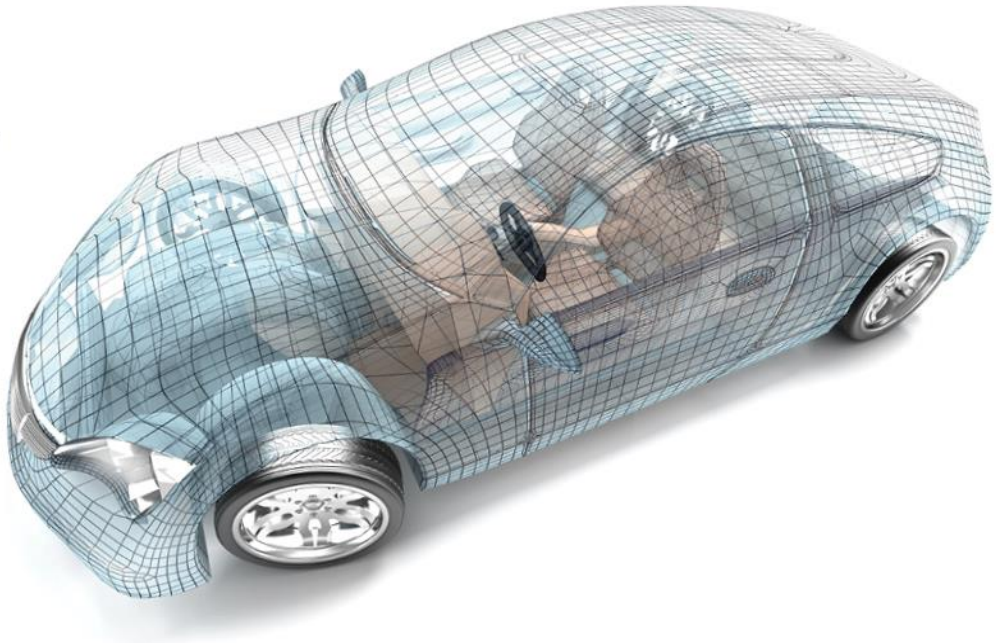
TCC 2020

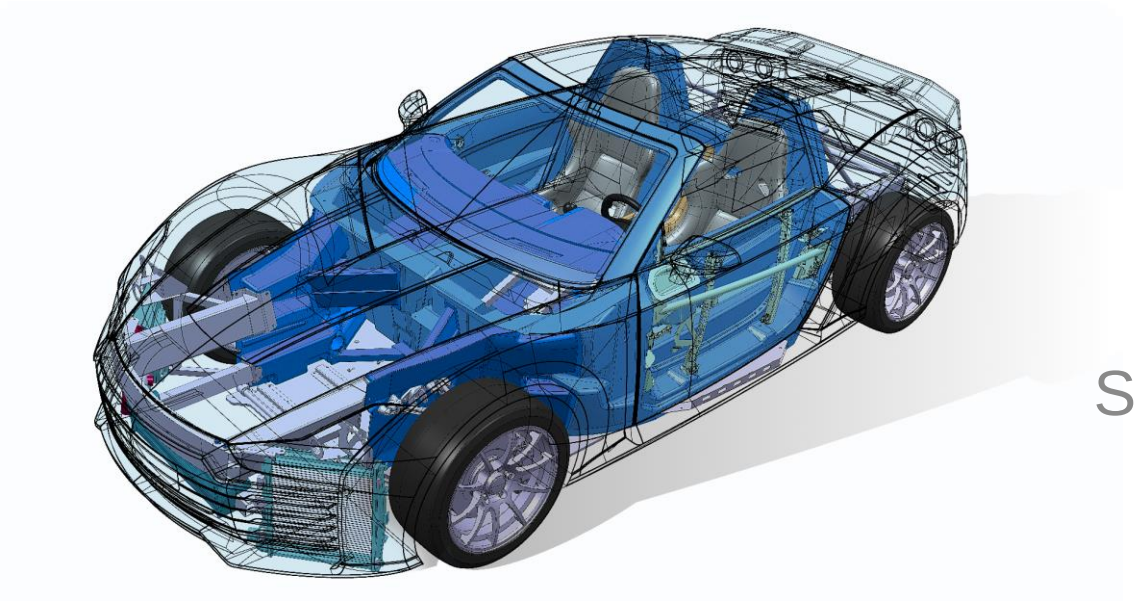
THERMOPLASTIC COMPOSITES CONFERENCE

APRIL 29 – MAY 1, 2020 | SAN DIEGO, CA, USA
HYATT REGENCY LA JOLLA AT AVENTINE



ACCELERATING THE DEPLOYMENT OF STRUCTURAL THERMOPLASTIC COMPOSITES FOR NEXT GENERATION AUTOMOTIVE AND TRANSPORTATION APPLICATIONS

Presented By: Adam Halsband
Managing Director
Forward Engineering North America



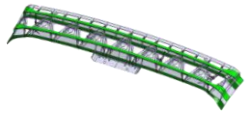
Structural Thermoplastic Composites

Solutions = **Material** + Process + Design

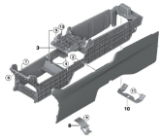
STRUCTURAL THERMOPLASTICS IN AUTOMOTIVE | EXAMPLES

Airbag Housing

Roof Crossmember & Frame



Center Console



A-B-C- Pillar Reinforcement

Front Hood Structure

Frontend Structure

Tailgate Structure

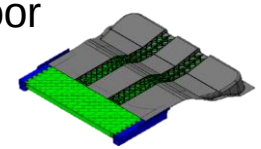
Housing Electrical Components & Sensors

Gas Tank Carrier/ Spare wheel well

Bumper Carrier, RCAR system

Rear Wall

Floor



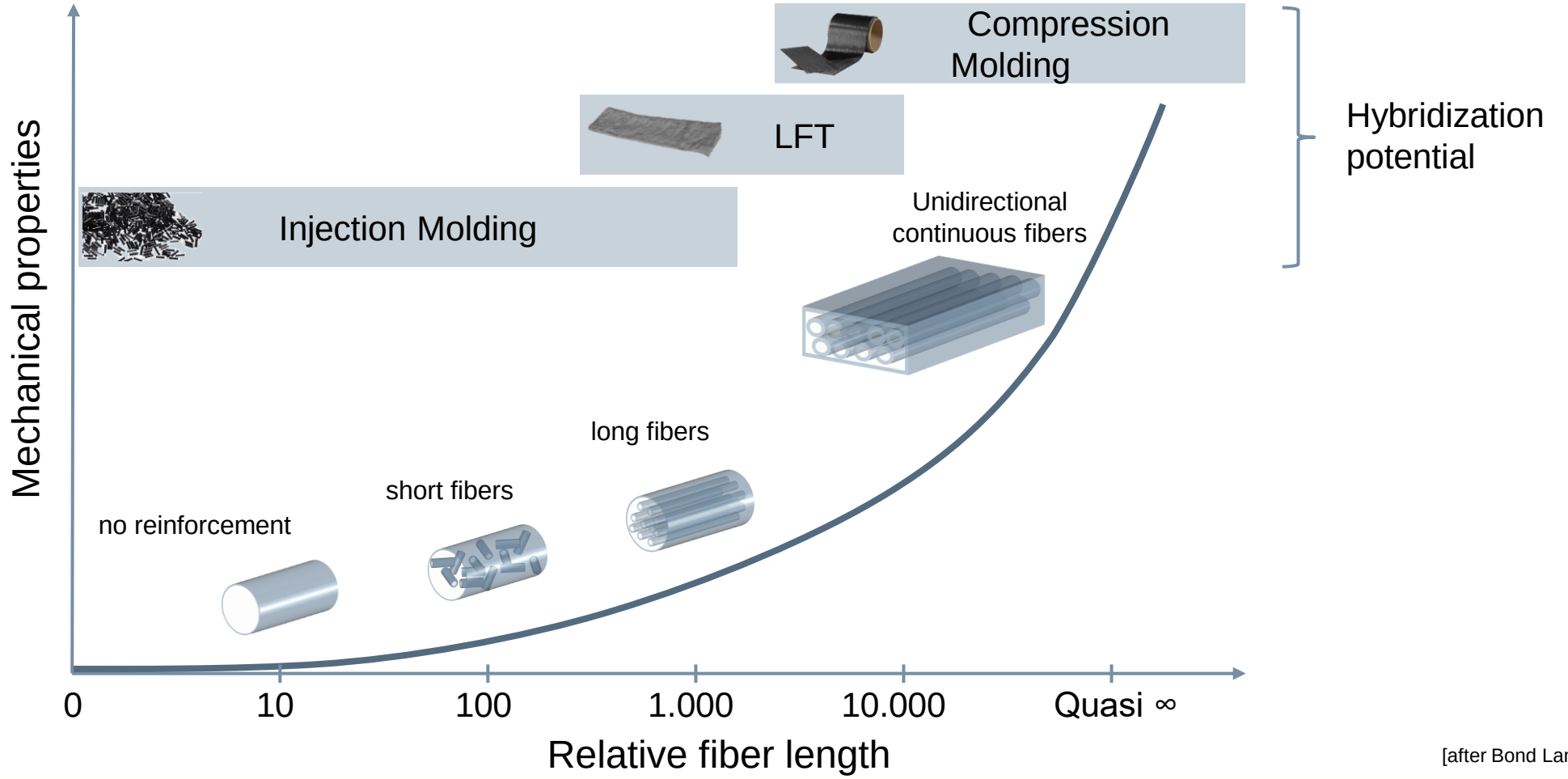
Pedalbox

Battery Housing

Door Structure & Components

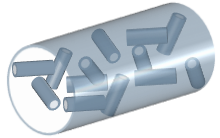
Front and Rear Seat Structures

INCREASING PERFORMANCE BY REINFORCING THERMOPLASTICS



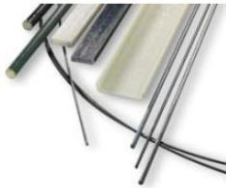
[after Bond Laminates]

SET OF MATERIALS FOR STRUCTURAL THERMOPLASTICS

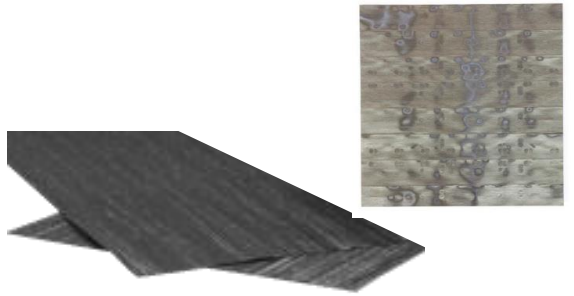


Short fiber IM-Compound
(fiber length < 1-5 mm)
- fiber content up to 60% weight
- high performance plastics

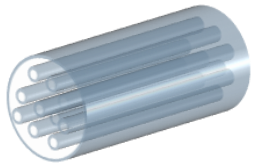
UD TAPE



PROFILES

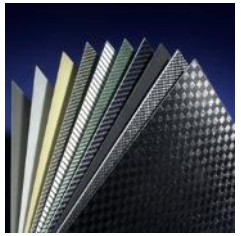


TP-SHEET
- Layup of UD-Tape

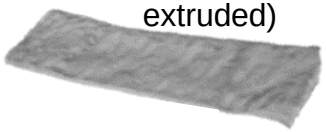


Long fiber
(fiber length 5 - 20 mm)
- IM-Compound/ Granulate
- D-LFT (Direct long fiber TP, extruded)

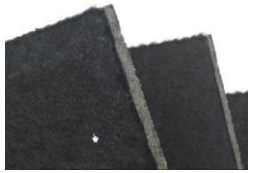
Materials for thermoplastic composites

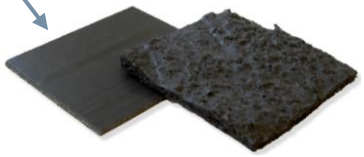


ORGANOSHEET
- Multiple layers of woven fabric
- NCF (Non crimped fabric)
- Tailor made: Organosheet + locally reinforced by Tape



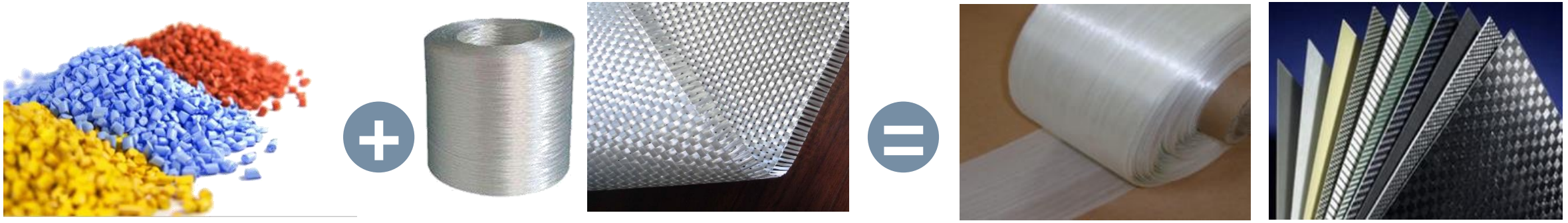
LWRT
- Light weight reinforced TP
- Sandwich material with random fibers in skin layer



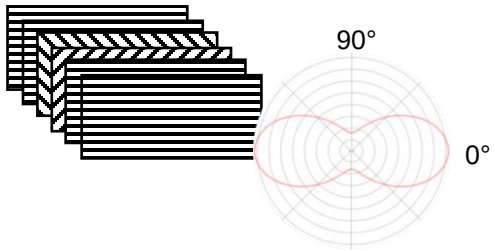
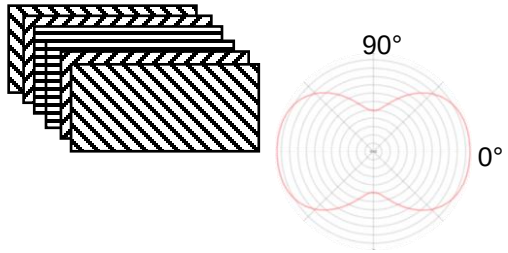
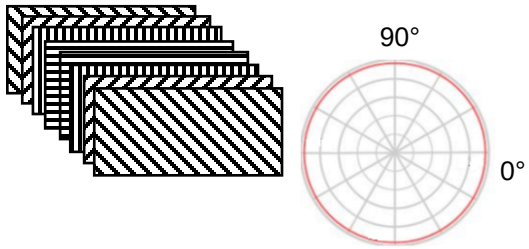
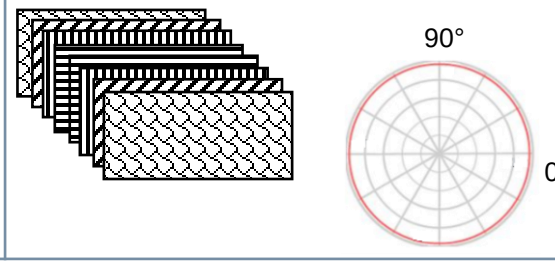


GMT/ CMT
- Consolidated sheets with random fiber orientation
- Long fiber <50-100mm

CONTINUOUS FRTP SEMI-FINISHED PRODUCTS

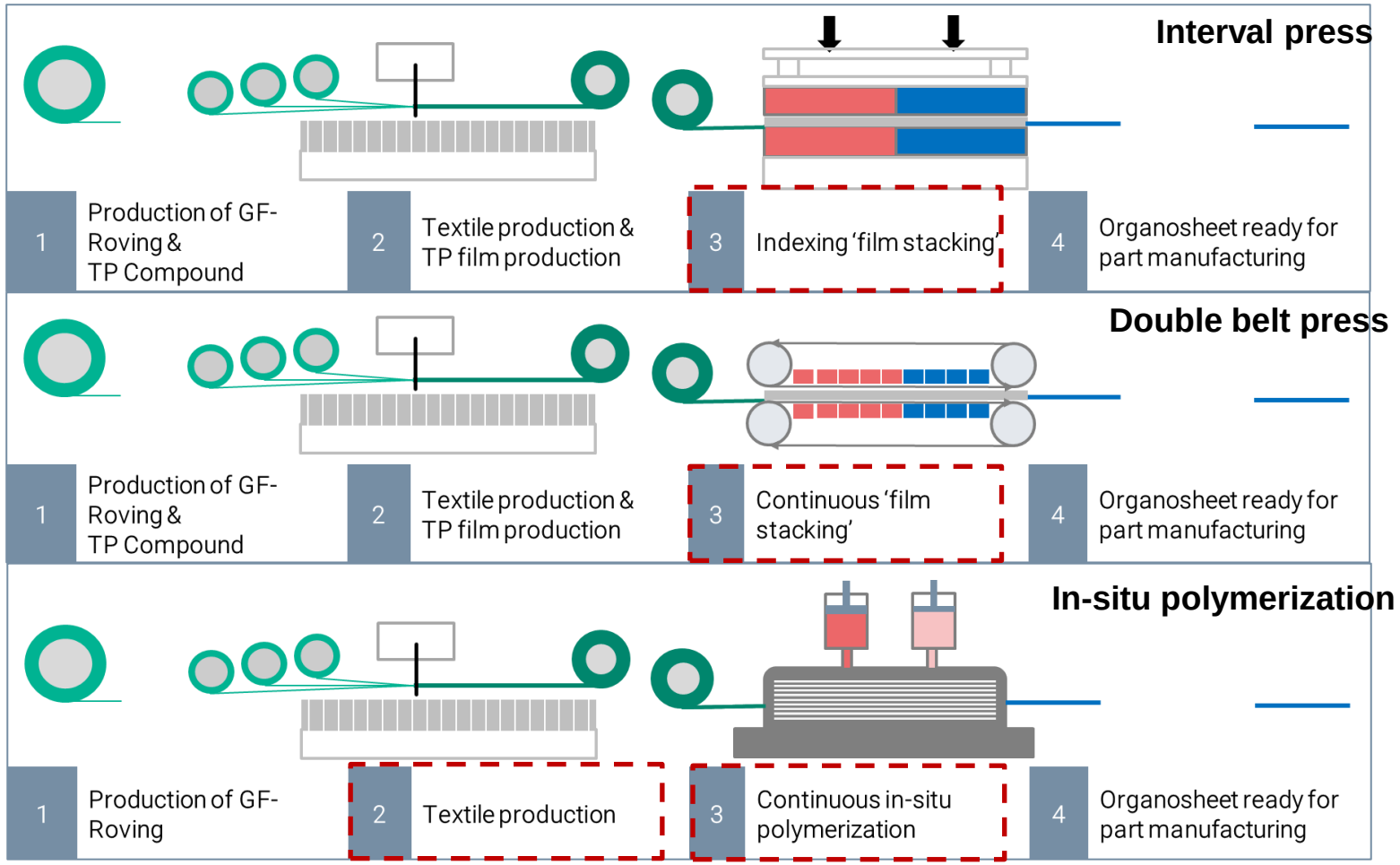


Thermoplastic → **Continuous** → **Semi-finished products**

Highly anisotropic	Middle anisotropic	Quasiisotropic	Quasiisotropic – Impact/Tough
e.g. 60-80% 0° + 40-20% ±45°	e.g. 40-50% 0° + 60-50% ±45°	25% 0° + 25% 90° + 50% ±45°	25% 0° + 25% 90° + 50% ±45°
			

ORGANOSHEET PRODUCTION

- **Interval press**
  - Indexing process with heating & cooling molds
  - Input: textile + TP film or direct compounding (any TP material)
  - Flexible process (profiles possible)
  - Relatively low investment cost
- **Double belt press**
  - Continuous heating & cooling process with small pressing rolls
  - Input: textile + TP film or direct compounding (any TP material)
  - High surface quality, even with thin laminate
  - High modularity and flexibility
- **In-situ polymerization**
  - Input: textile + caprolactam for polymerization
  - Good impregnation and high FVF
  - Speed independent of fabric & weight
  - Strict process control due to high moisture sensitivity, resin formulation
  - Limited availability of usable materials



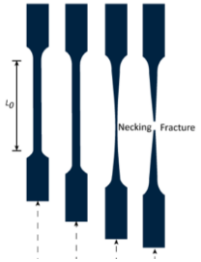
CRITERIA FOR AUTOMOTIVE LIGHTWEIGHT POTENTIAL

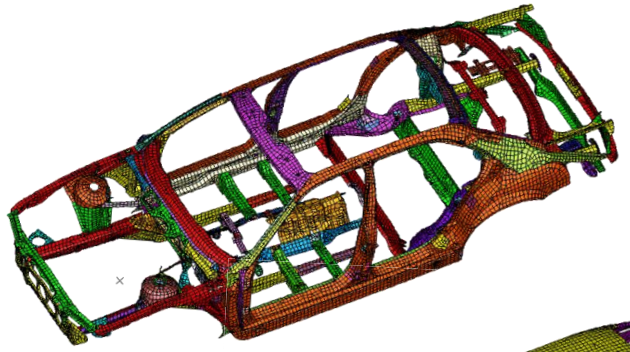
The following evaluation on lightweight potential is best practice OEM approach for automotive components for material selection. The lightweight potential is most important to evaluate the material's suitability for (simplified) target applications.

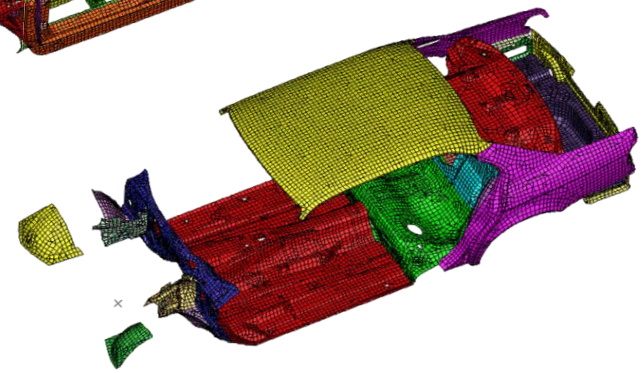
Beam/ Carrier structures (Weight percentage in a steel body ~ 65%)

1. $\frac{E}{\rho}$ Specific Stiffness: Elastic Modulus/Density

2. $\frac{R}{\rho}$ Specific Strength: Tensile strength/Density

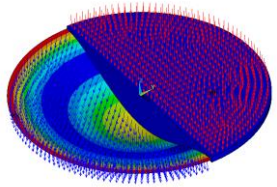






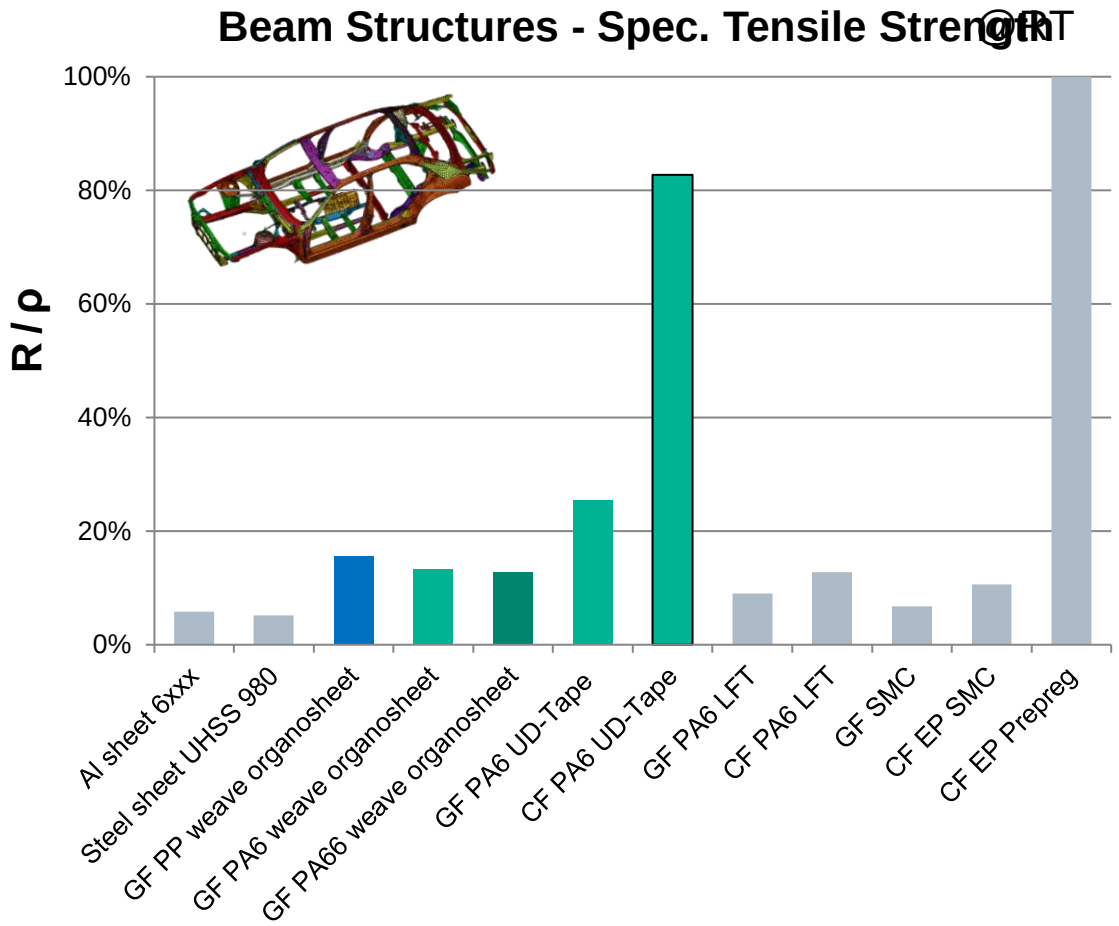
Shell structures (Weight percentage in a steel body ~ 35%)

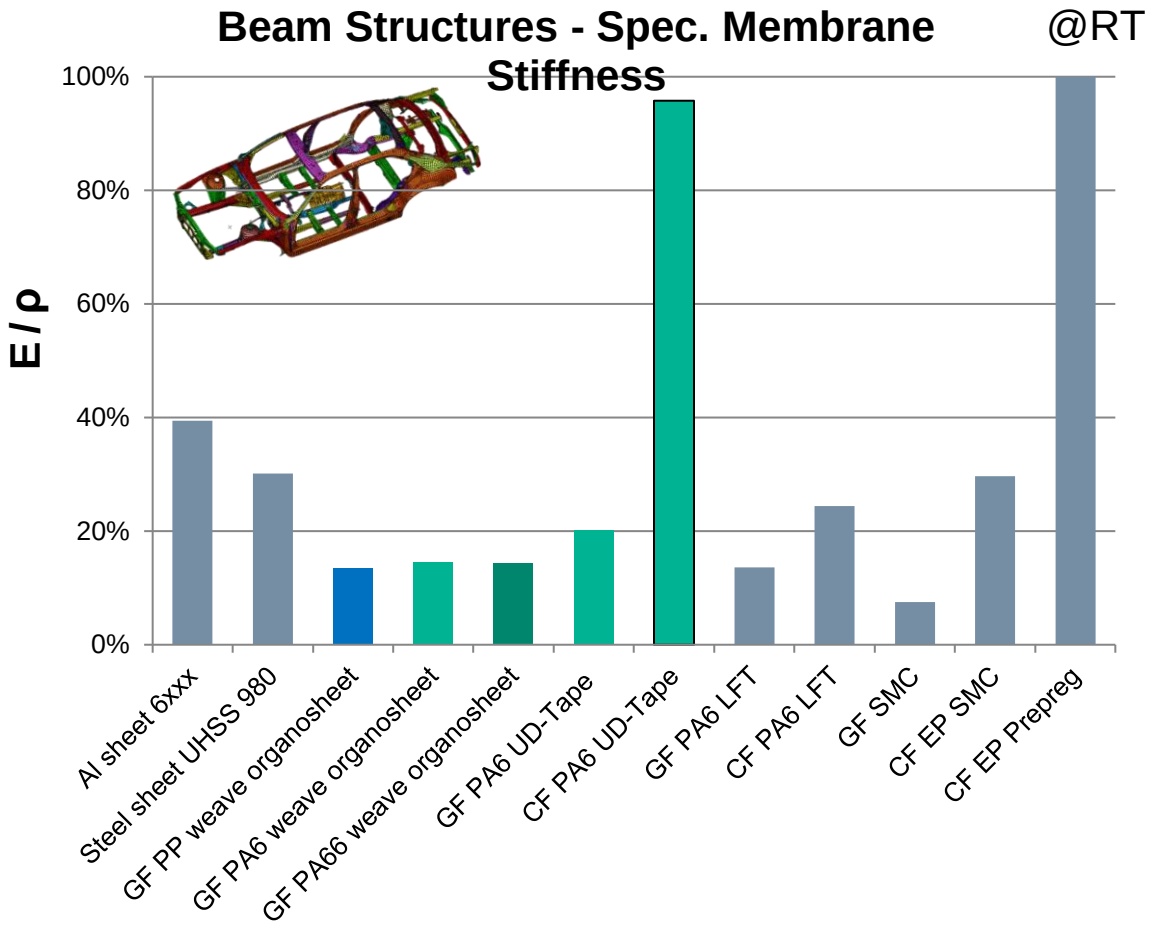
1. $\frac{\sqrt[3]{E}}{\rho}$ Specific Plate bending stiffness:



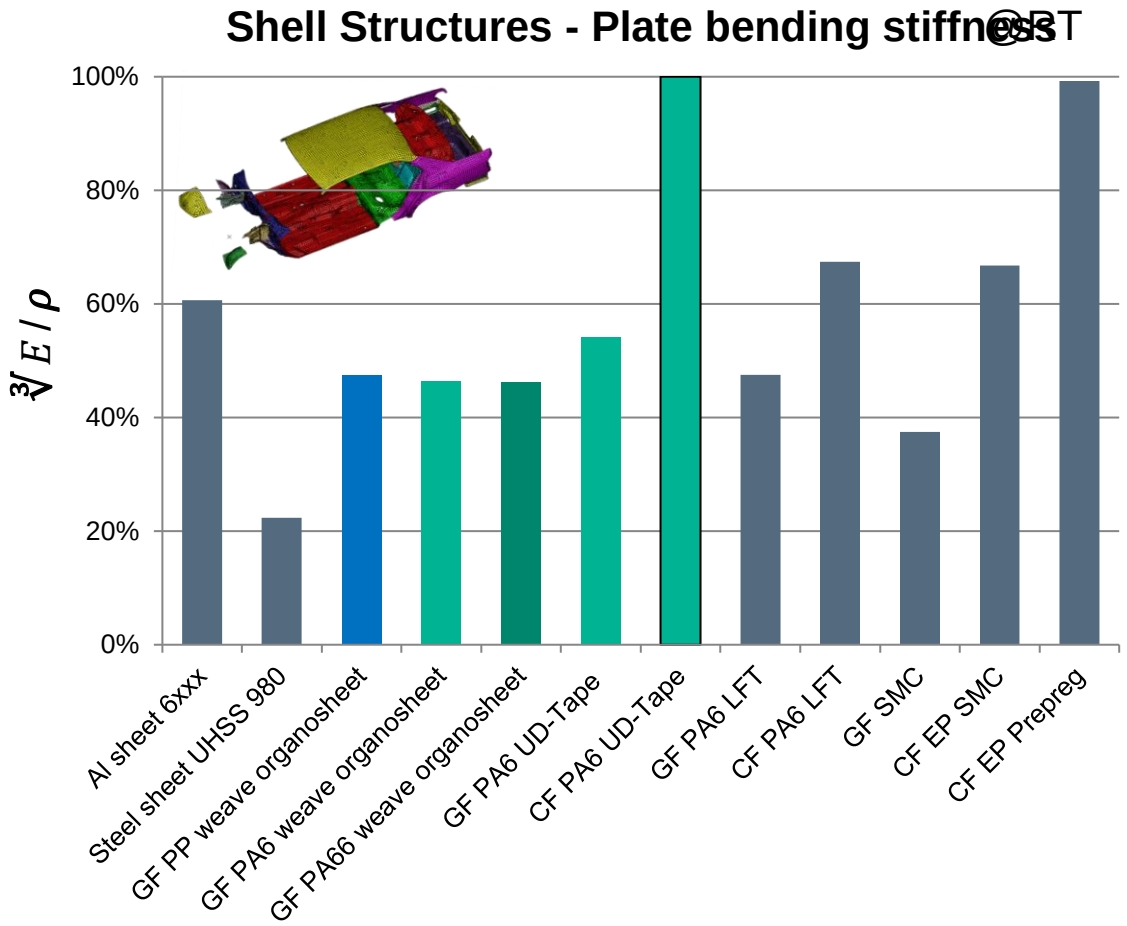
[Source: Lüdke, B.: Funktionaler Rohkarosserie-Leichtbau, von den Anforderungen an die Rohkarosserie zu den Anforderungen an die Rohkarosseriewerkstoffe. VDI Bericht, Bd. 1543 (2000)]

MATERIAL CHARACTERISTICS



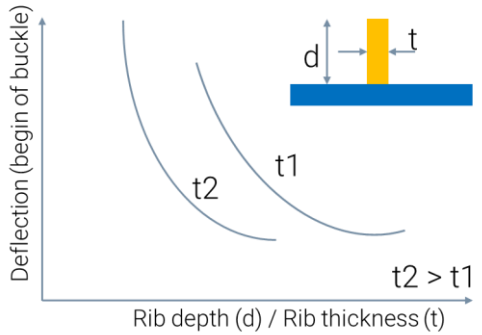


MATERIAL CHARACTERISTICS



Shell Structures w/ Ribs

- Improve structural rigidity and stability
  - ✓ Ribs can constrain local deformation efficiently and increase the structure stiffness (“rigid”) and anti buckling (“stable”)



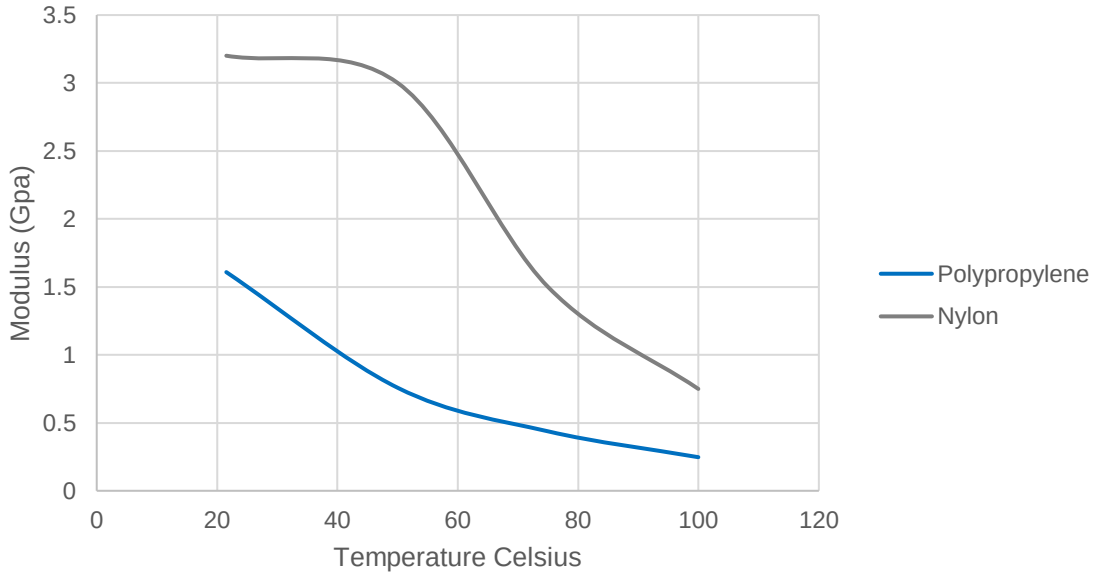

[Lanxess]


[Brose]

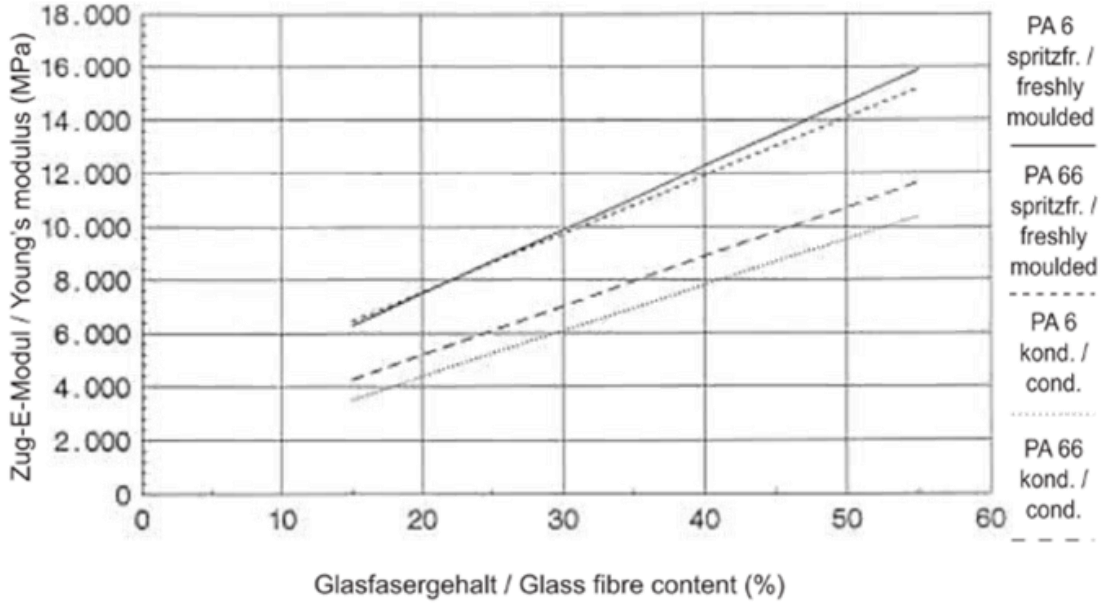
- Higher damage strength
  - ✓ Distributing load at high stress areas as well as constrain crack initiation & development.
- Energy/Impact absorber
  - ✓ Rib pattern can be designed to absorb crash / impact energy efficiently

TEMPERATURE AND MOISTURE DEPENDENCY

- Temperature dependency

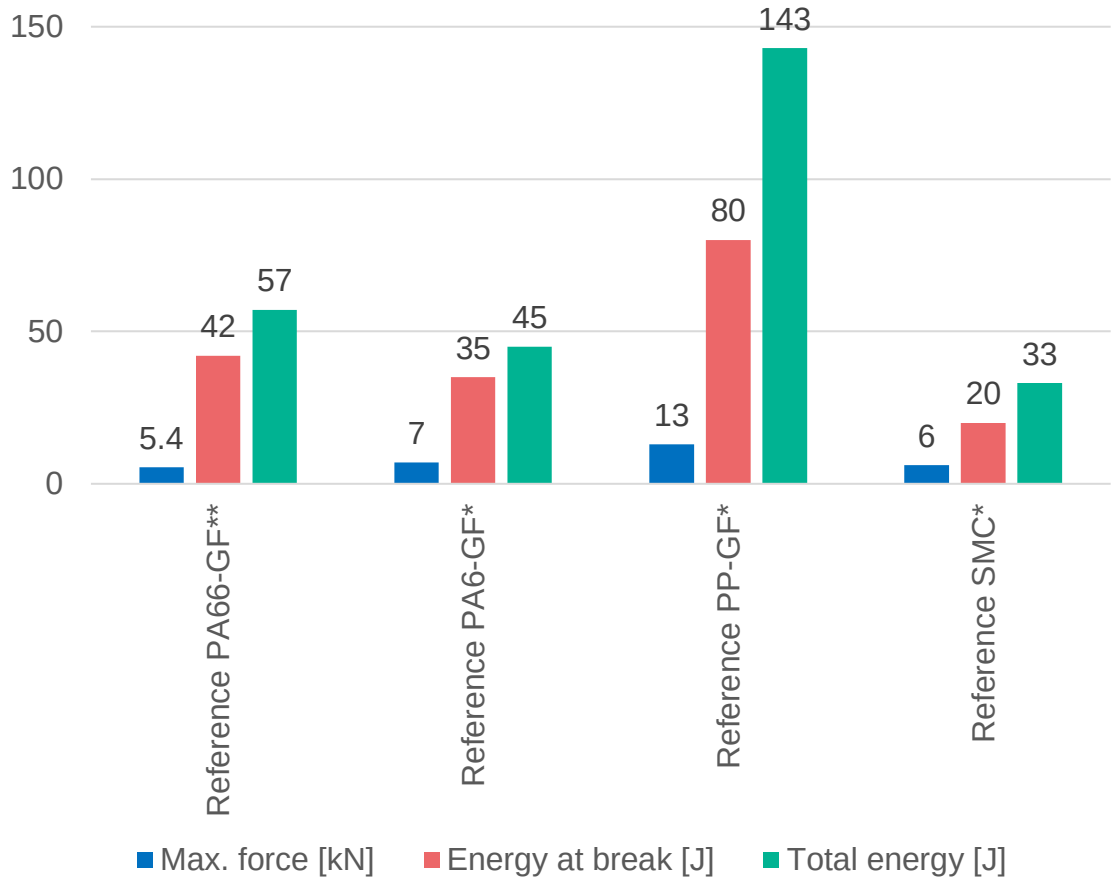


- Moisture dependency



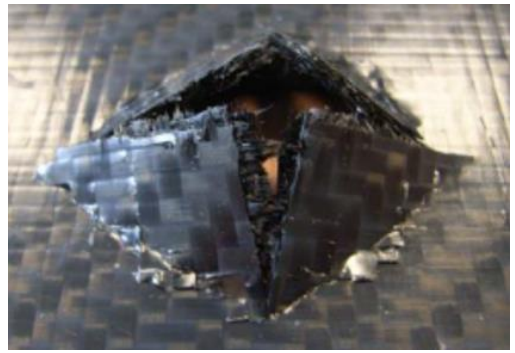
[Source: Dominghaus, Elsner et al.: **Kunststoffe**, Eigenschaften und Anwendungen, 8. Auflage, Springer Heidelberg, 2012]

MATERIAL CHARACTERISTICS - IMPACT



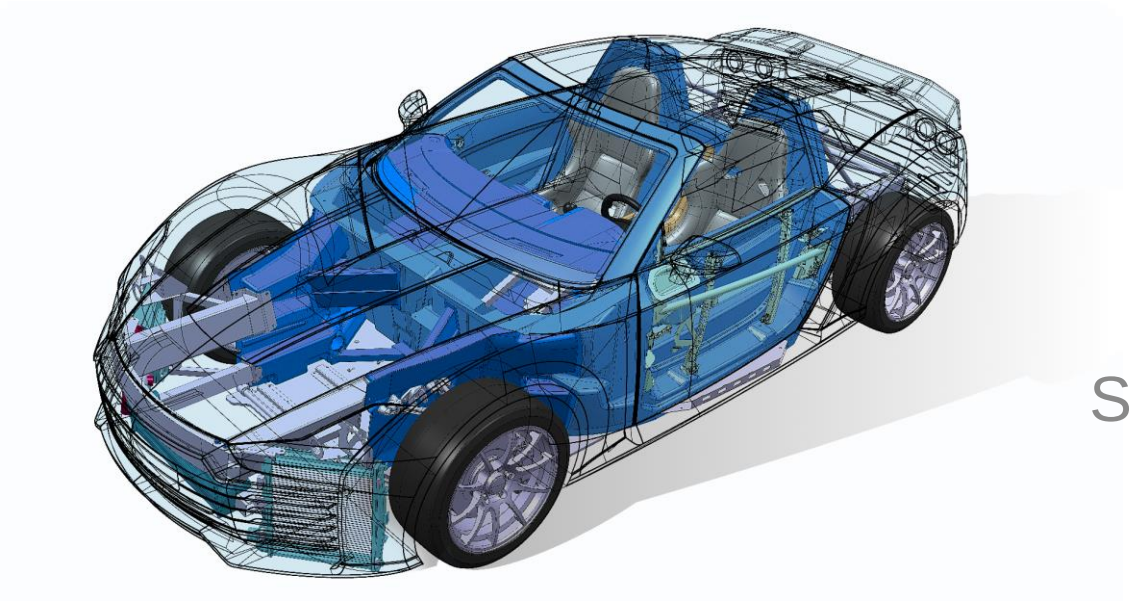
- Organosheet offers also high impact resistance, especially with continuous glass fiber (woven, NCF)
- PP-GF has even better impact properties and therefore often is used for impact components like underbody parts

Reference PP-GF*



Reference less ductile PA6-CF*

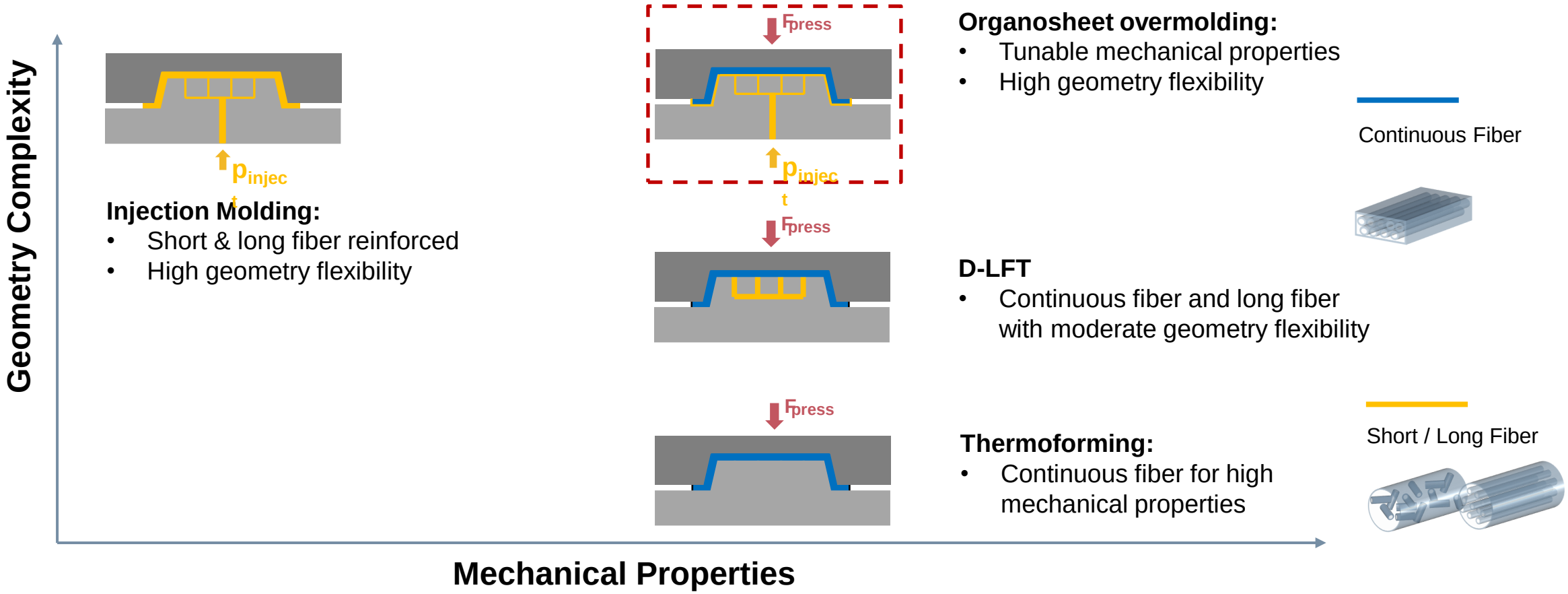
* Plate impact test [Elring klinger], tested benchmark values, all woven fabric, except for SMC, 2mm panel, after DIN EN ISO 6003-2



Structural Thermoplastic Composites

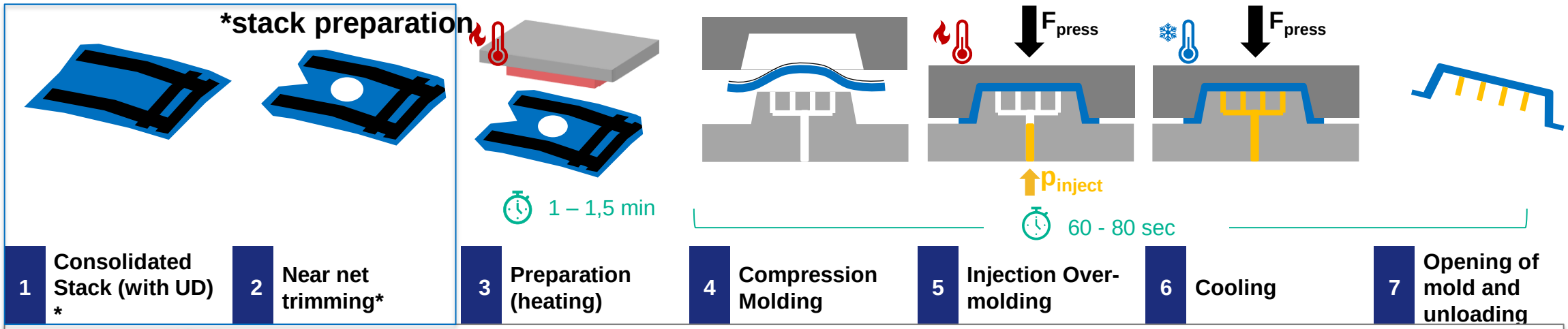
Solutions = Material + **Process** + Design

COMBINING INJECTION MOLDING AND THERMOFORMING



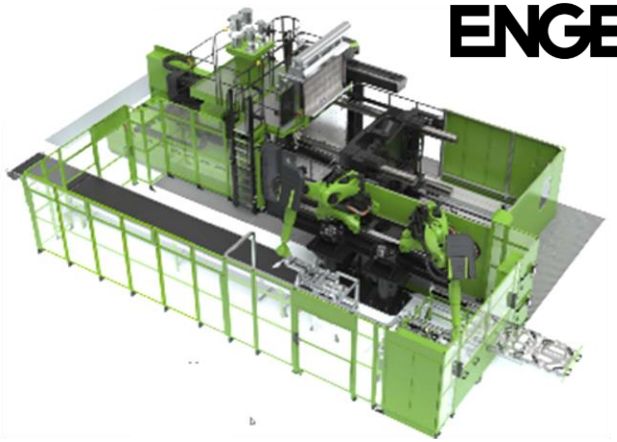
➔ **Organosheet overmolding combines the advantages of Injection Molding and Thermoforming**

ORGANOSHEET OVERMOLDING



Organomelt – Tape Stacking Unit

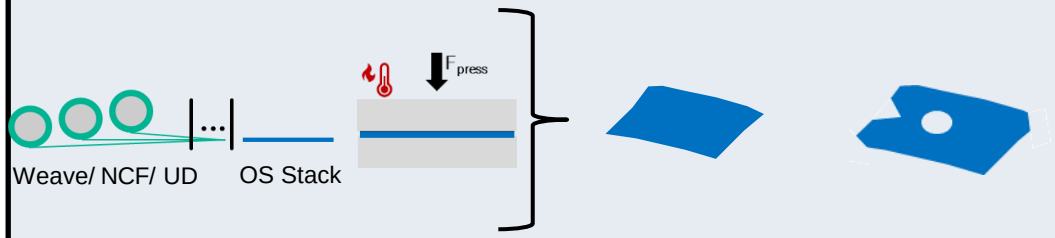
ENGEL Organomelt Process



Organomelt – Overmolding Production Cell

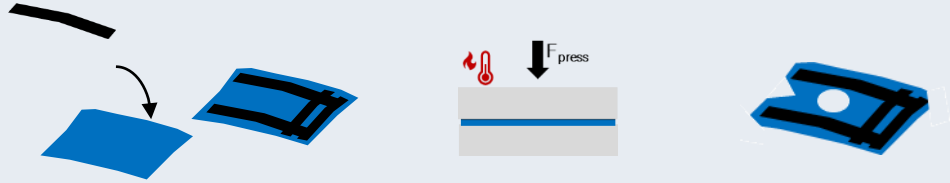
ORGANOSHEET STACK PREPARATION

Case 1: Basic Organosheet (OS) Stack (Layup)



0 Layup Preparation | 1 Consolidated stack ● | 2 Near net trim ● ●

Case 2: OS Stack w/ Automated Tape Placement

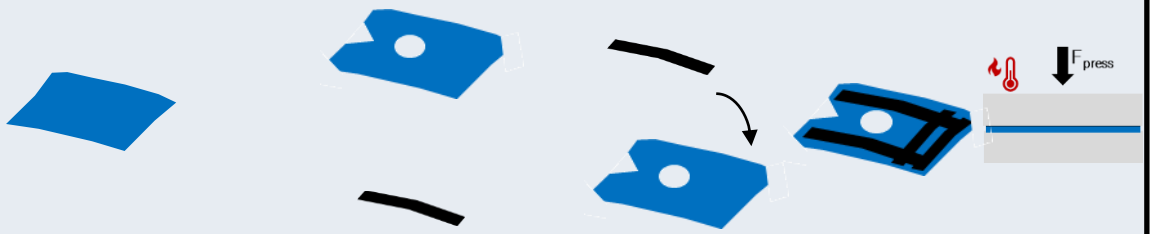


1.1 Tape laying on consolidated stack ● ● | 1.2 Consolidation ● ● | 2 Near net trim ● ●

Case 3: OS w/Tape Placement /in-situ Consolidation

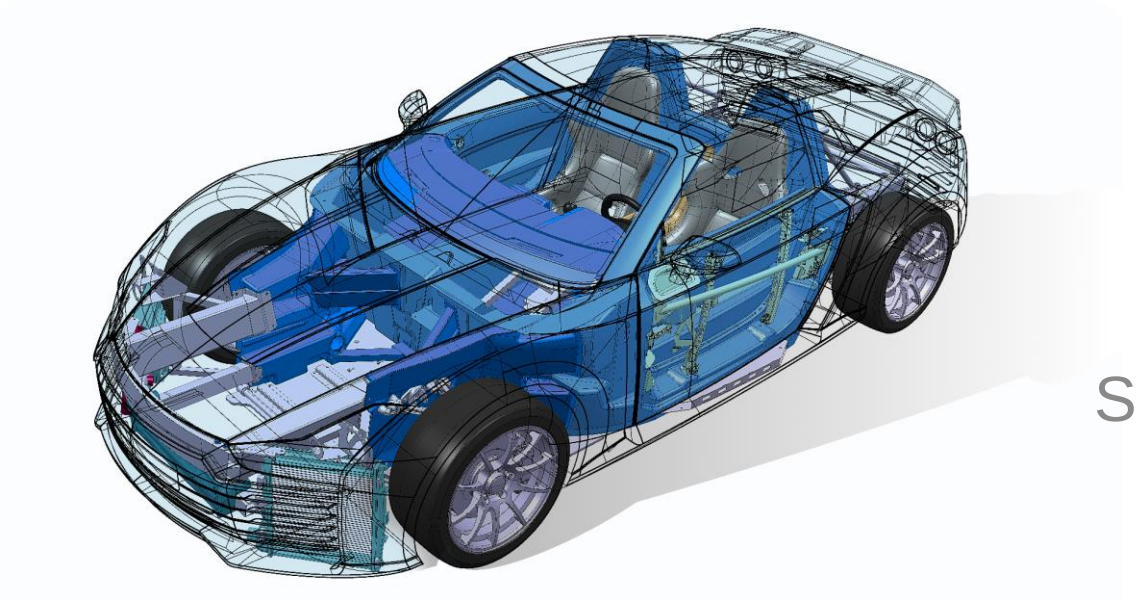
1 Tape laying with in-situ consolidation ● ● | 2 Near net trim ● ●

Case 4: OS Stack w/ Automated Tape Placement



1 Consolidated stack ● ● | 2.1 Near net trim ● ● | 2.2 Tape laying and consolidation ●

● Material supplier ● Tier 1 / Tier 2

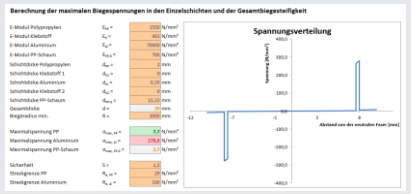


Structural Thermoplastic Composites

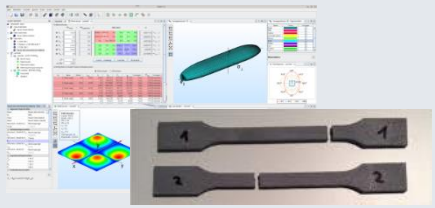
Solutions = Material + Process + **Design**

SIMULATION DRIVEN DESIGN FOR COMPOSITE PARTS

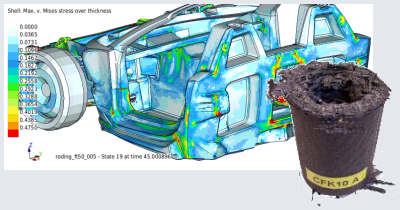
Analytical calculation
Predimensioning
Use of FE database



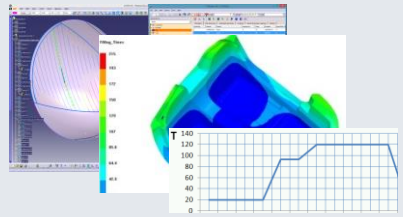
Definition of materials and lay-up, Def. of **static** material data



Creation of **dynamic** material card, Coupon- & Component Testing

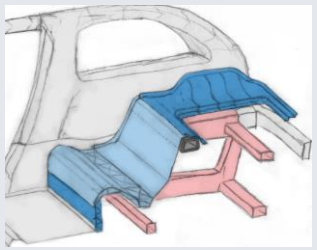


Process Simulation, Def. of Parameters & Tolerances

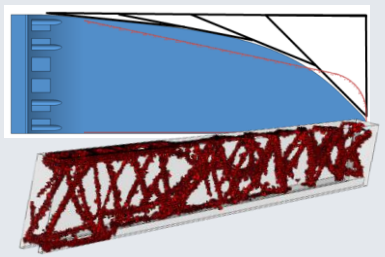


DEVELOPMENT TRACK FOR MATERIAL PROPERTIES

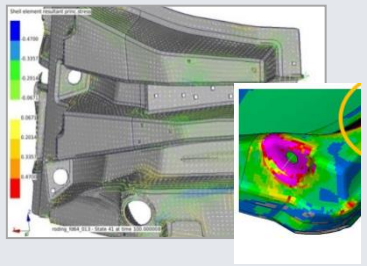
DEVELOPMENT TRACK FOR GEOMETRY (SIMULATION DRIVEN DESIGN)



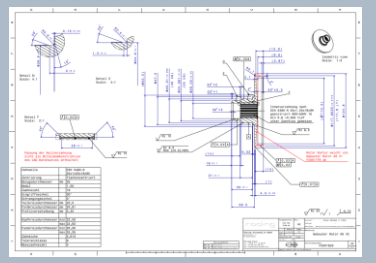
Concept drafts/ sketches



Basic CAD models/ Use of Topology Optim.



Detailed CAD models & CAE- Lay-up Optimization



Final part documents & development reports

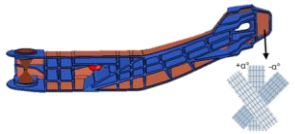
SIMULATION DRIVEN DESIGN & MATERIAL CHARACTERIZATION

- **High interaction of organosheet and IM material**
  - ✓ **Mass and cost saving by optimizing organosheet & ribs in parallel**

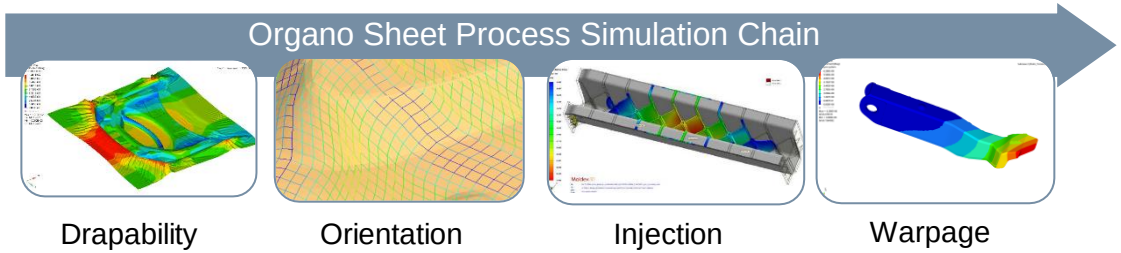
1.) Topology optimization

2.) Rib structure design

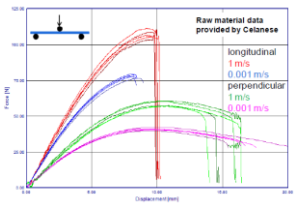
3.) Layup optimization



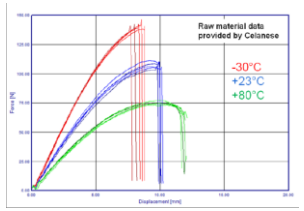
- **High process dependency**
  - ✓ **Early verification of process defects and increase of structure prediction level**



- **Material specific FEA strategy**
  - ✓ **Reliable prediction under diverse loading conditions** (High dependency of T, strain rate etc.)



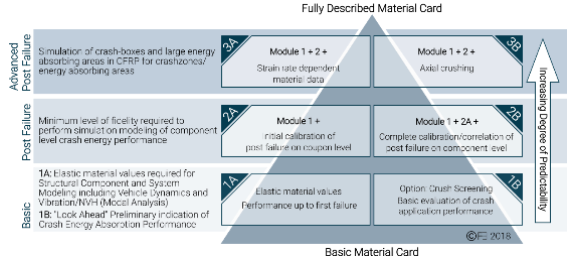
Strain rate dependency (PPGF)



[DYNAmore GmbH]

Temperature dependency (PPGF)

- **Specific material development strategy**
  - ✓ **Full understanding of complex material behavior, characterization methods**
  - ✓ **Increased FEA predictability and interpretation**



ORGANOSHEET SOLUTIONS = MATERIAL + PROCESS + DESIGN

[Lanxess/Audi]

[Lanxess/Brose]

Seat pan, seat back

- PA6/PP based organosheet overmolding
- High strength application thanks to GF organosheet and ribs -> good energy absorption (crash)

[Porsche 918 Spyder]

Brake Pedal

- PA6-GF based organosheet overmolding
- High strength application thanks to GF organosheet and ribs

[Porsche 911 Cabriolets]

A Pillar insert:

- PA6 based organosheet overmolding
- High strength and rigidity application (for roll-over) thanks to GF organosheet and ribs

[Lehomit]

Tunnel:

- Organosheet (CF/GF hybrid + UD tape) overmolding
- High strength and stiffness application

[Brose/Ford]

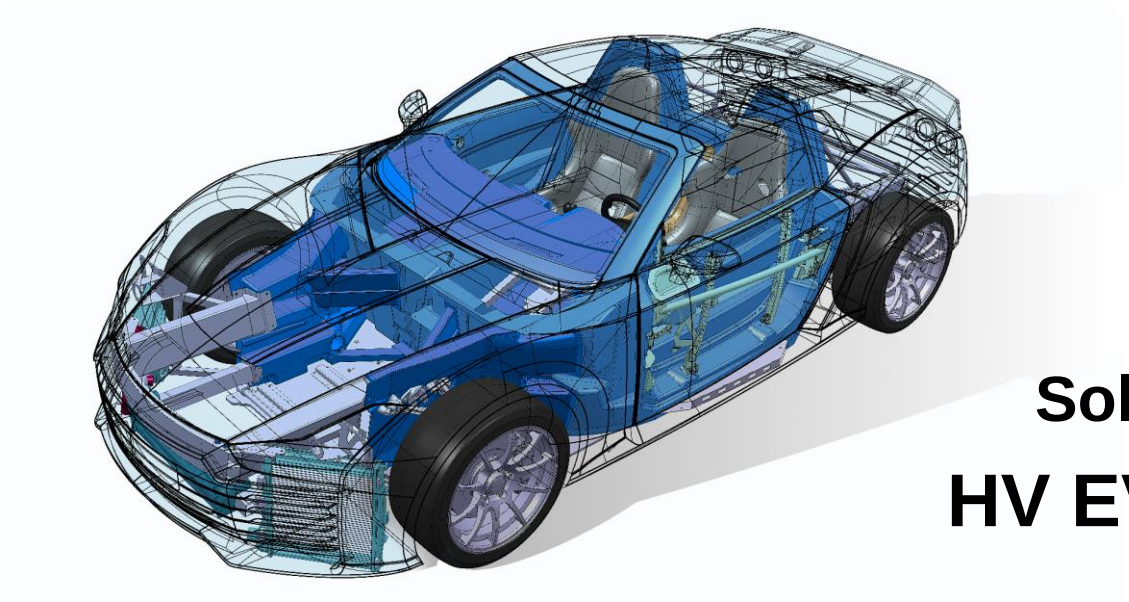
Door module carrier

- PP-GF based organosheet overmolding
- Balanced application between crash, strength and stiffness

[ElringKlinger / Bentley]

Underbody protection

- PP based organosheet + LWRT
- High impact resistance application



Structural Thermoplastic Composites

Solutions = Material + Process + Design

HV EV BATTERY ENCLOSURE CASE STUDY

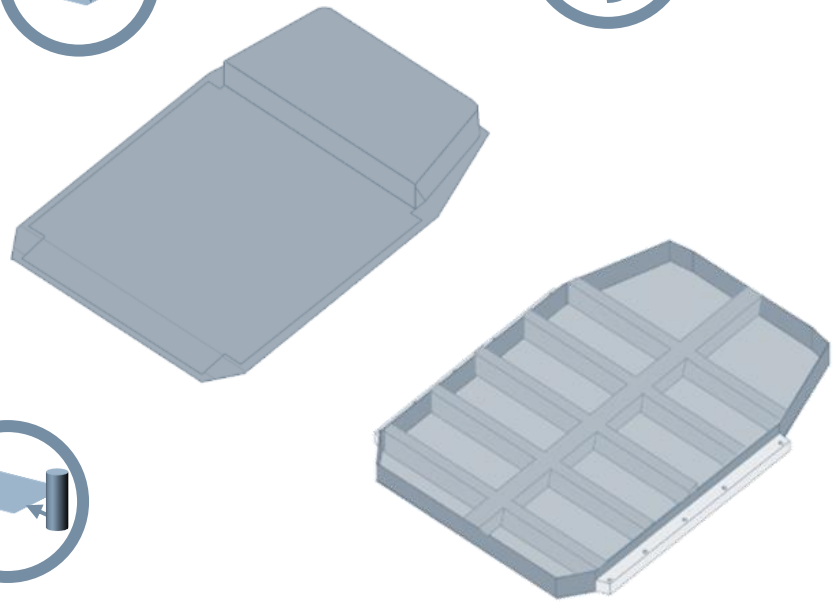
HV EV BATTERY ENCLOSURES – OPPORTUNITIES & CHALLENGES

Global torsion & bending stiffness
→ Intelligent load path management

Fire resistance (internal/external)
→ FST-appropriate material & design

Thermal Management
→ Appropriate Material Concept
→ Cooling System Integration

Mechanical shock
→ High strength module & battery attachment



Moisture/ Liquid Intrusion
→ Sealing Layout

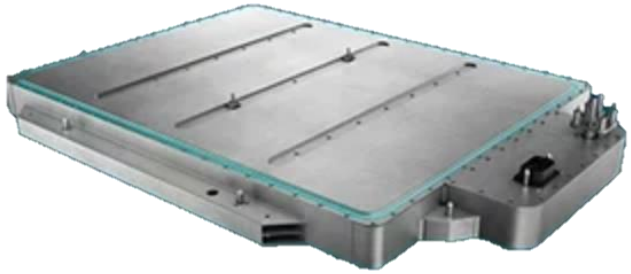
Side/Front/Rear Crash or Crush
→ Structural integrity
→ Energy absorbing structure

EMC & Grounding
→ Electroconductive material & design

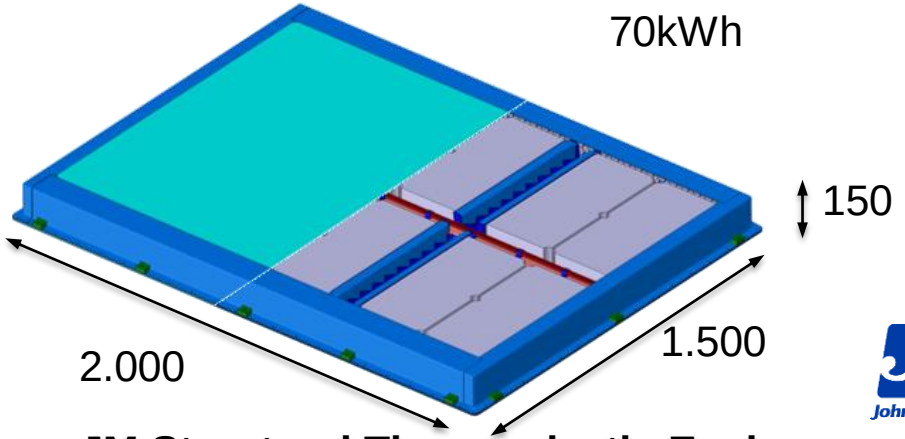
Ground impact
→ Energy absorbing tray

CONCEPT OVERVIEW: REFERENCE COMPARISON

STRUCTURAL THERMOPLASTIC HV EV BATTERY ENCLOSURE CONCEPT DEVELOPMENT



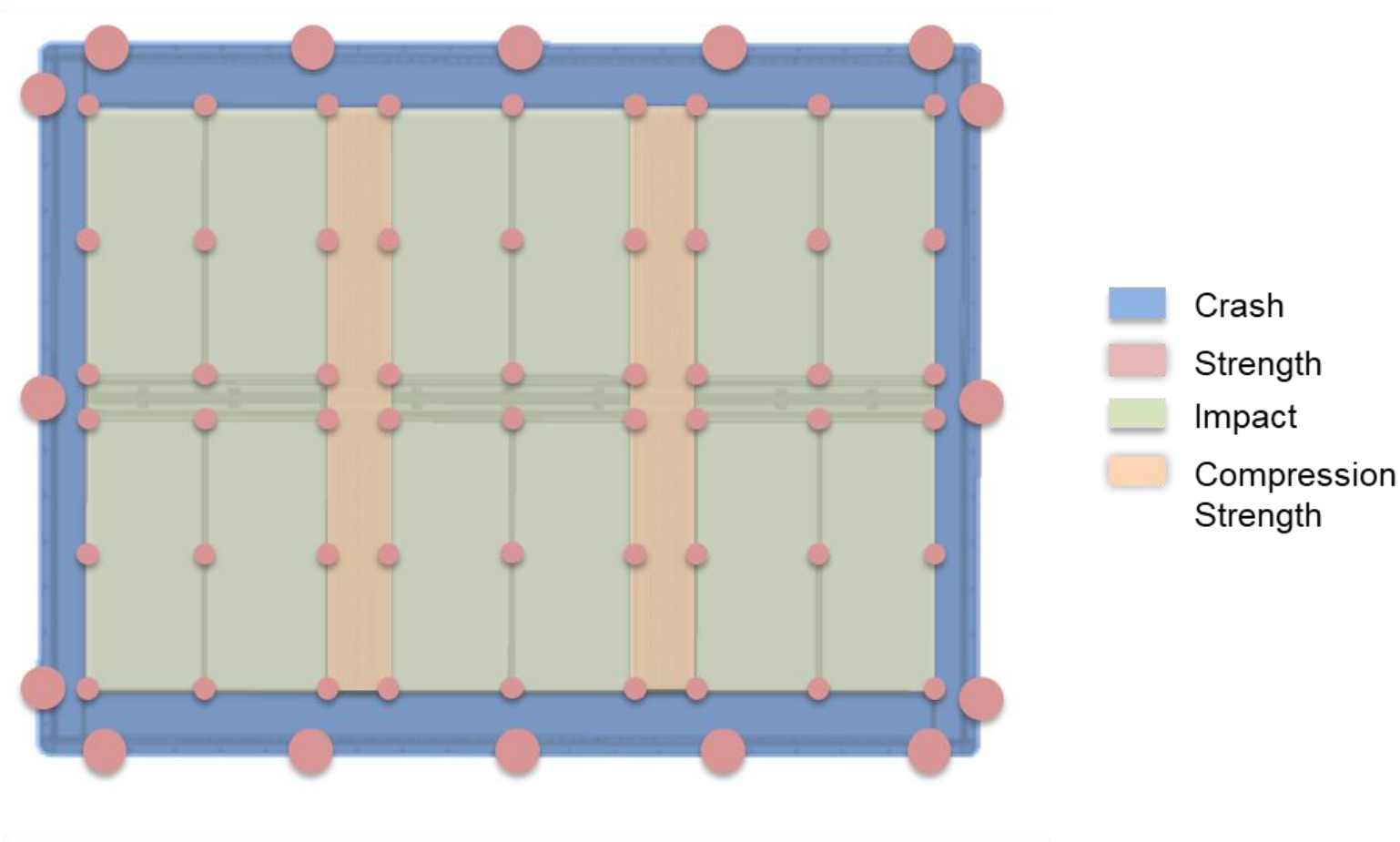
[Nio]



	Typical Aluminum Enclosure	JM Structural Thermoplastic Enclosure Concept	
		GF intensive	CF-GF hybrid
Typical Weight:	100 -120 kg	similar to reference	80 kg (**-20%**)
Parts:	> 30 parts	**11 parts**	**11 parts**
Typical cost*:	$950 – $1,200	**less or equal**	+ 20-30%

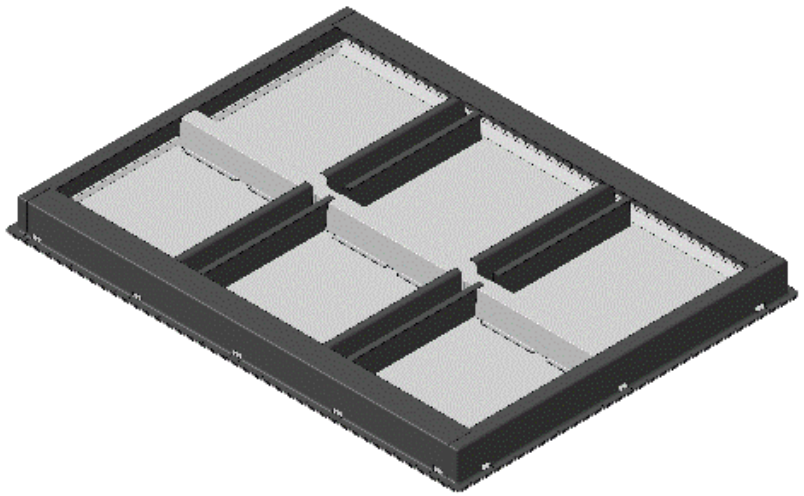
*including asembly

STARTING POINT & STRESS LANDSCAPE

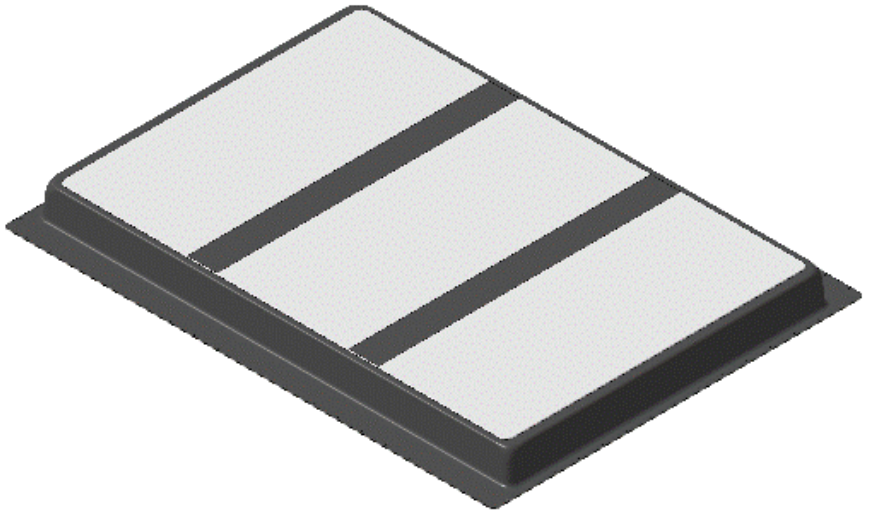


CONCEPT OVERVIEW: CF-GF HYBRID SKELETON STRUCTURE

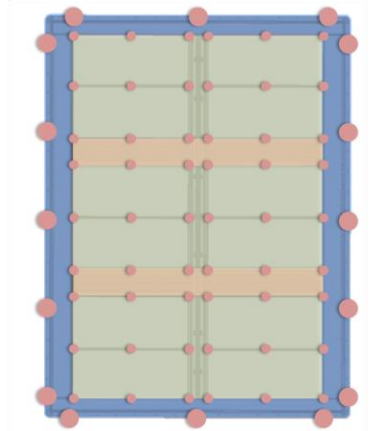
- CF skeleton structure & local reinforcement according to global load paths
- Tailored, load-appropriate layup



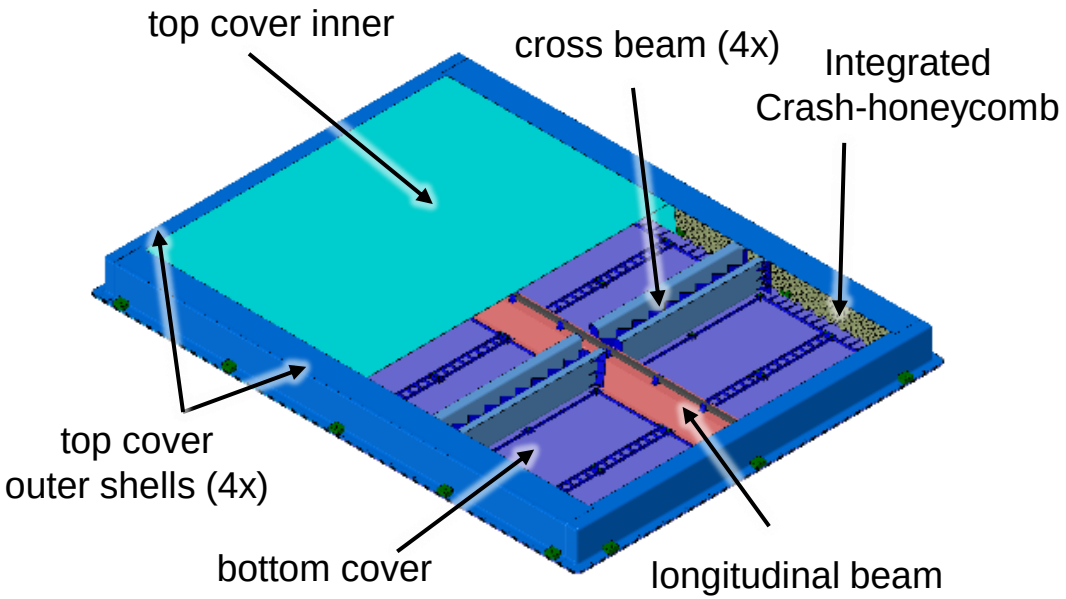
CF-GF multi-material design with CF skeleton structure

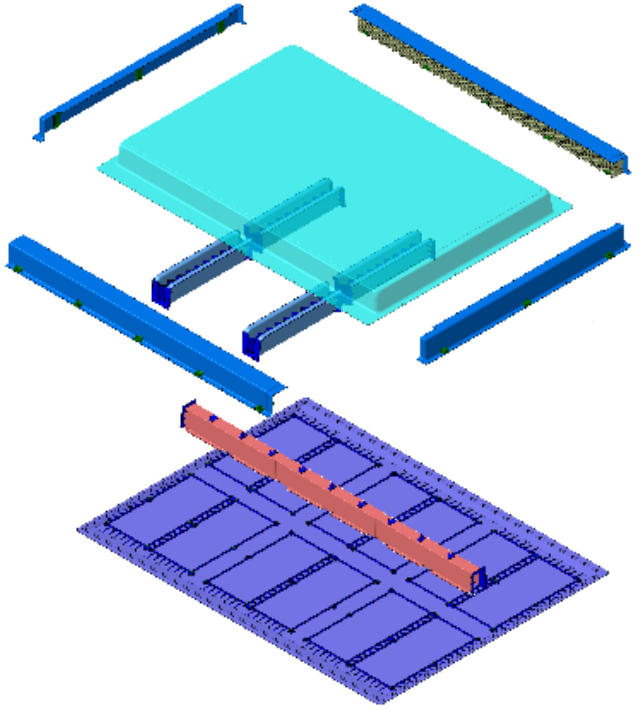


Top cover inner:
CF reinforcement of GF base layup in main load paths



JM STRUCTURAL THERMOPLASTIC BATTERY ENCLOSURE



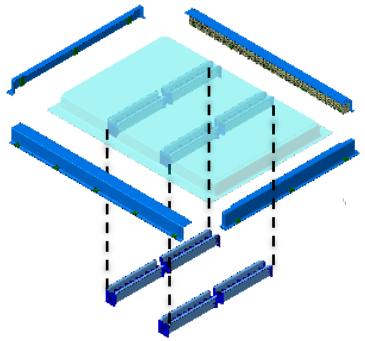


Isometric view with section cut of top cover inner

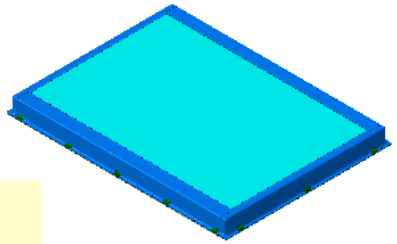
Exploded view of assembly

https://www.torqeedo.com/us/en-us/technology-and-environment/battery-technology.html

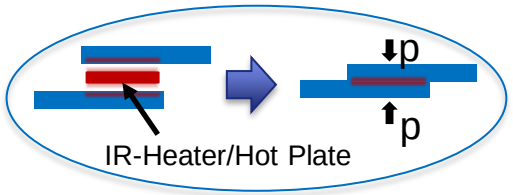
CONCEPT OVERVIEW: ASSEMBLY & JOINING STRATEGY

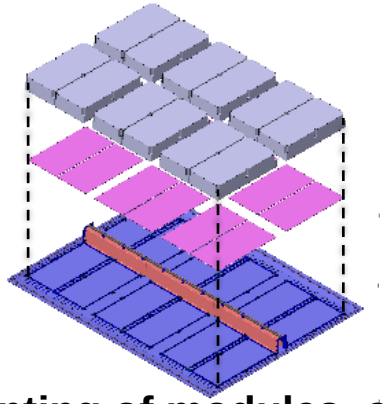


Subassembly Top Cover

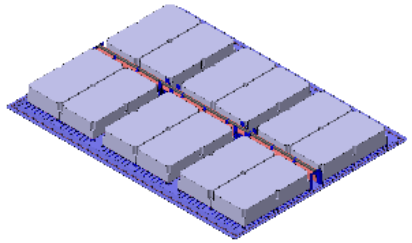


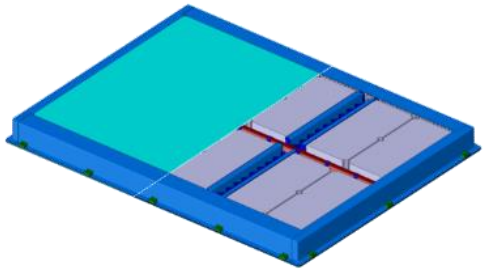
Joining by:
- structural fasteners
- thermoplastics welding (hot plate, ultrasonic,…)





Mounting of modules, cooling plate & HV wire



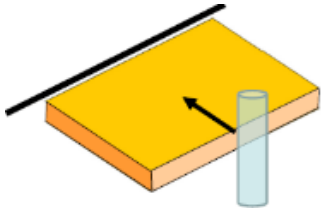


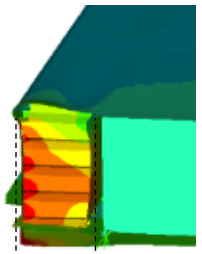
FINAL ASSEMBLY

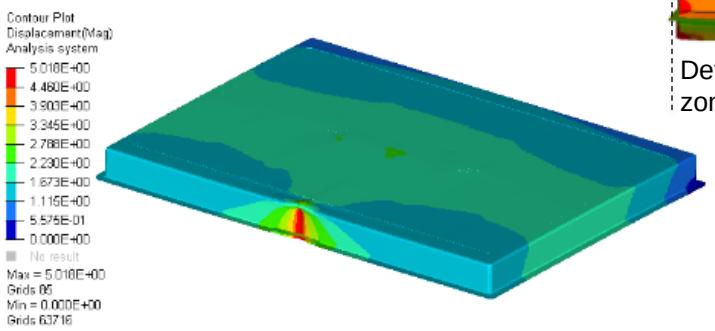
Subassembly Bottom Cover

CONCEPT OVERVIEW: CAE ANALYSIS OF MAJOR LOAD CASES

Crush resistance to side pole (100 kN)





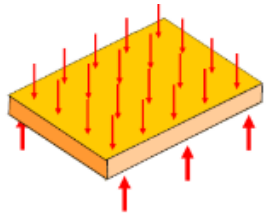


Defo zone

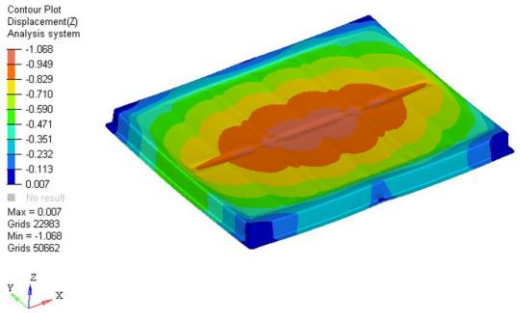
"No intrusion" zone

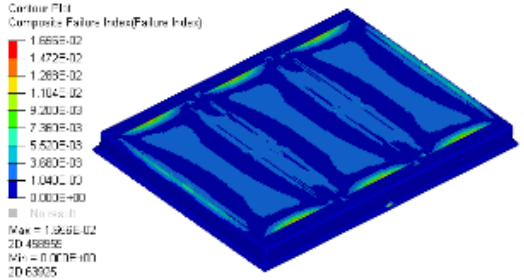
Results:

- Intrusion resistance meets target level of > 100kN
- Fulfillment of static load case as starting point for dynamic simulation in second step



Structural stiffness: 10g static loading

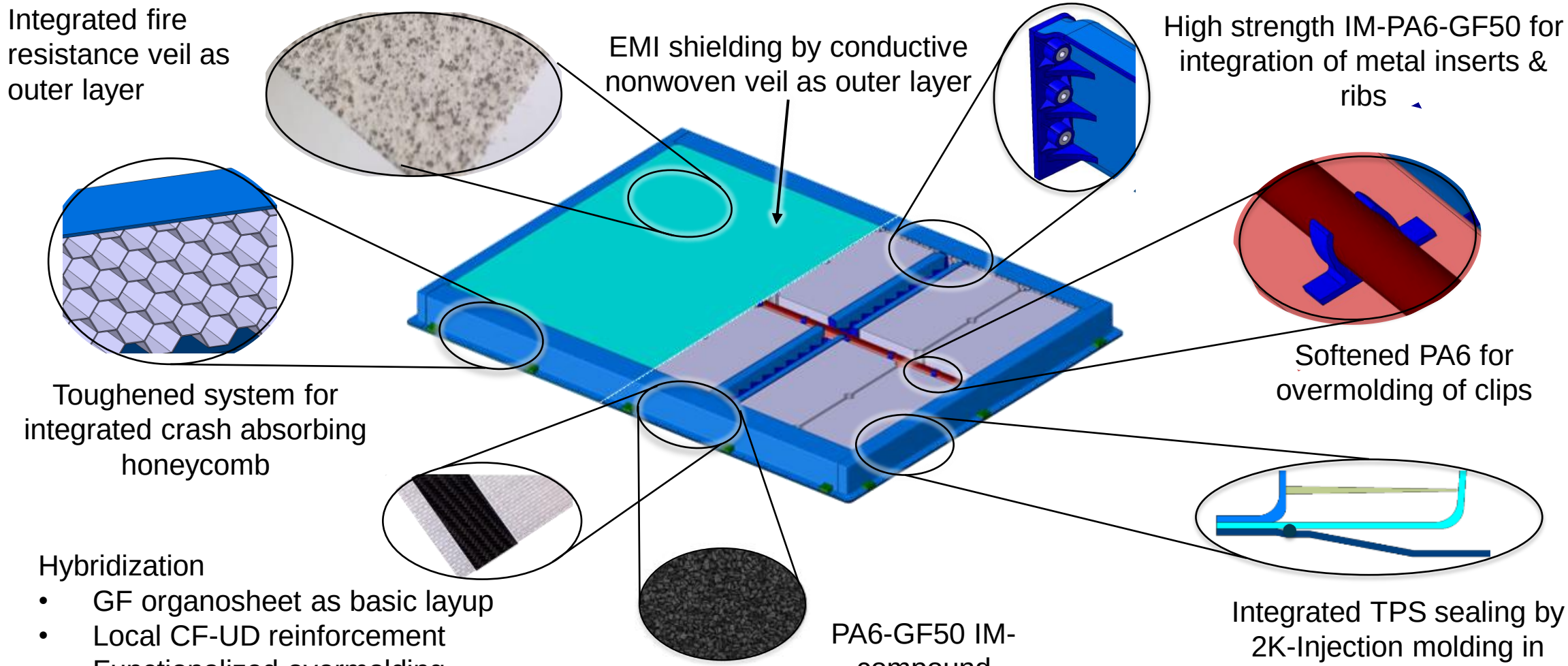




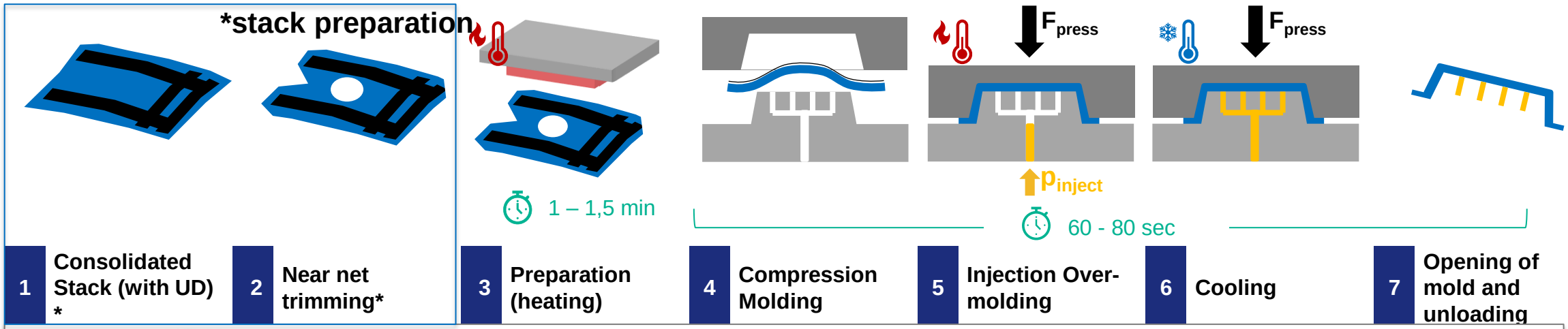
Results:

- Effective use of the complete structure to maximize bending and torsional stiffness
- Loads are on a relatively low level, as part dimension gets mainly defined by crash load cases

CONCEPT OVERVIEW: RIGHT MATERIALS IN THE RIGHT PLACES



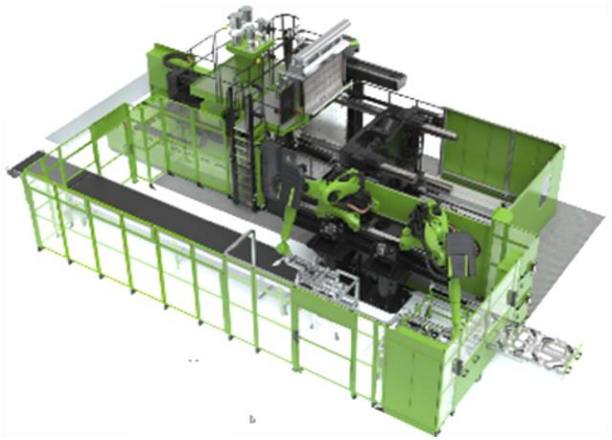
ORGANOSHEET OVERMOLDING



1	Consolidated Stack (with UD) *	2	Near net trimming*	3	Preparation (heating)	4	Compression Molding	5	Injection Over-molding	6	Cooling	7	Opening of mold and unloading

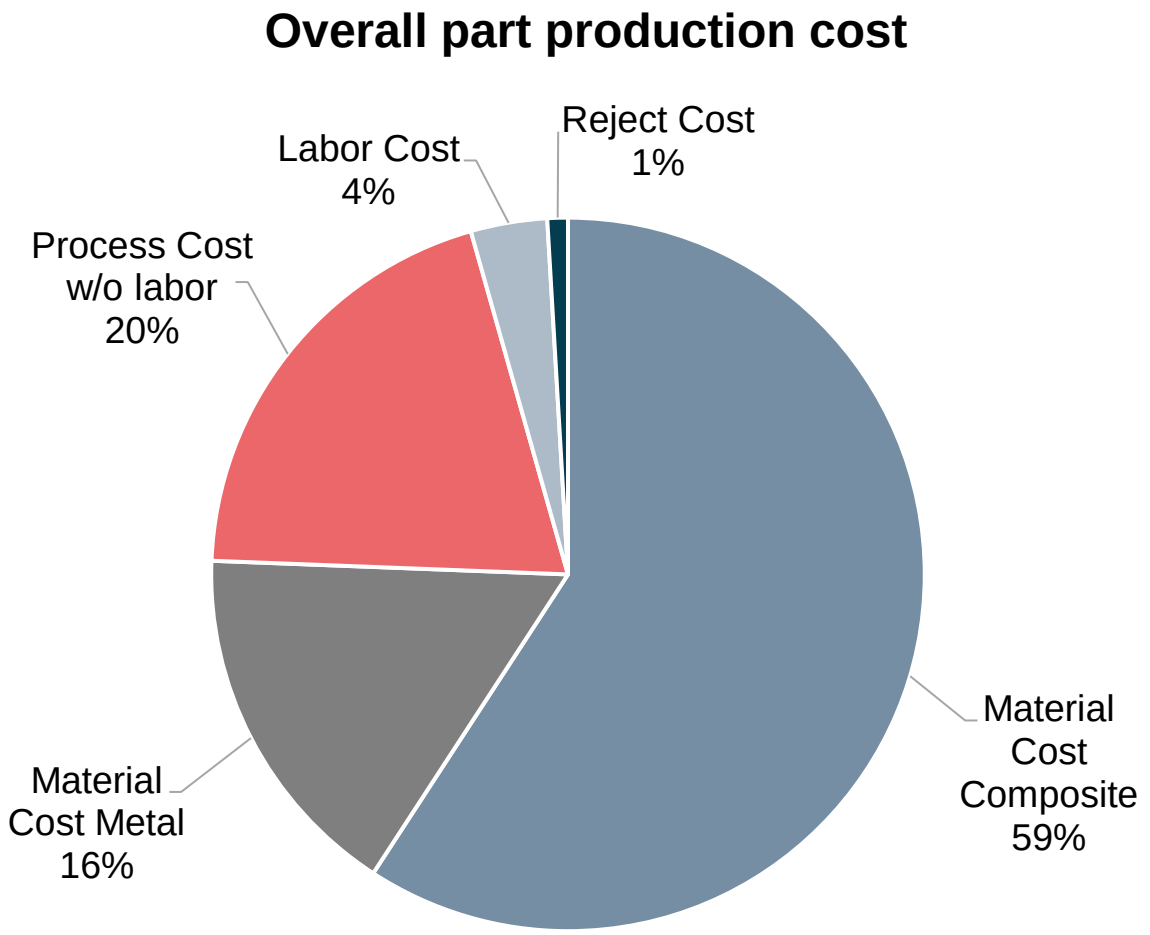
Organomelt – Tape Stacking Unit

ENGEL Organomelt Process



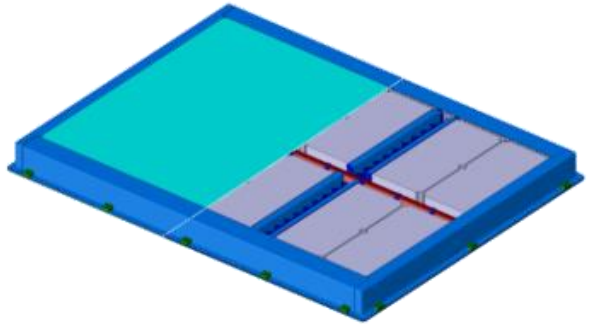
Organomelt – Overmolding Production Cell

OVERVIEW PART PRODUCTION COST



- Part production for a battery enclosure system with
  - A TP organosheet overmolded top and bottom cover + 2nd Tier floor
  - Pultruded TP cross beams
  - Aluminum longitudinal crash beams
  - Metal joining elements
- Providing
  - A weight reduction about 20 %
  - A reduction of single parts about 50 %
  - A reduction of part production cost about 30 %
  - … compared to a typical metal battery enclosure

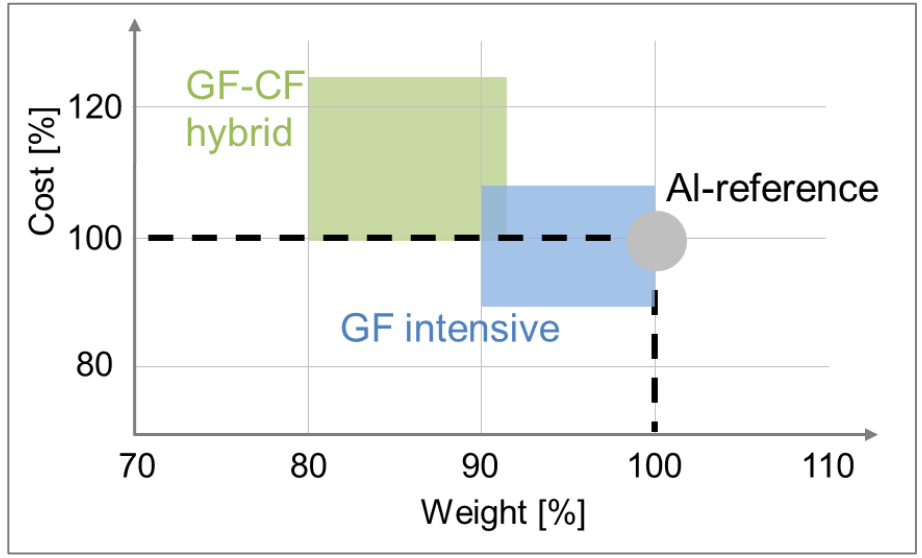
JM STRUCTURAL THERMOPLASTIC BATTERY ENCLOSURE



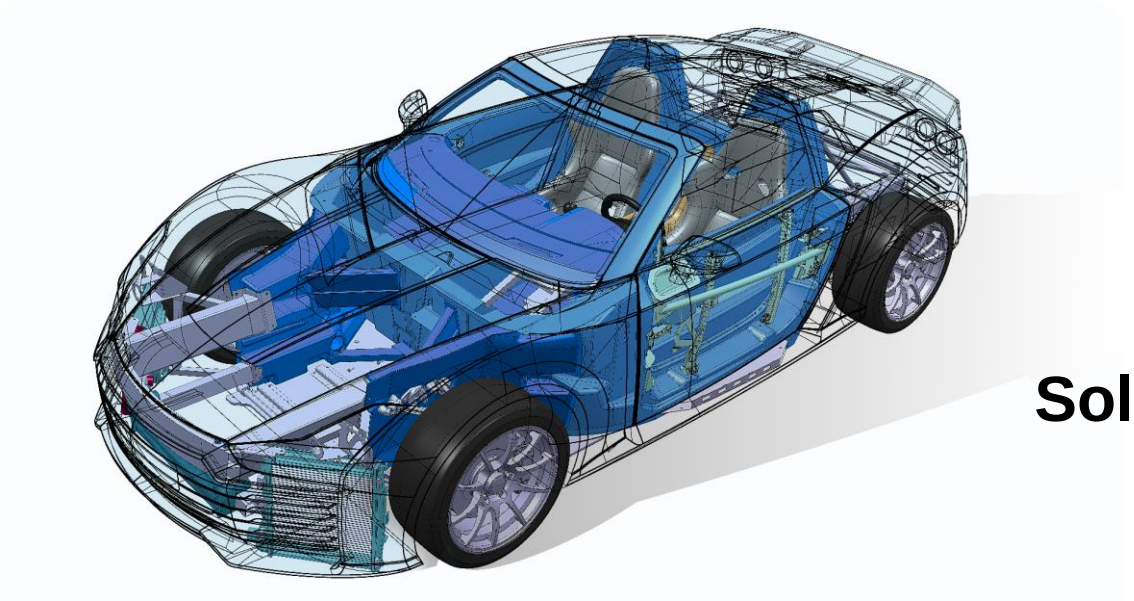
Structural Thermoplastic Battery Enclosure

- Cost-effective Mixed Material Solution
- Compatible thermoplastic composites and compounds
- Scalable, proven organosheet overmolding technology
- Efficient use of package space for optimized crash performance
- Flexible modular design supports mass customization
- Turn-key solution through robust supply chain

Concept attractive across EV platforms



JM AP Nylon organosheets enable scalable, cost effective thermoplastic composite solutions.



Structural Thermoplastic Composites

Solutions = Material + Process + Design

SUMMARY

ORGANOSHEET TECH UNLOCKS POTENTIAL FOR TP COMPOSITES

INTEGRATION

High functional integration (insert, attachment, reinforcement etc.)

High part integration (one part feasible), less assembly steps compared to metal solution

High hybridization

Integration of complex design geometries

LIGHTWEIGHT

> 20% - 50% weight saving to IM / metal

Load path efficiently addressed by UD / organosheet

High flexibility on design type

High degree of formability

High joining flexibility

COST EFFICIENT

Low material cost & scrap Comparable overall cost to metal

Cost efficient production (one shot process)

Less assembly cost compared to metal solution

High cost down potential

INDUSTRIALIZATION

Low cycle time

Fully automatable

Supplier maturity level

Proven technologies for high volume production

ADD ON VALUES

Recycling, sustainability

Class A application

Combination of function & visible application

THANK YOU!

ACCELERATING THE DEPLOYMENT OF STRUCTURAL THERMOPLASTIC COMPOSITES FOR NEXT GENERATION AUTOMOTIVE AND TRANSPORTATION APPLICATIONS

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