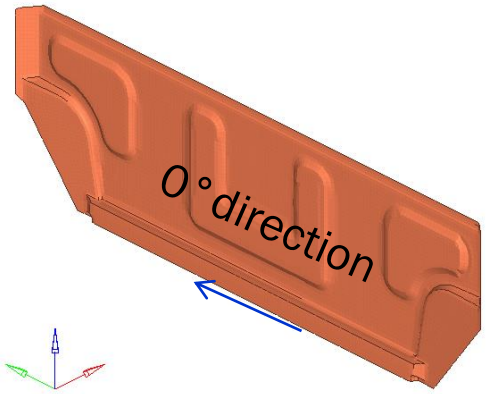


Side panel-RH
Elebment:11039
Node:11136

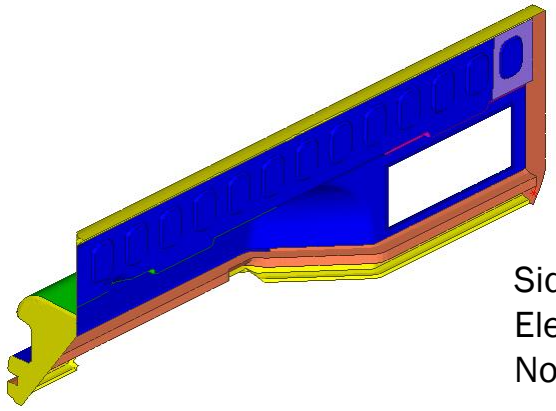


Floor
Shell element:37322
Solid element:93316





Front panel
Element ： 8620
Node :8498



Side panel-LH
Elebment:11011
Node:11105

Development of structural floor panel

Improvement of stiffness by sandwich floor design

Performance material selection

- JM Neomera® organosheet
- HD PET Foam Core
- AGESIA CIB welding

Leading to

- Tougher skin – high impact, strength,…)
- Higher density – high compression resistance
- Cohesive skin-core bond

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Johns Manville

AGESIA
STRUCTURAL COMPOSITE TECHNOLOGY

Neomera® Organosheet by Johns Manville

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Fiber reinforcement

+

PA-6 polymer matrix

=

- variety: GF, CF, hybrid options
- isotropy level can be built-into the fabric/ chopped fibers

- polymer produced *in-situ*
- high molecular weight
- no thermal degradation
- recyclable

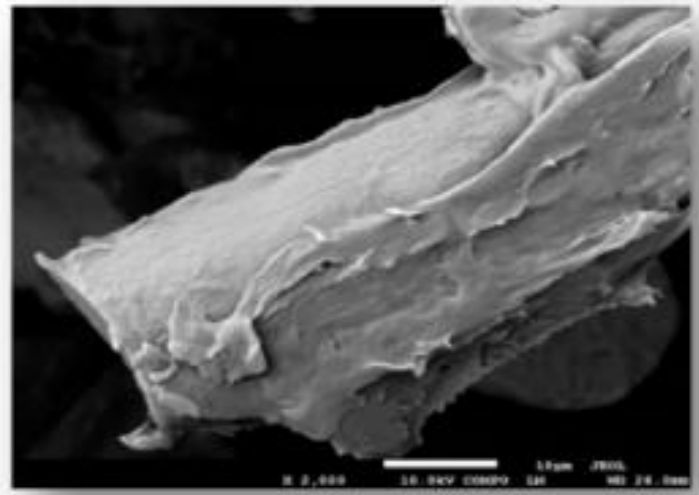
- cost effective due to continuous manufacturing process
- up to 3mm without consolidation
- easy to handle unlimited shelf life
- suitable for conventional processing methods

Johns Manville NeoMera®

Proprietary process of JM

Additional interface performance advantages for glass fiber reinforcements

JM Reactive Glass Technology



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Johns Manville

Neomera® Organosheet by Johns Manville

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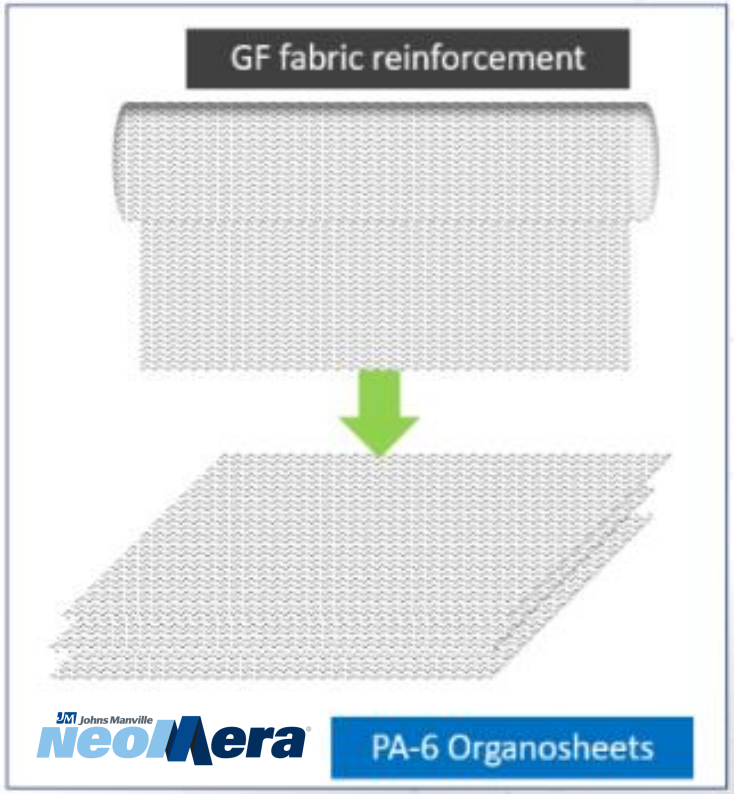
JM technology for PA-6 organosheets

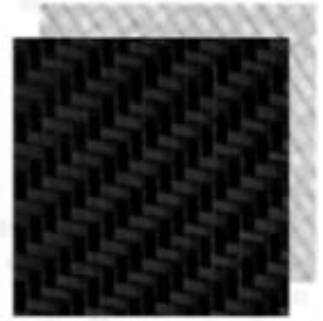
JM Johns Manville NeoMera®



JM Technology (Anionic Polymerization)

Caprolactam impregnation & *in-situ* polymerization

- **low** viscosity caprolactam
- **low** reaction temperature
- **low** cost
- **low** carbon footprint
- **high** molecular weight PA6
- **high** throughput
- **high** value for money
- **fully** recyclable



- Pioneering technology
- **Proprietary continuous manufacturing process**
- **Demonstrated for fabrics and chopped fiber reinforcements**

Provided by:
Johns Manville

Advantages of Johns Manville NeoMera®

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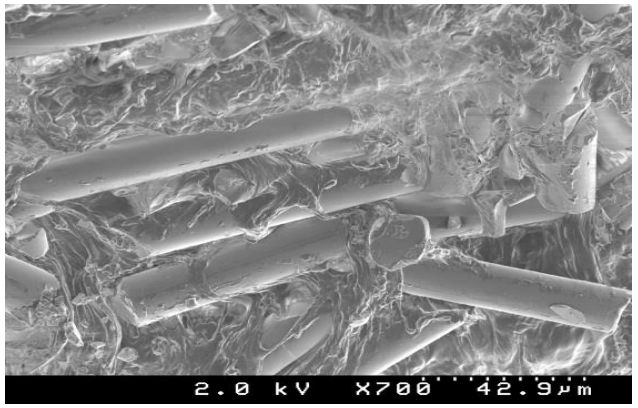
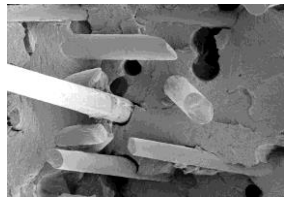
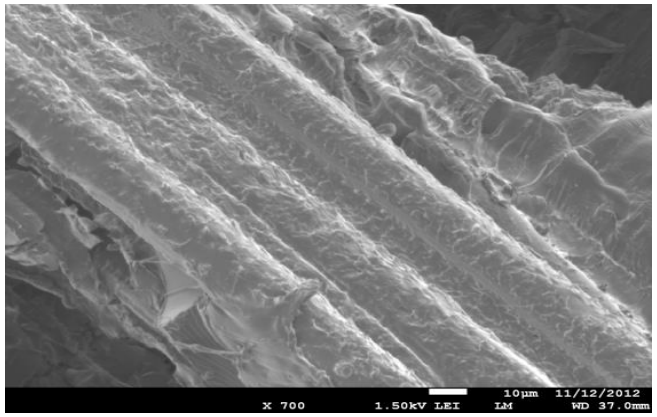
JM StarRov® 886 is key to Neomera® performance

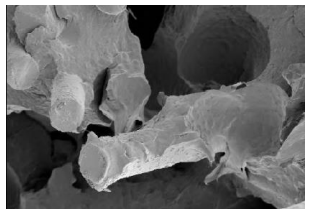
Weak fiber-resin bonding
Failure at fiber/resin interface due
To bonded activator groups





Strong fiber-resin bonding
Failure in resin matrix because of
glass grafting with PA-6





Advantages

- Unique IP protected product
- High heat resistance – short term 200° - long term 180°
- Single-step process – cost efficient
- High degree of polymerization – high molecular weight
- No thermal degradation:
  reaction @165°C – melting >215°C
- Fire resistant without additives

Covalent Intermediate Bonding CIB

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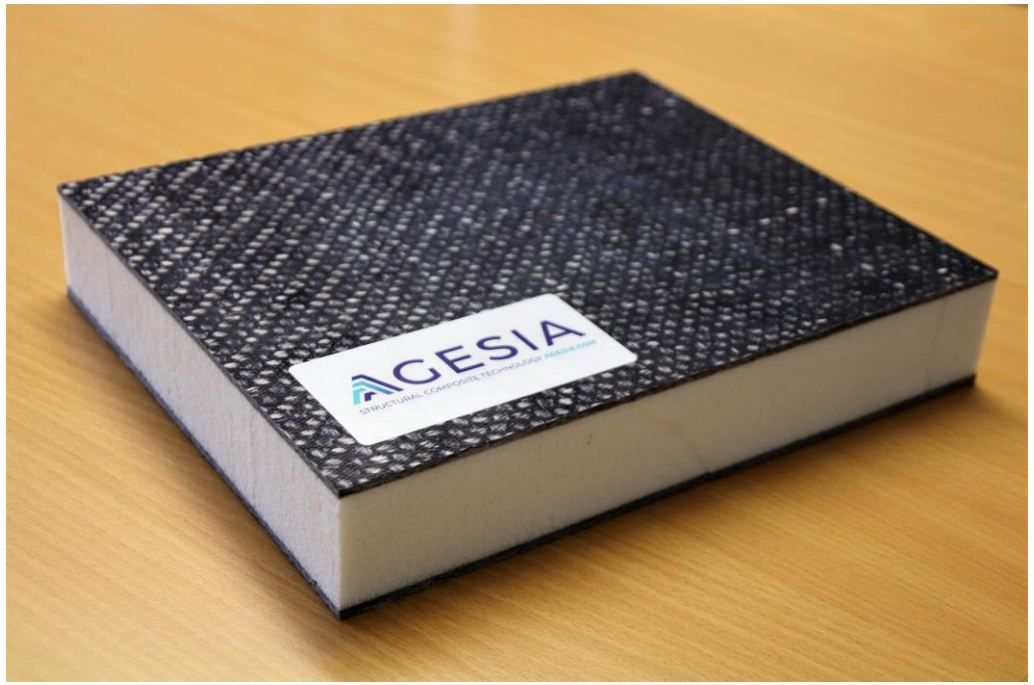
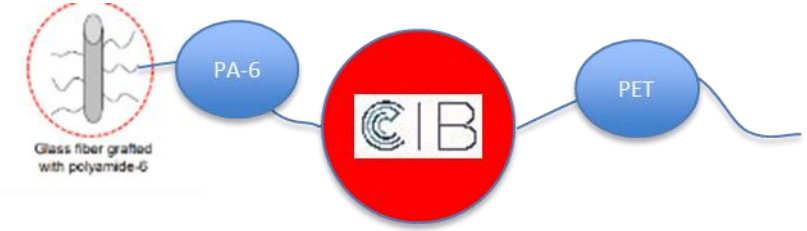


CIB
COVALENT INTERMEDIATE BONDING

Provided by:

AGESIA
STRUCTURAL COMPOSITE TECHNOLOGY

- CIB® process opens the PET and PA-6 molecules
- Under low pressure and low temperature, PA-6 and PET chains are connected
- Covalent Bonding
- Due to the covalent bonding of PA-6 to the sized glass in the Neomera process, the PET is in one chain over CIB connected to the glass.



Water absorption of sandwich

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Test: 30 hours in 60°C water

- ❑ + 0,75% Weight increase
- ❑ - 7% E-Modulus decrease

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Sandwich panel truck floor Testing

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- Panel top 3mm OS-6 + 12,5mm PET-foam density 120g/l + bottom panel 2mm OS-6
- Load 600kg
- >352000 cycles 100mm up + 100mm down
- 20 cycles 200 mm up + 200mm down

No damage or plastic deformation

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Sandwich panel truck floor Fatique

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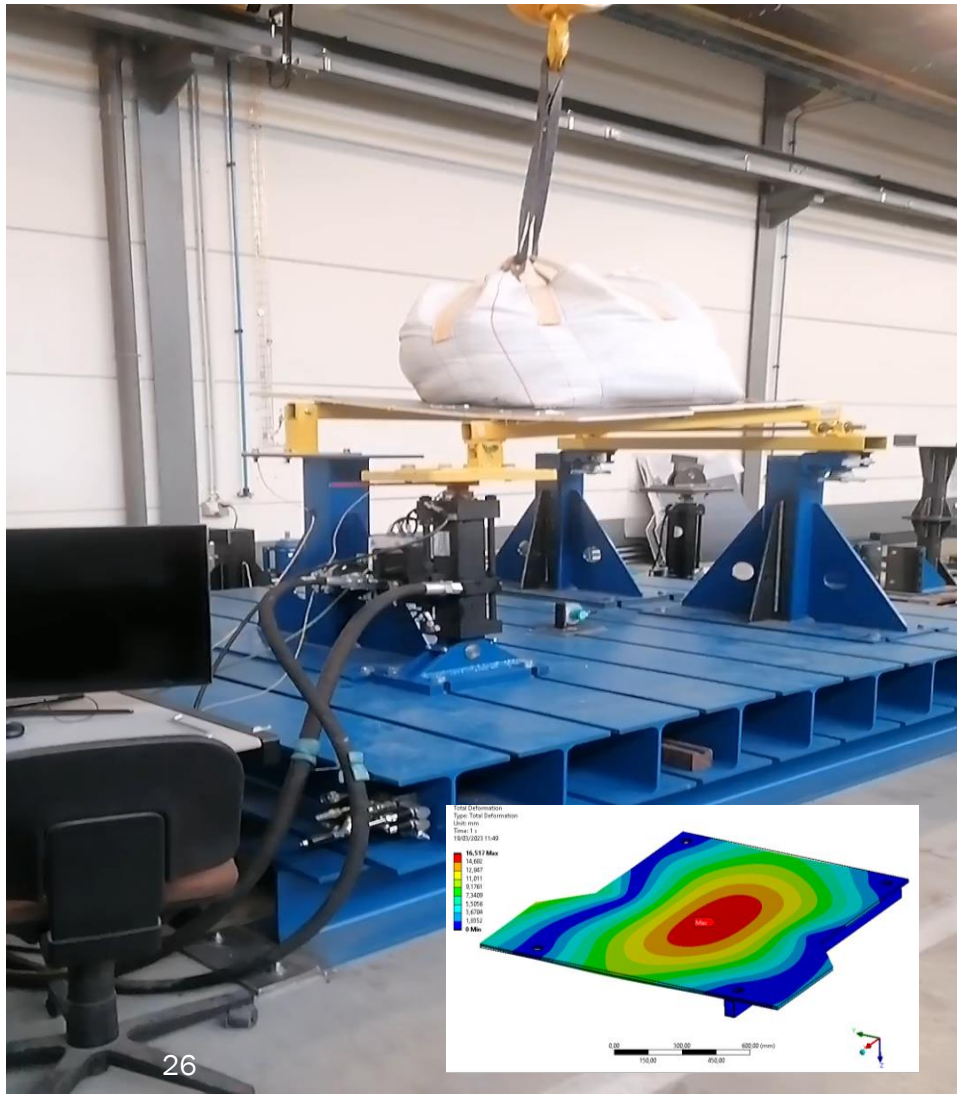

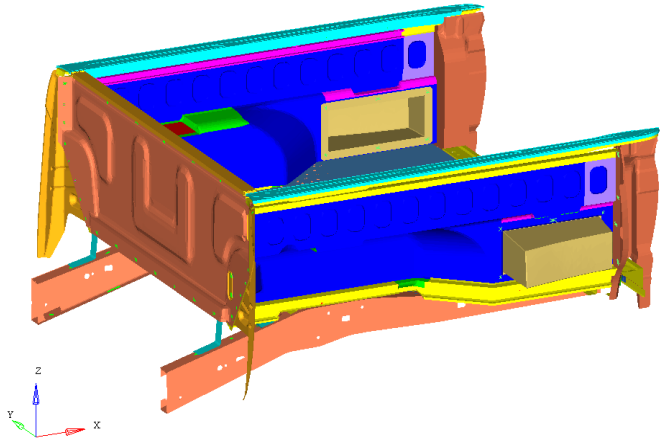

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STRUCTURAL COMPOSITE TECHNOLOGY

JM
Johns Manville

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No damage or plastic deformation

Provided by:
AGESIA
STRUCTURAL COMPOSITE TECHNOLOGY

Truck floor Load Bearing Test

AGESIA STRUCTURAL COMPOSITE TECHNOLOGY

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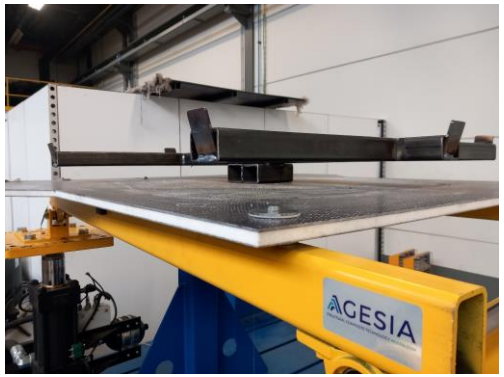
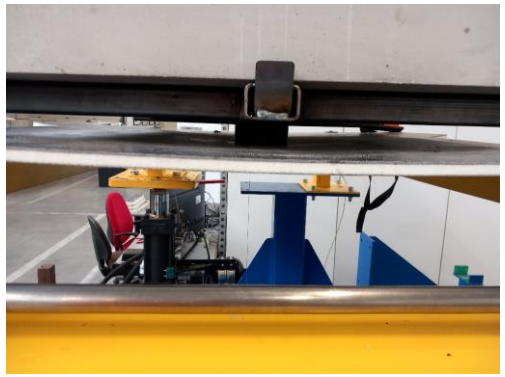
- Load surface 150 x 160mm
- Perfect linear behaviour
- No damage
- After removal weights, no plastic deformation.
- Defection returned to 0 mm

Johns Manville



Frame



1 Ton

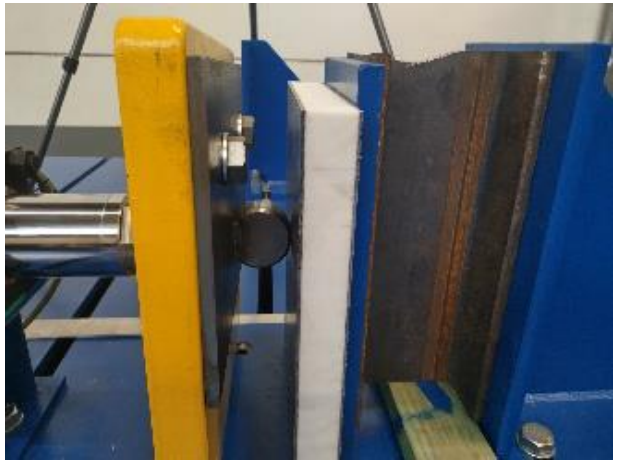
2 Ton

3 Ton

Metal frame touches panel

AGESIA STRUCTURAL COMPOSITE TECHNOLOGY

Steel pallet cart wheel test for heavy truck trailor panel



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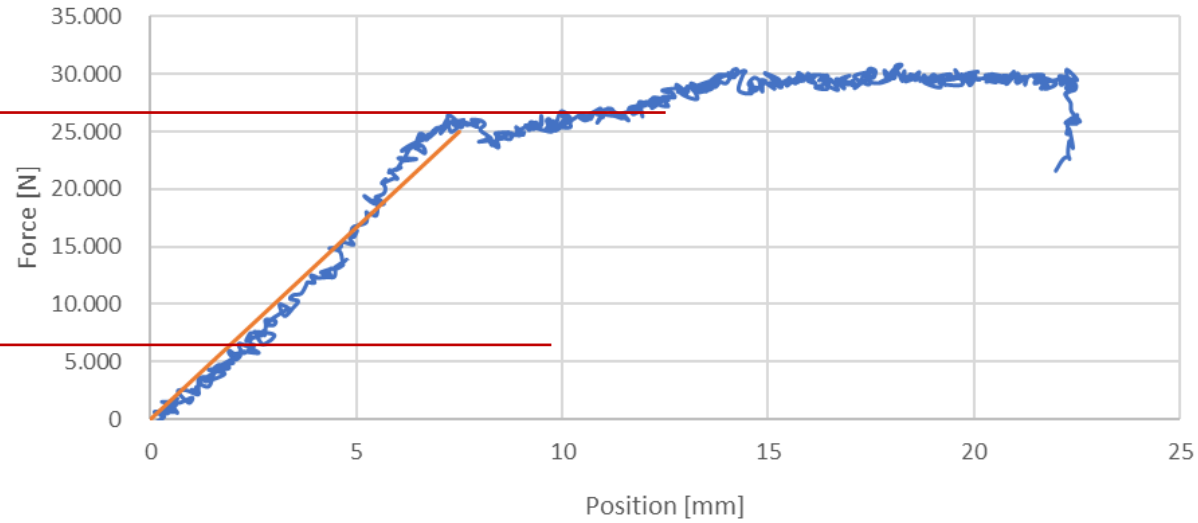
JM Johns Manville

Local impact
(Steel pallet cart wheel)

3mm OS-6 40mm PET foam 3mm OS-6

Local Collaps: 25 kN

Required: 7 kN



Provided by:
AGESIA STRUCTURAL COMPOSITE TECHNOLOGY

Comparison with existing material solutions

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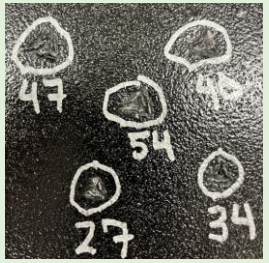
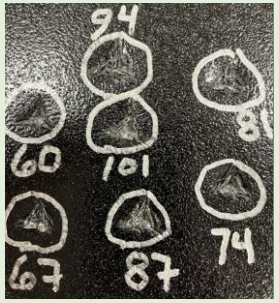
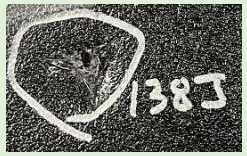
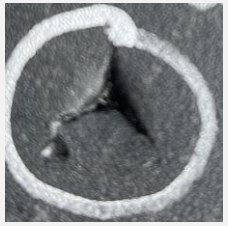
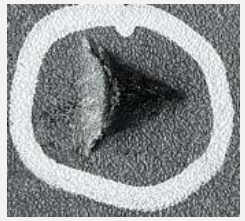
Impact Energy (J)	SMC Frontside	SMC Backside	Result
27			Significant structural damage as the crack propagates through the material. Note that the through crack on the Backside is much larget that the front side. And that the SMC once damaged in this manner is damaged forever as a structural element.
34			
34			

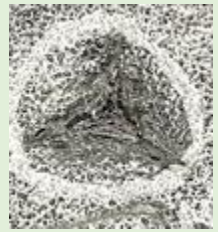
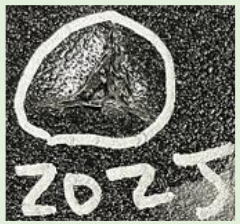
Impact Energy (J)	Aerlyte Frontside	Aerlyte Backside	Result
27, 34, 40, 47, 54		No damage	Only small damage to the front face. Crack does not propogate as it is stopped by the continuous glass fiber fabric. Composite panel remains a structural ememt
60, 67, 74, 81, 87, 94, 101		No damage	
138		No damage	
147		No damage	

Test results provided by

TOYOTA

The Aerlyte/Johns Manville/ Agesia Composite floor is remarkably more impact resistant than SMC and PA6/CF and remains a structural element after being impacted

Product	Impact Energy (J)	PA6/CF Frontside	PA6/CF Backside	Result
Truck Bed on Market	27			Test results provided by TOYOTA Significant structural damage as the crack propagates through the material. Note that the through crack on the Backside is much larget that the front side. And that the PA6/CF material once damaged in this manner is damaged forever as a structural element.
	34			
	40			
	76			

Impact Energy (J)	Aerlyte Frontside	Aerlyte Backside	Result
156			At 156J the first hint that the impact face has propagated to the Backside face.
175			B-side fabric has suffered puncture and local fiber failure but the crack does not propagate
193			
202			

Summary & Outlook

Although not fully tested yet, the partner expect best in class specifications:

- Reduced mass
- Increased cargo volume
- Superior impact performance of the floor to all alternative materials such as steel, aluminum, SMC, PA6 (injection-molding grade), PA/CF random discontinuous fiber reinforced panels
    - Floor consists of a sandwich panel utilizing composite skins having continuous, aligned fibers in fiber volumes not achievable by other composite options
    - Neomera® skins being in situ polymerized PA6 offers extremely high molecular weight and toughness not achievable from PA6 IM
    - Top skin is thicker for impact
    - Bottom skin can be thinner and optimized for load carrying capacity as it does not see direct loading or impact

AERLYTE JM Johns Manville AGESIA STRUCTURAL COMPOSITE TECHNOLOGY

Summary & Outlook

Maximum design flexibility and cost

- The assembly creates a mechanically interlocking design capturing the floor without the need for fasteners or adhesives
- Each vertical component (front and side panels) can be optimized for functionality, performance, material/process (steel or aluminum stamping, PA6 IM, SMC CM
- The floor as designed is compatible with a continuous manufacturing process without the need to pocket special components like collars/compression limiters for connection with the frame
- The flat floor allows for decorative films to be applied, potentially facilitating customer provided artwork incorporated into a printed film that can be assembled to the floor and sequenced into assembly plant

AERLYTE Johns Manville AGESIA STRUCTURAL COMPOSITE TECHNOLOGY

Summary & Outlook

Maximum serviceability of the floor

- The assembly creates a mechanically interlocking design capturing the floor without the need for fasteners or adhesives This allows the floor to float within the assembly and accommodate torsional loads from the frame as the vehicle traverses uneven terrain

- The mechanically interlocking design also eliminates the need for pocketing fastening component such as collars/compression limiters into each floor which would add extensive cost and complexity in management of the high, localized stresses found at components. The floor can easily be replaced if damaged over the life of the vehicle

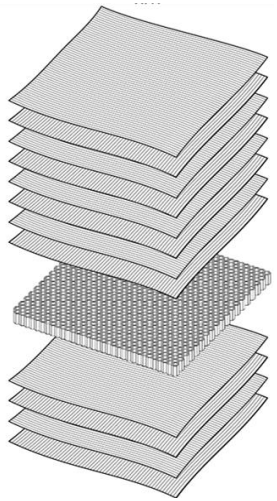
100% recyclable thermoplastics are utilized

AERLYTE Johns Manville AGESIA STRUCTURAL COMPOSITE TECHNOLOGY

Outlook

AERLYTE

- Transfer Multi Piece Truck Box in industrial applications
- **More skid plates** and protection covers to come
  → expansion of cost efficient tape based products
- **Expand cost efficient tape based products to battery cover protection** and energy absorption systems
- Transfer of **tape flakes** as cost efficient semi-finished materials to replace LFT-pellets for improved fiber length retention
- Further develop **overmolding concepts** in compression and injection molding together with our research and industrial partners
- Providing **new and tailor-made thermoplastic semi-finished material formats**
- Providing **engineering expertise** in materials, manufacturing and product development



Thank you to our partners

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TOYOTA

MARWOOD

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STRUCTURAL COMPOSITE TECHNOLOGY

SIMUTENCE
Digital Composites Engineering

Fraunhofer
ICT

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in cooperation with
Fraunhofer

Thank you!

AERLYTE

Engineered Lightweight Performance

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