North American Pultrusion Conference

Developing Flame Resistant Polyurethane based Pultrusion for Automotive Battery Applications

Chris Korson

BASF Corporation

ACMA American Composites Manufacturers Association | EPTA

Who is BASF?

ACMA American Composites Manufacturers Association

EPTA

BASF – We Create Chemistry

Chemicals

Petrochemicals

Intermediates

Materials

Performance Materials

Monomers

Industrial Solutions

Dispersions & Pigments

Performance Chemicals

Surface Technologies

Catalysts

Coatings

Construction Chemicals*

Nutrition & Care

Nutrition & Health

Care Chemicals

Agricultural Solutions

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BASF – We create chemistry

Top 100 global automotive suppliers (2021)

Rank	Company	Sales (in $100 million)
1	Bosch	491.44
2	Denso	435.69
3	ZF	393
…		
9	BASF We create chemistry	213.53

Source: Automotive News, June ,2022

BASF is the only materials and/or chemical company in the top 100 suppliers

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Elastocoat® Polyurethane Pultrusion Systems: The Story Continues…….

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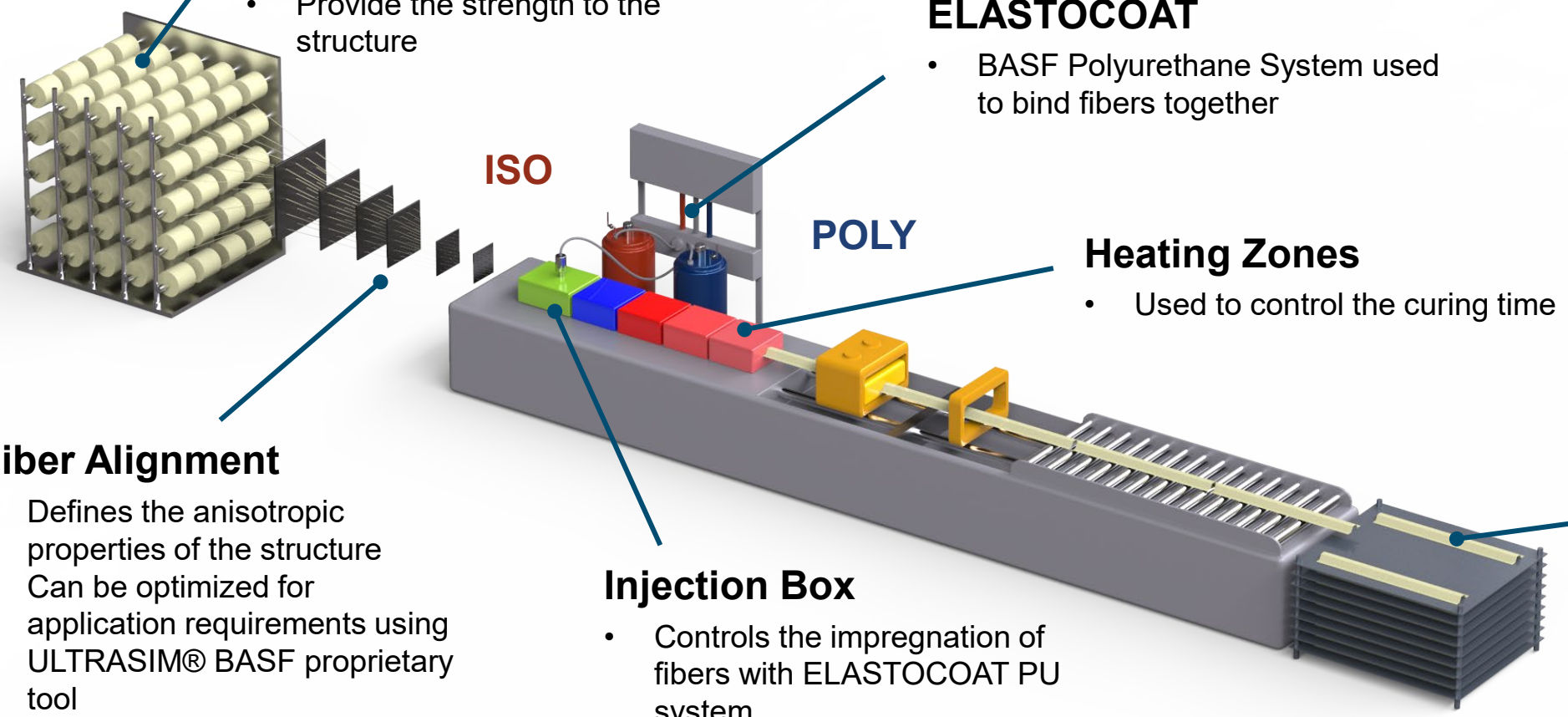
EPTA

PULTRUSION – BASF Focus



Roving and Fiber Matts

- Provide the strength to the structure

ELASTOCOAT

- BASF Polyurethane System used to bind fibers together

Heating Zones

- Used to control the curing time

Fiber Alignment

- Defines the anisotropic properties of the structure
- Can be optimized for application requirements using ULTRASIM® BASF proprietary tool

Injection Box

- Controls the impregnation of fibers with ELASTOCOAT PU system

Customized Length Profiles

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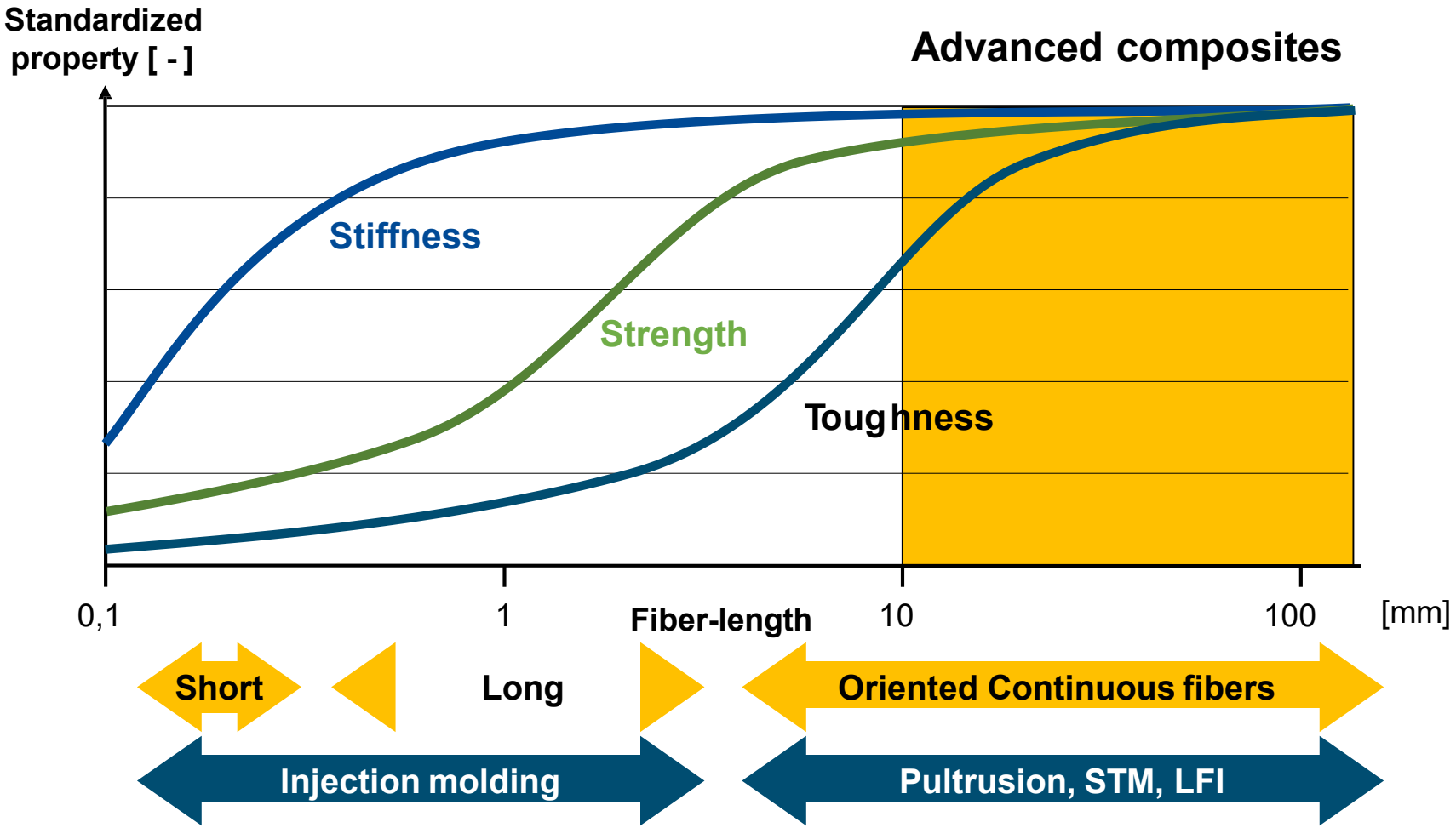
Properties as a Function of Fiber-Length



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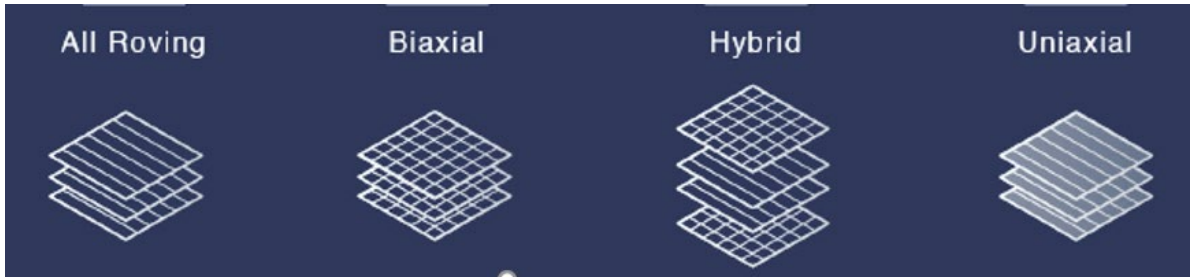
Fiber Versatility

- Fiber Type
  - Glass
  - Carbon
  - Natural
- Fiber Configuration



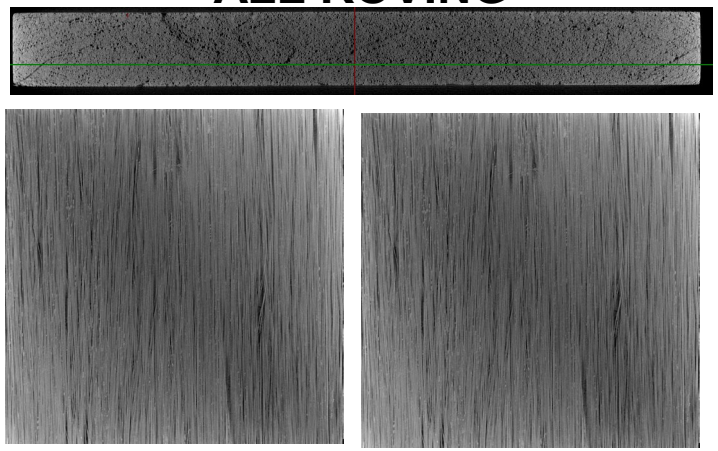
- Fiber Mixing
  - Type
  - Configuration
- Sizing
  - Coats and Protects the fiber
  - Interface of the fiber to the matrix
  - Effects the physical performance of the end component

Fiber Architecture (CT Scan Pictures)

Transversal

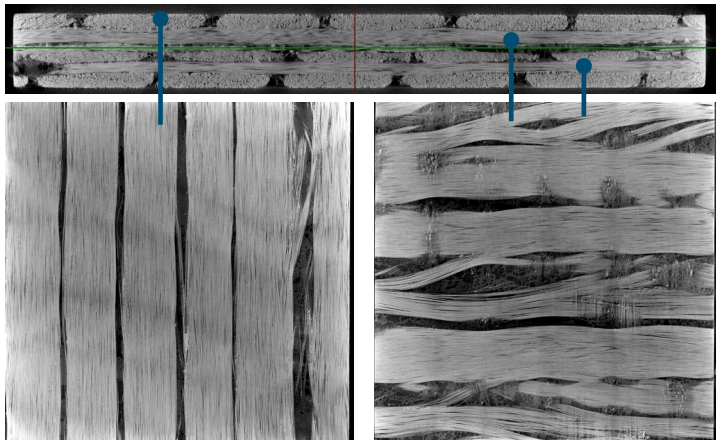
Layer to Layer

ALL ROVING



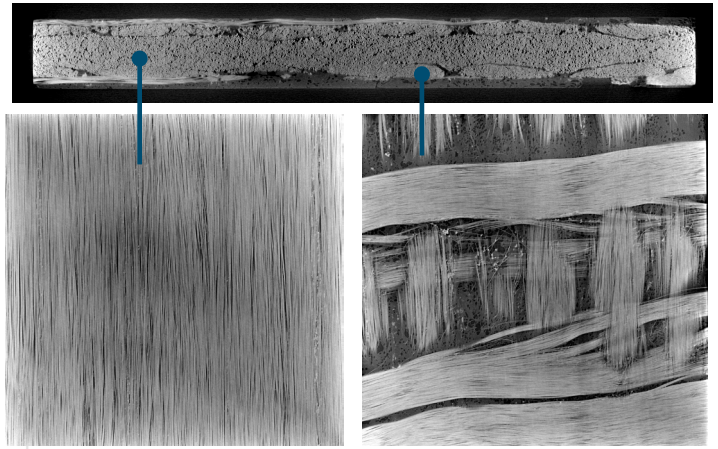
- Loose glass rovings bonded by resin

BIAXIAL



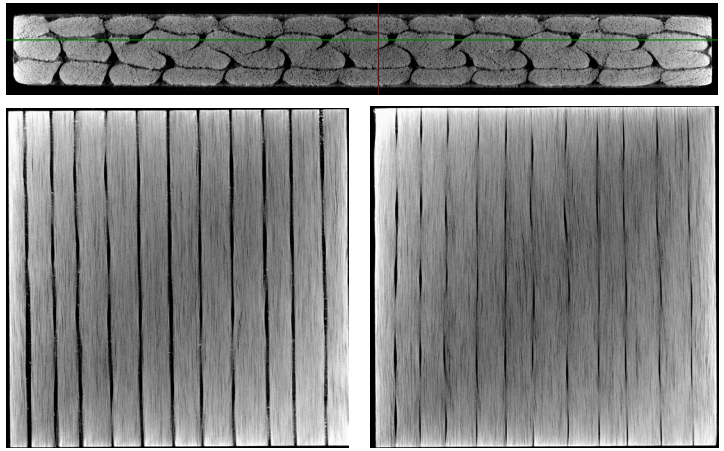
- Alternating layers of 0° and 90° oriented glass roving

HYBRID



- Top and bottom layer: biaxial
- Middle layer: all roving

UNI-AXIAL



- Bundled glass rovings bonded by veil

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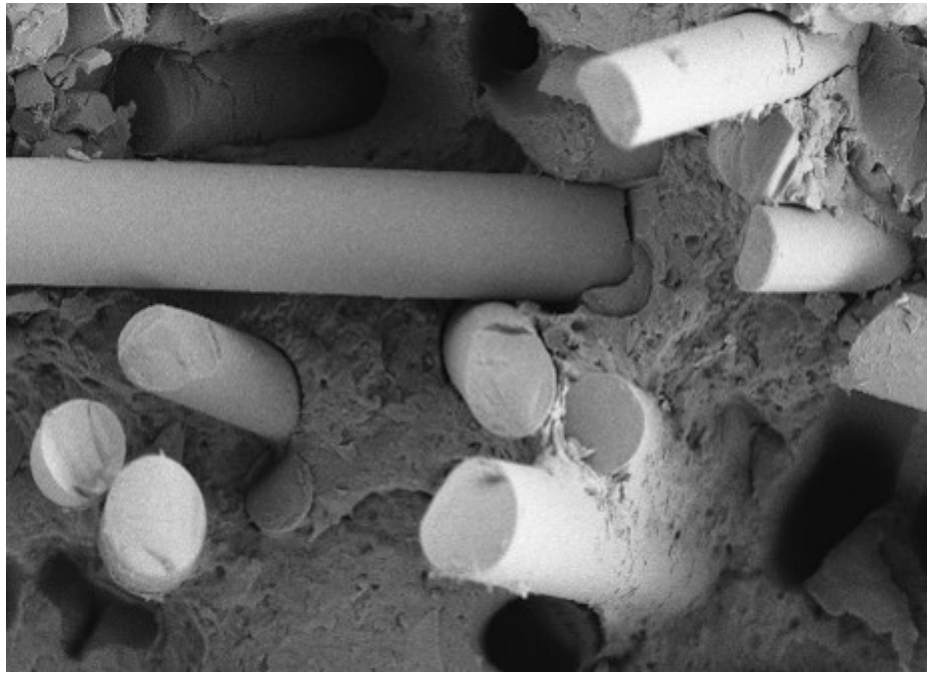
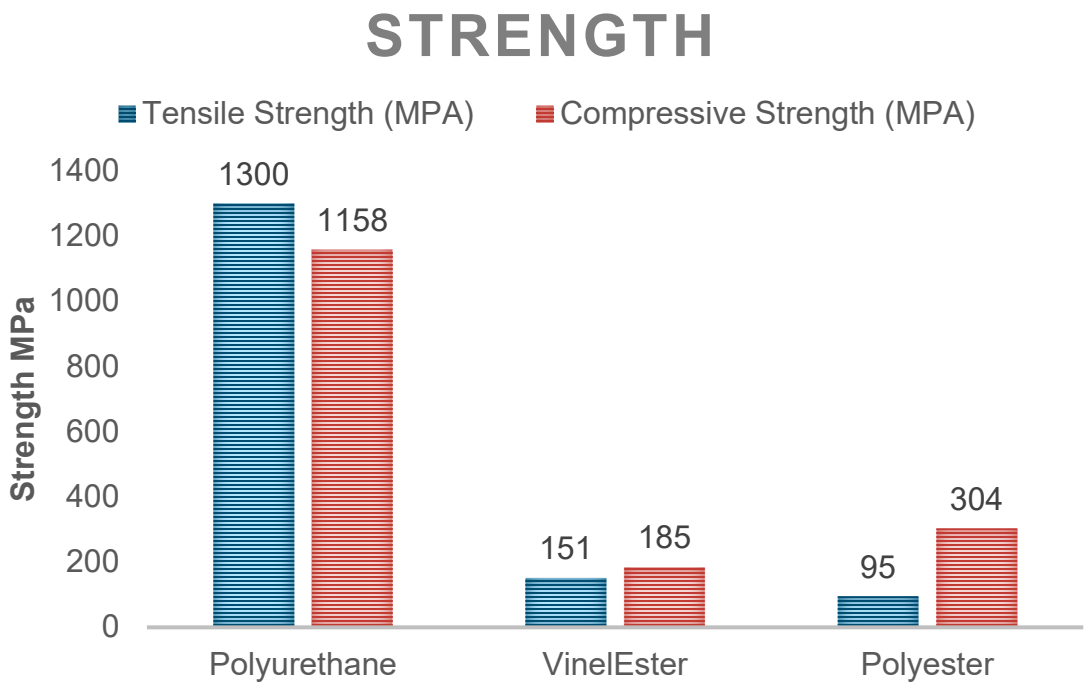
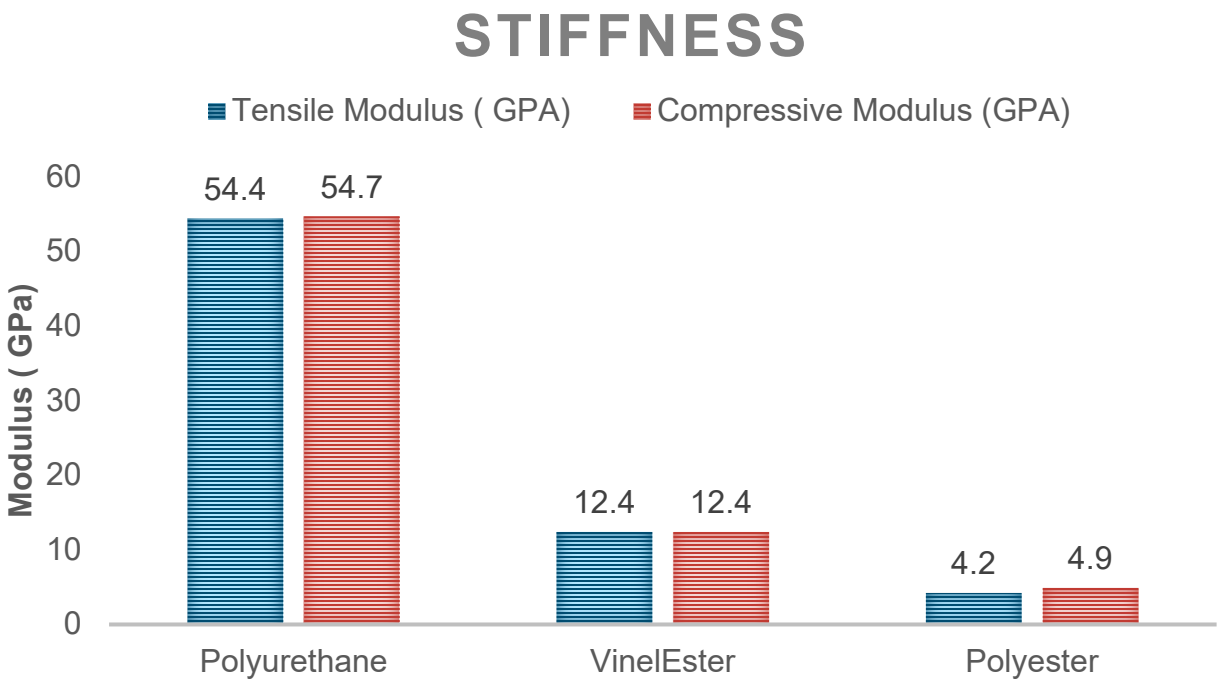
Matrix Materials

- Matrix Type
  - Thermoplastic (Low viscosity, reactive, etc)
  - Thermoset (Epoxy, Polyurethane, Polyester/Vinyl ester)
- Environmental Performance
  - Temperature
  - Mechanical
  - Chemical
  - UV
- Processing
  - Line Speed
  - Wet out



Matrix Materials





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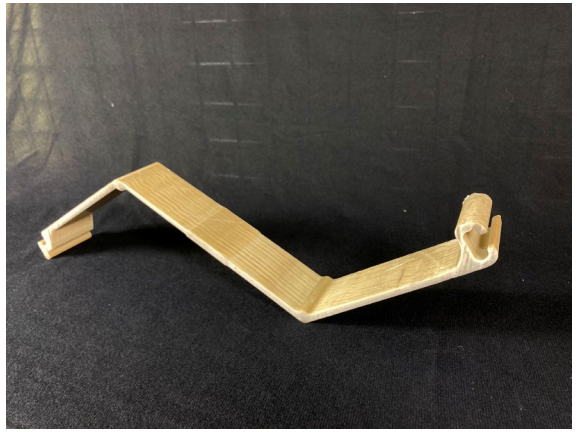
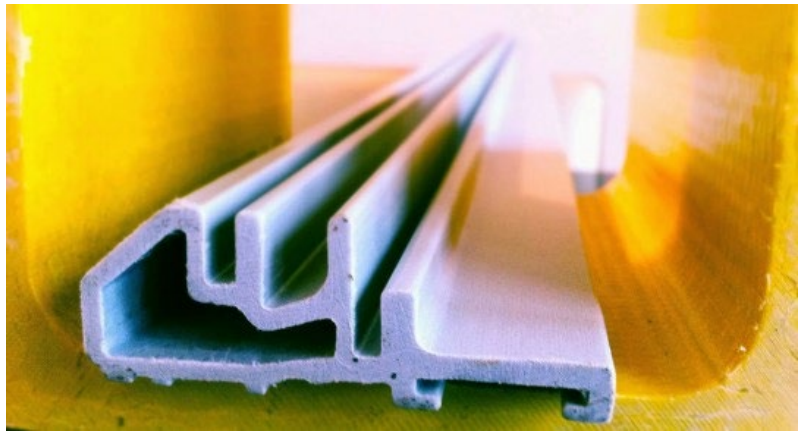
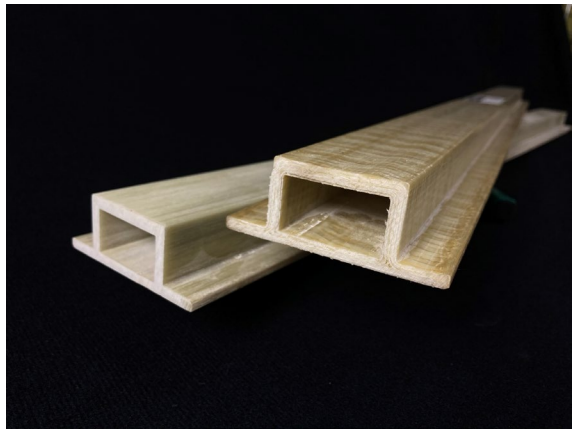
Elastocoat® Polyurethane Pultrusion Systems

- Fixed Profile
  - Flat/Open,
  - Closed
  - Multiple wall profiles
- Wall Stock
  - Minimum 1mm
  - Maximum over 6 mm
  - Constant Wall thickness is optimum
- Sweep or Run
  - Typically, Straight
  - Curved
  - Compound Curve







Elastocoat® Polyurethane Pultrusion Systems

Continuous Composite Value Proposition Advantage vs Metal Solutions

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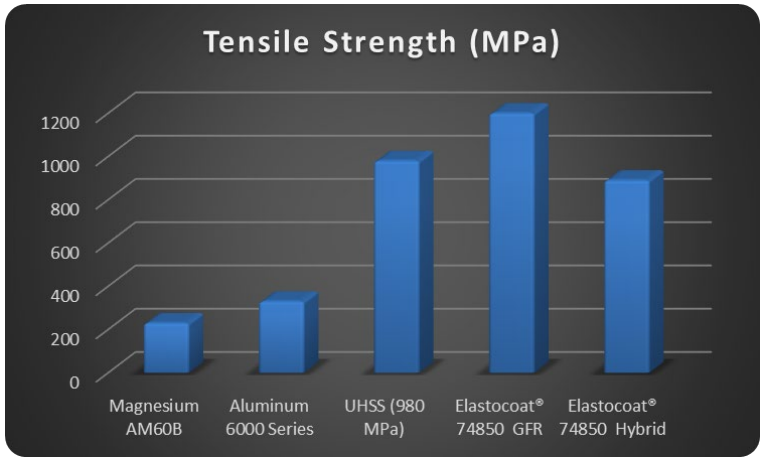
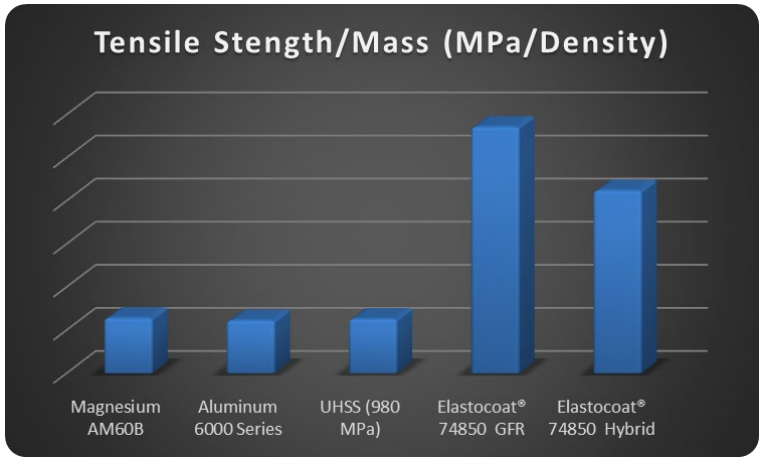
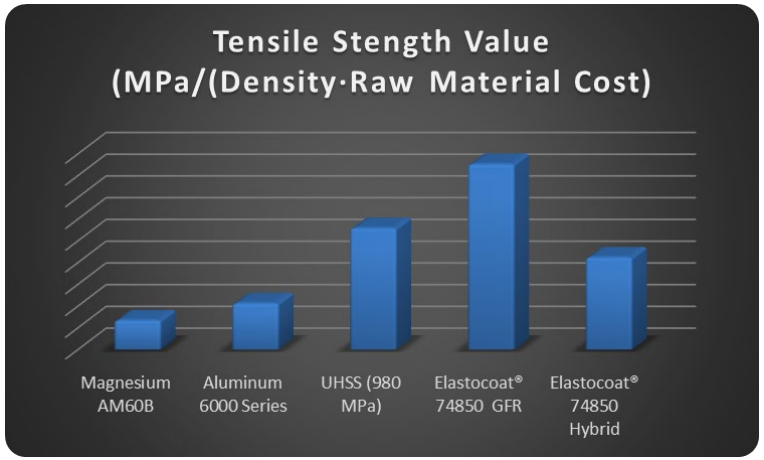
Elastocoat® Polyurethane Pultrusion Systems

Continuous Composite Value Proposition Advantage vs Metal Solutions







High Strength

Lower Mass

Cost Competitive

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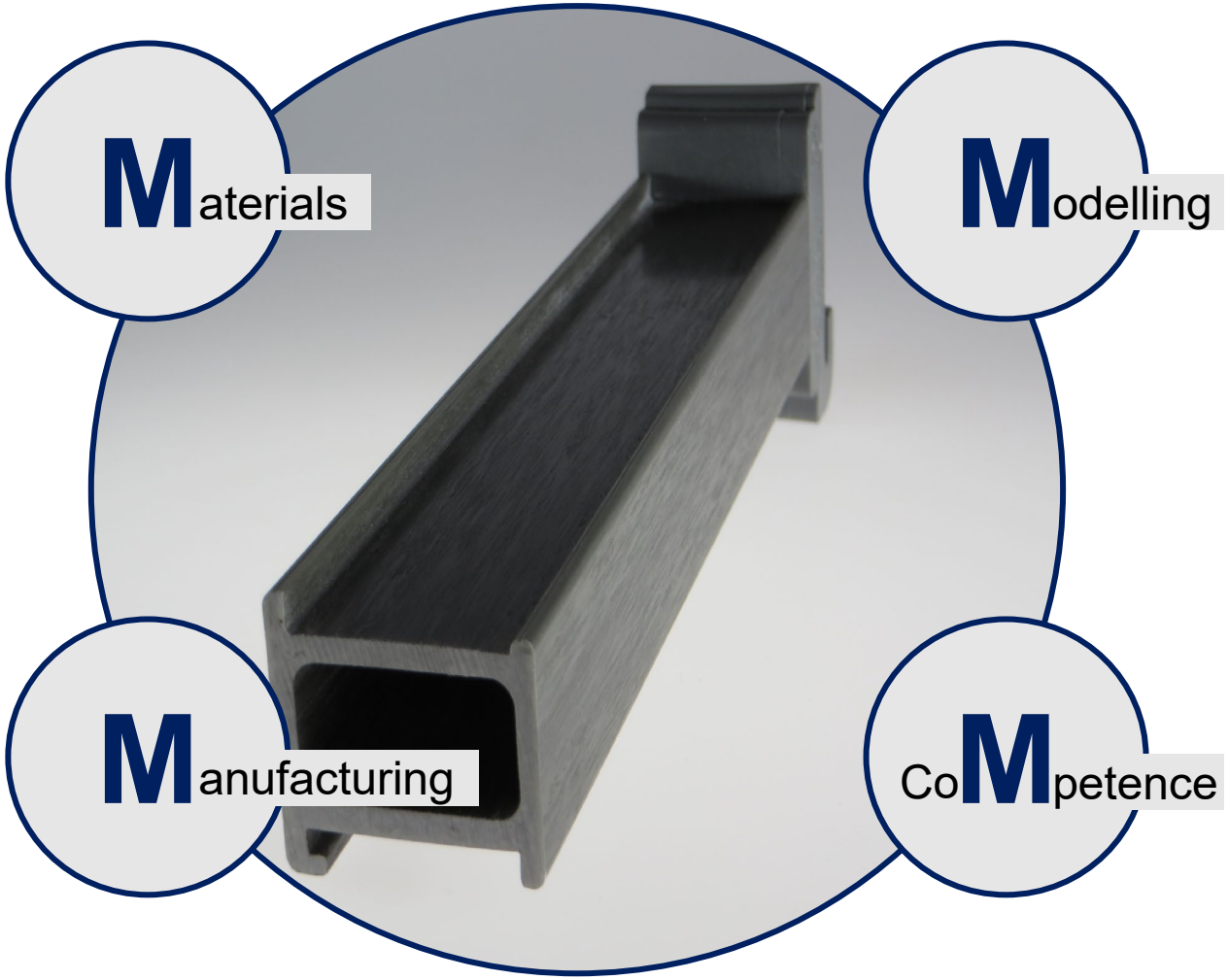
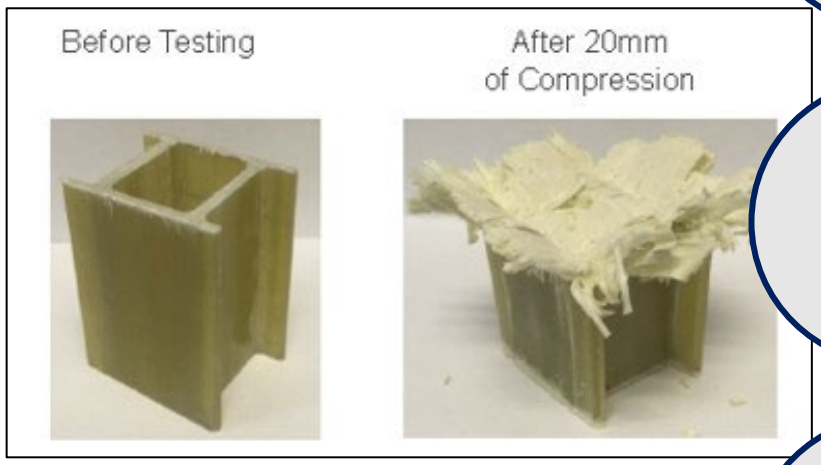
BASF is the leader in the Automotive Pultrusion Market!



Materials Elastocoat® 74850

- Large Processing Window
- Good Wet-out of Fibers
- Excellent Mechanical Properties (80% Rovings).
  - Flex Modulus: ~ 58 GPa
  - Flex Strength: ~1.5 GPa
  - Elongation to Fail: ~3.0%
- Volume Fraction is variable up to 80% GF
- Chemistry has good adhesion to Glass Fiber and Carbon Fiber
- Line speed up to ~~48"/min~~ 60"/min



L&L Products

Modelling

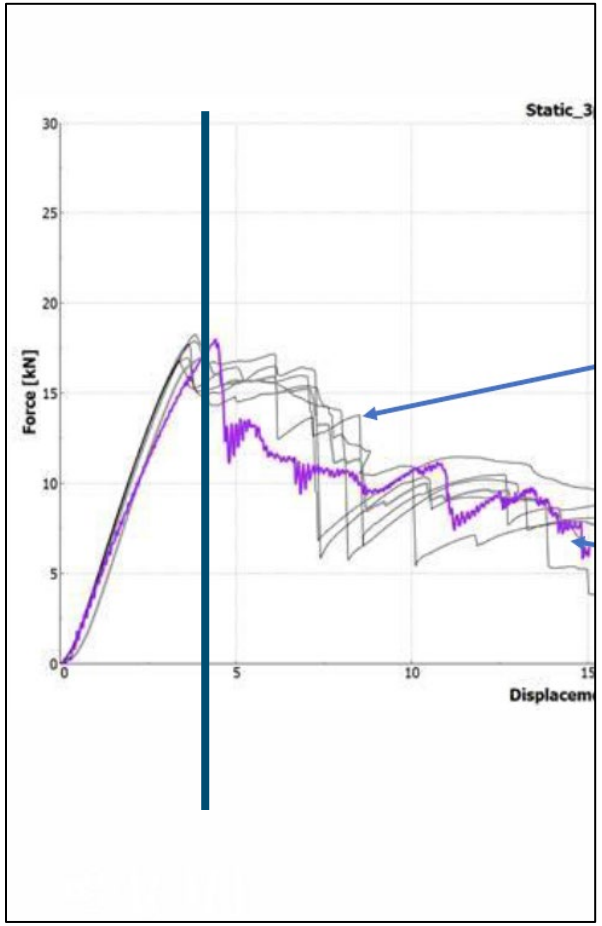
Manufacturing

CoMpetence

Modelling

Composite Modelling is…. tricky….

- Very predictable up until yield
- Matrix and Fiber Behave independently at the point of failure.
- Fiber Layup Variation
- Geometry dependencies
- Loading dependencies
- Processing/Wetout effects
- MAT Card Selection or Internal Development



Materials

Manufacturing

CoMpetence

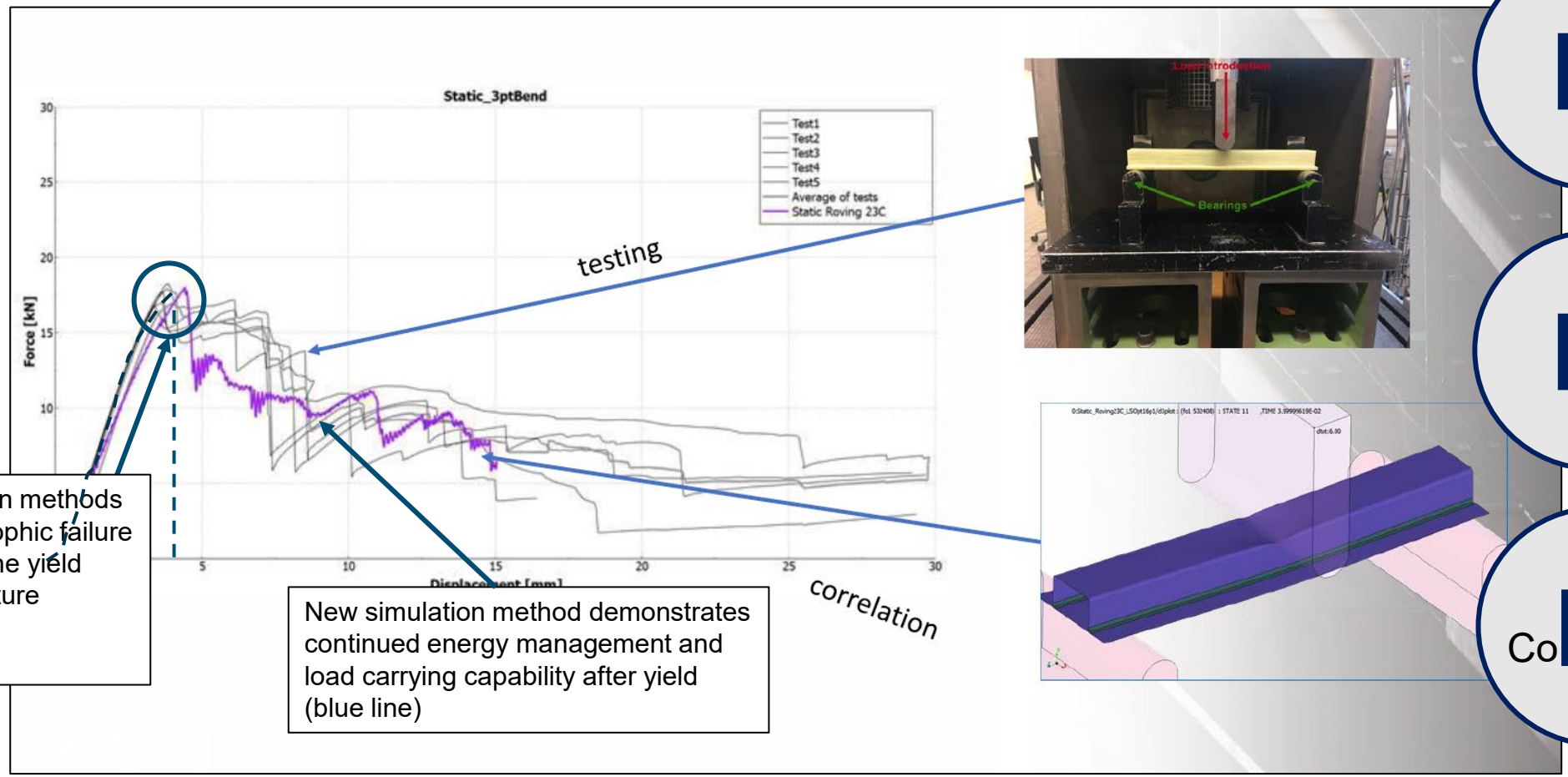
New Computer Simulation Methodology

Modelling

Materials

Manufacturing

Co**M**petence



Current simulation methods indicates catastrophic failure during the near the yield point of the structure (dashed line)

New simulation method demonstrates continued energy management and load carrying capability after yield (blue line)

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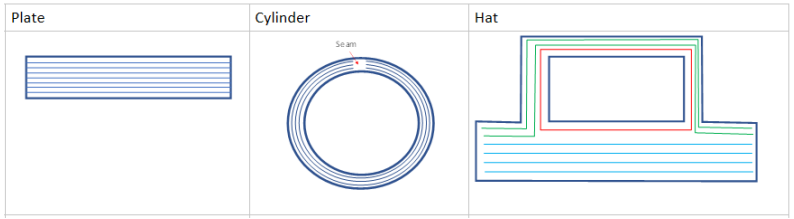
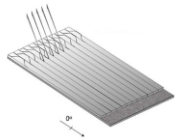
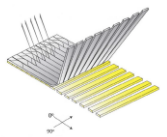
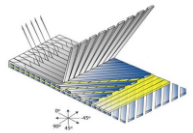
Modelling

Sample Generation

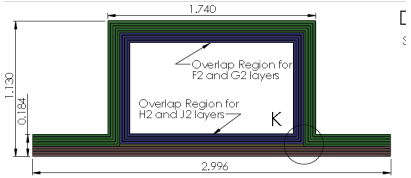
Die - Process
Injection Box
ISO + RESIN



Geometry

Architecture	0º Unidirectional	0-90 Biaxial	0º/+45º/90º/-45º Quadraxial
End Use	Ultrasim Characterization	Ultrasim Validation	
Picture			

Fiber Orientation



Layer	Product	Width-1 (in)	Width-2 (in)	FWF (%)	FVF (%)	Orient	Rot.	Fiber Wt (oz/yd^2)	Layer Thk (in)	Total Wt (lb/ft^2)
A	E-LR 2410	3	-	76.3	63.0	Dn	0	23.94	0.021	0.22
B	E-LR 2410	3	-	76.3	63.0	Dn	0	23.94	0.021	0.22
C	E-LR 2410	3	-	76.3	63.0	Dn	0	23.94	0.021	0.22
D	E-LR 2410	3	-	76.3	63.0	Dn	0	23.94	0.021	0.22
E1, E2	E-LR 1708	4.875	1.5	76.2	63.0	Dn	0	18.82	0.016	0.17
F1, F2	E-LR 2410	4.875	5.5	76.3	63.0	Up	0	23.94	0.021	0.22
G1, G2	E-LR 2410	4.875	5.5	76.3	63.0	Up	0	23.94	0.021	0.22
H1, H2	E-LR 2410	4.875	5	76.3	63.0	Up	0	23.94	0.021	0.22
J1, J2	E-LR 2410	4.875	5	76.3	63.0	Up	0	23.94	0.021	0.22

Architectures

CHALLENGES

- Highly complex process
- 7+ Variables
- Early stage on pultrusion learning curve
- Temperature dependency
- Strain Rate dependency

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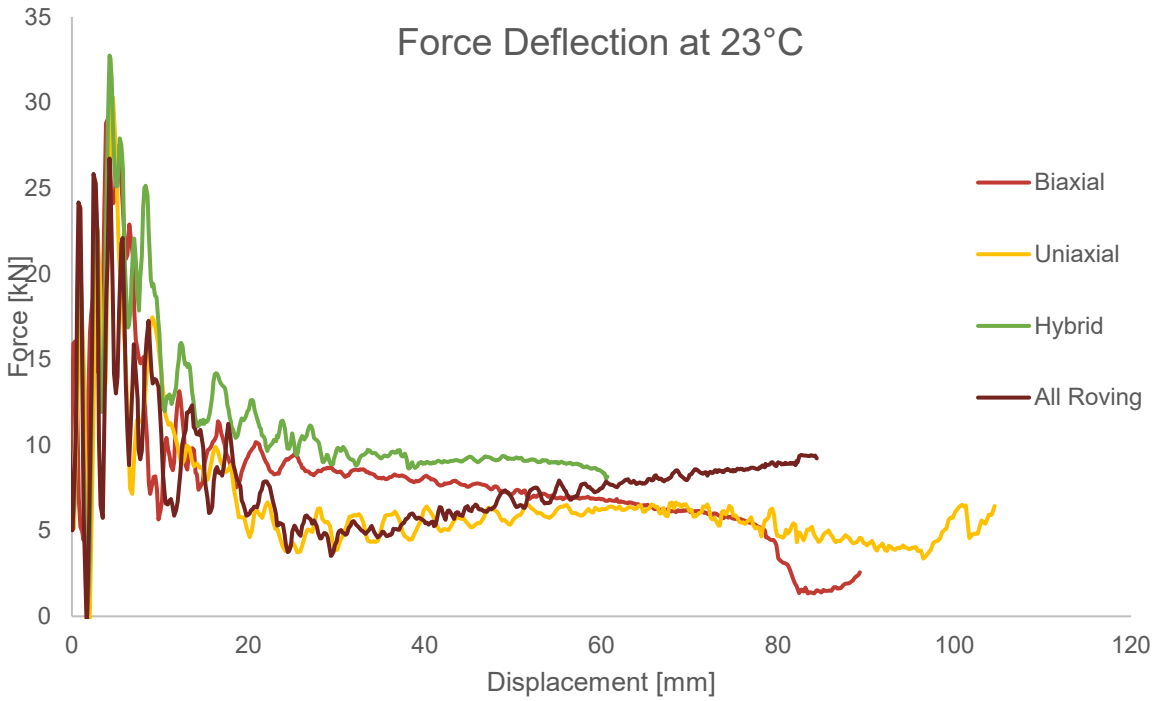
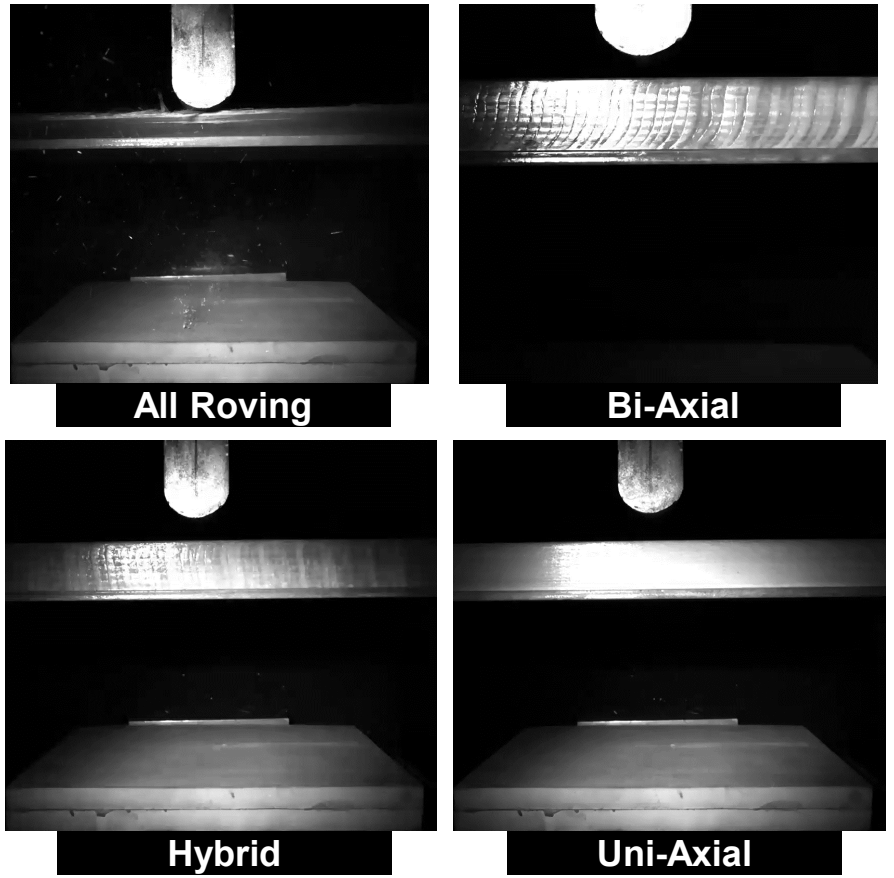
Modelling

Simulation Capabilities



3Pt Bending Impact on Four the Parts



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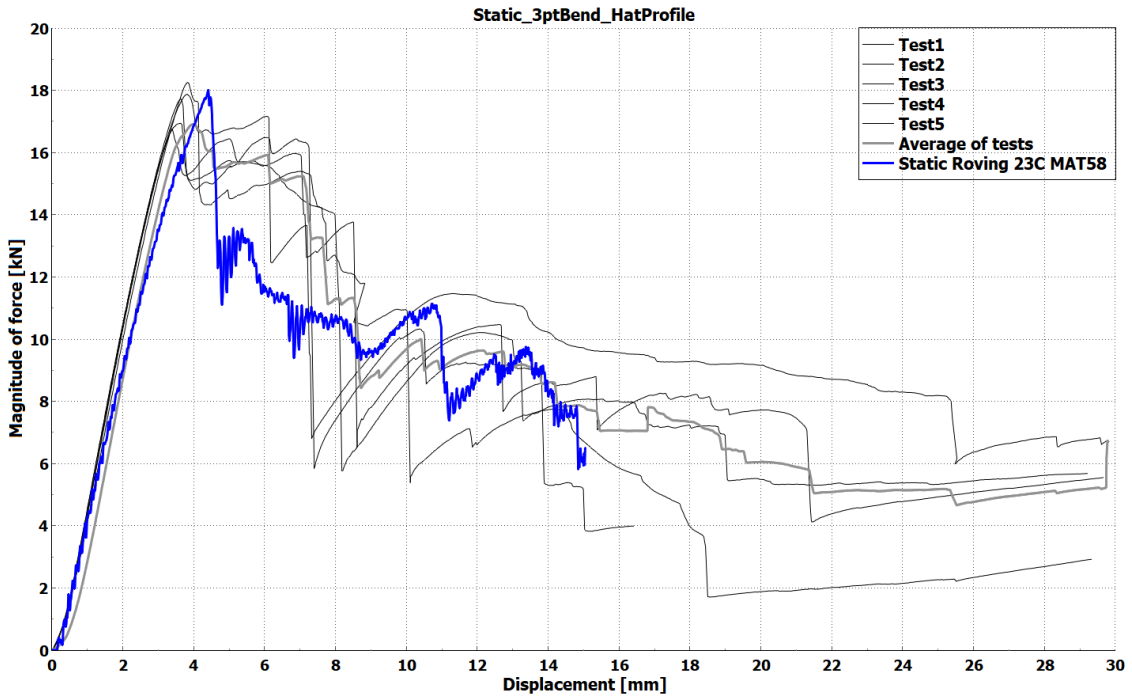
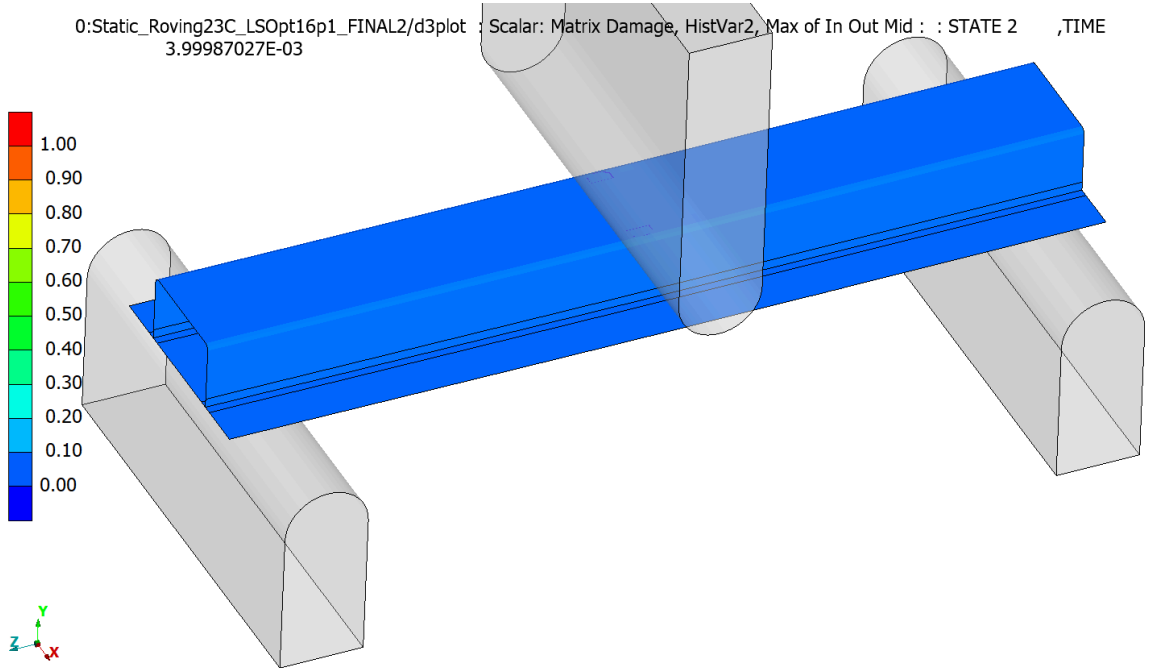
Modelling

Correlation of Static 3pt Bend Part

23°C

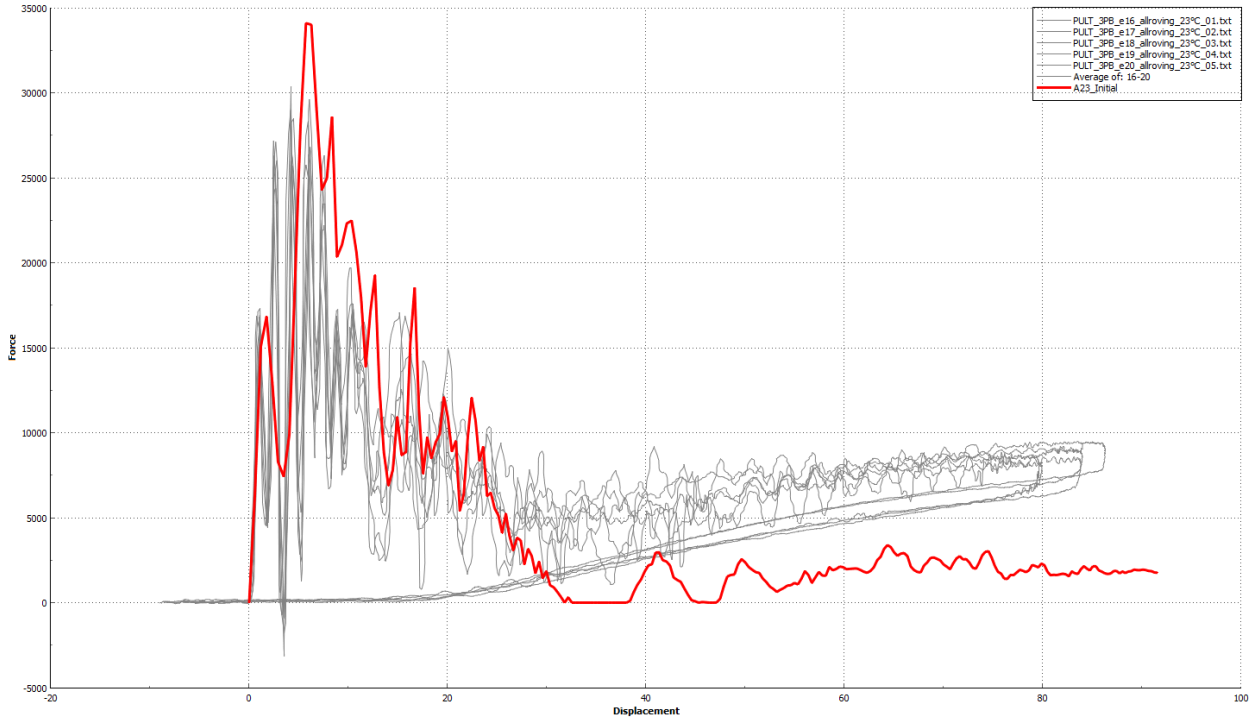


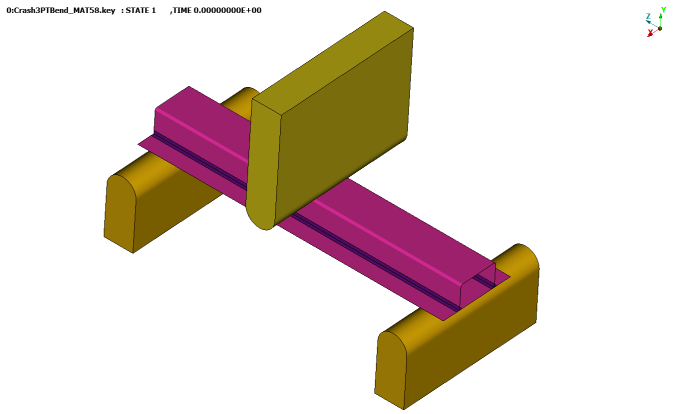


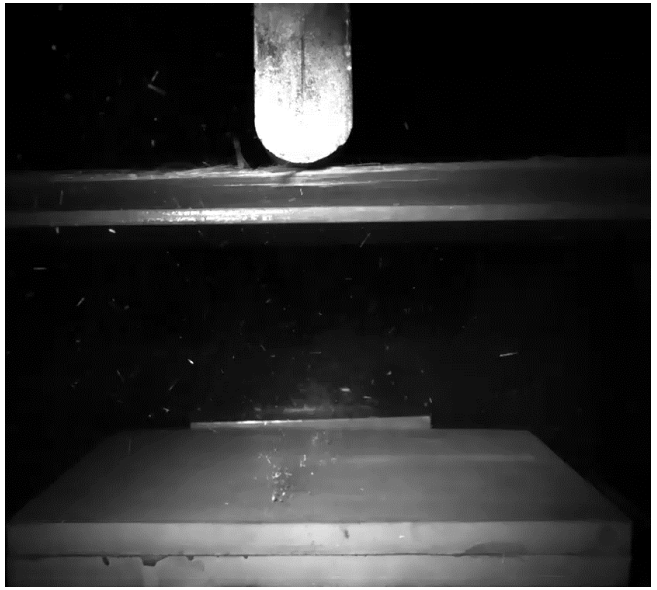
Modelling

Correlation of Crash 3pt Bend Specimen

23°C







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Manufacturing

- Processing
- Injection Box Design
- Wet out
- Fiber Alignment
- Line Speed Optimization
- Degradation Analysis
- Failure Analysis

Nuance of a Reaction (Iso and Resin) vs a Semi-Finished Good

Modelling

Materials

Co**M**petence

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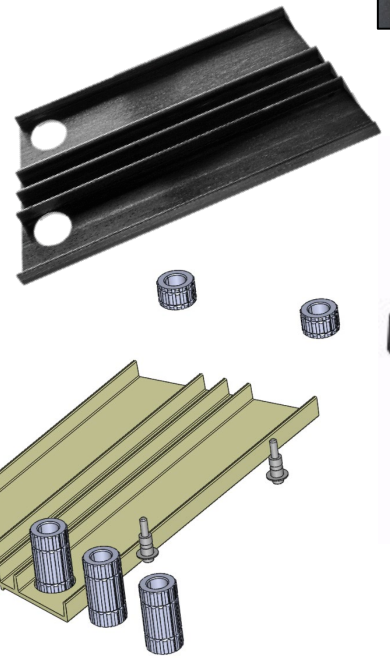
Manufacturing

Needs for Automotive Acceptance

- Higher processing rates (cost)
  - Maximize Fiber Wet-out
  - Material Delivery
  - Multiple Dies
- Bonding Strategies (vehicle assembly)
  - Insitu applied adhesives
  - Over molding / Insert Molding
  - Secondary operations



Modelling

Materials

CoMpetence

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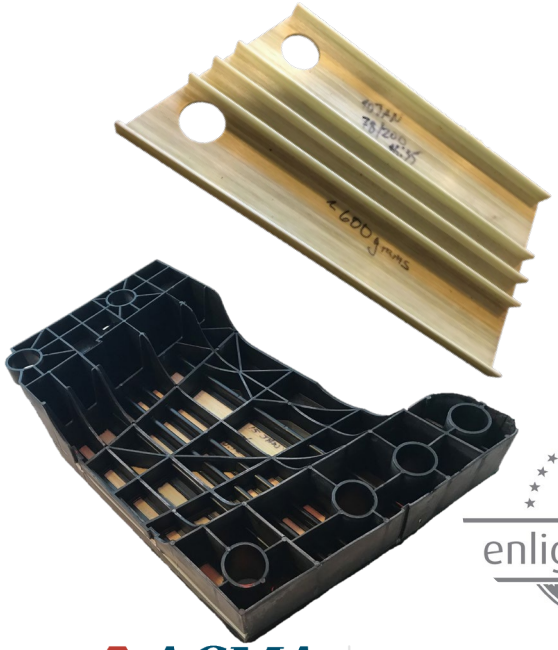
L&L Products

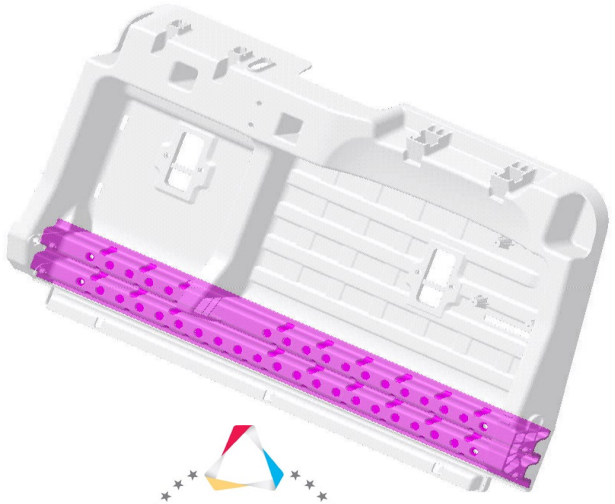
Pultrusion in Production

Pultrusion Value Proposition

CoMpetence



Altair enlighten award 2021



Altair enlighten award 2022

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L&L Products

Where do we go from here?

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Extending and Growing Product Life Cycle
Focus on "What we didn't know"

- Application Development – New Areas
  - Metal to Composite – Suspension Components and Energy Absorption (Value Prop Driven)
  - EV Apps – Battery and New Vehicle Architecture
  - Joining Bonding – Nonmetallic – Continuous Fiber
- Product Development – Focused on Learnings
  - Thermal Management for EV
  - Higher Performance (Mechanical Properties)
  - Sustainability
    - Bio-Content – (Resin and Fiber)
    - Thermoplastic
    - LCA - Transparency

Actual Pultruded Samples made at L&L

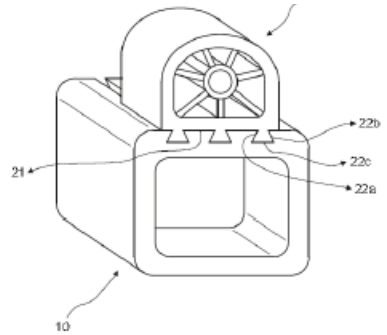


Image from Patent Application

Higher Performance Products

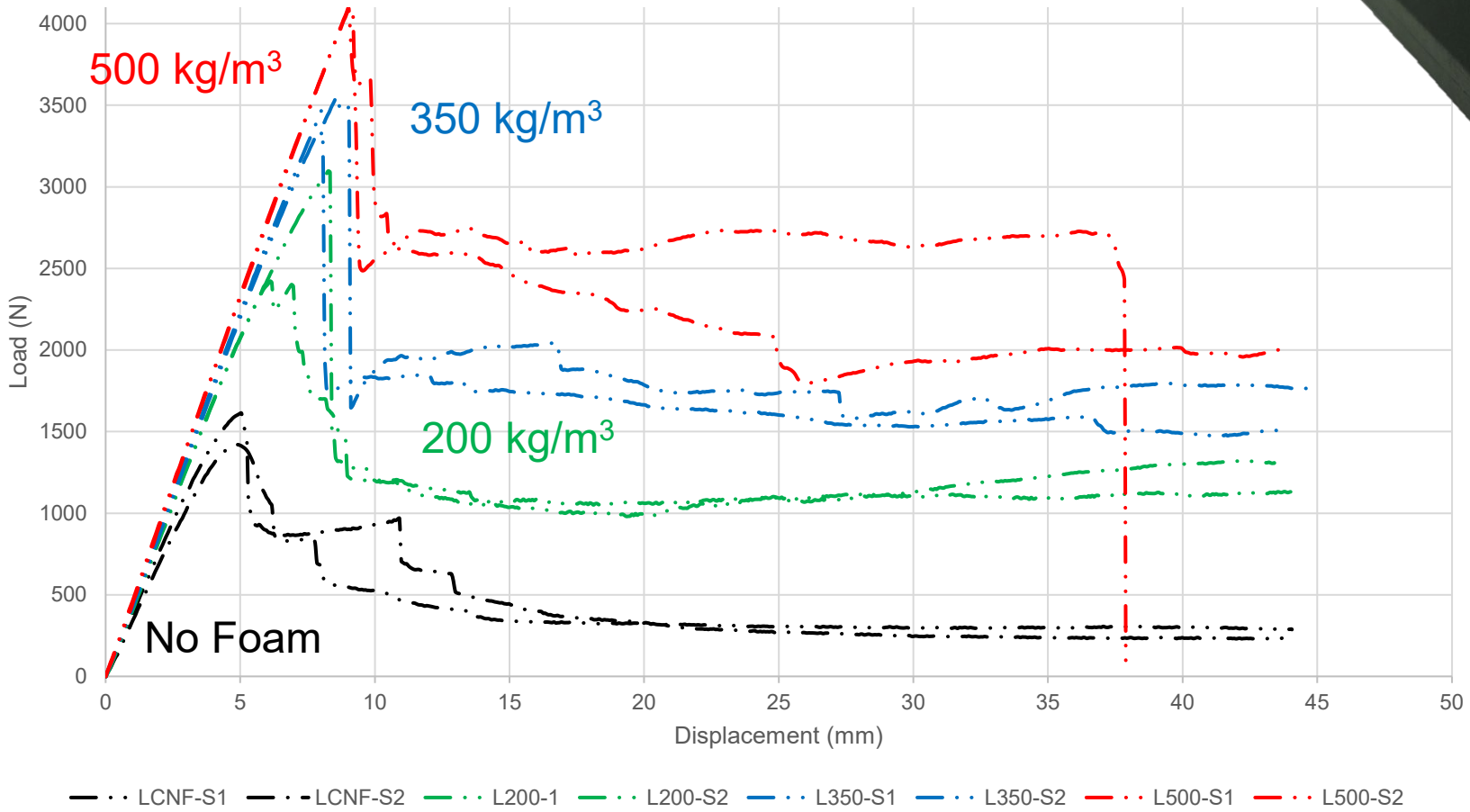
Elastocoat 74830

- Excellent Wet Out
- Good Mechanical Properties (80% Rovings).
  - Flex Modulus: ~ 52 GPa
  - Flex Strength: ~1.1 GPa
  - Elongation to Fail: ~4.0%
- Provides more ductility
- Chemistry has strong adhesion to Glass Fiber and Carbon Fiber
- Line speed up to 72”/min

Elastocoat HP EXP

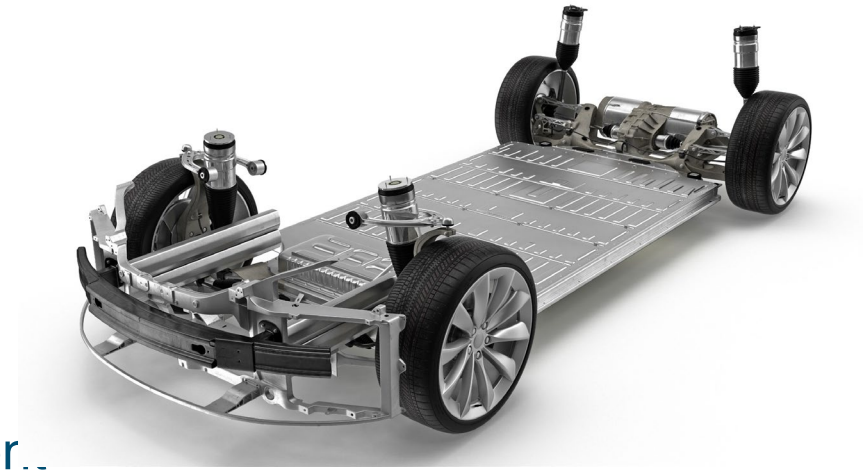
- High Tg < 200C
- Excellent Property Profile
  - Flex Modulus: ~ 60 GPa
  - Flex Strength: ~1.8 GPa
  - Elongation to Fail: ~3.0%
- Property Retention after long- and short-term heat exposure
- Line speeds up to 48”/min

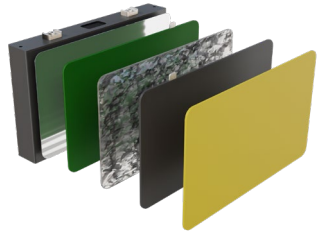
Increasing Pultrusion Performance Structural Foam

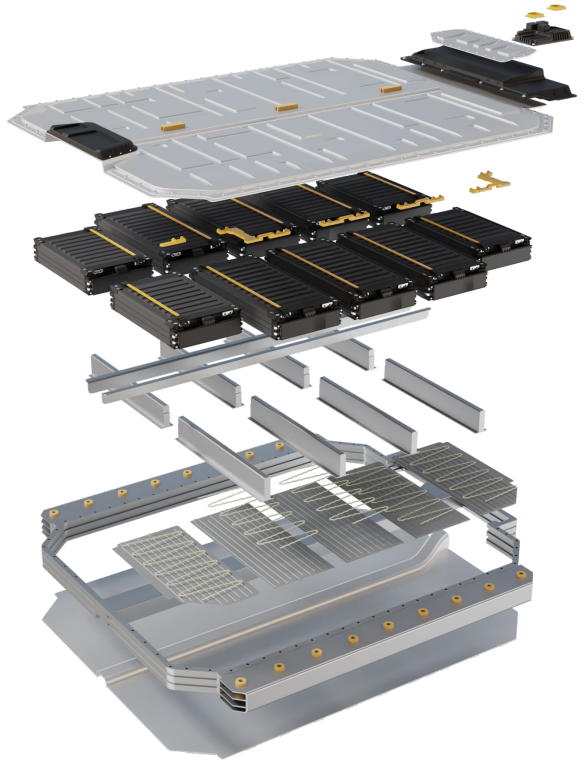


Focused Application Development
EV Battery Structure

- Outside the box
  - Rail reinforcement
  - Body pan structure
- Outer Structure
  - Side and Sill Reinforcement
  - Front and Rear Reinforcemer…
  - Speed Bump Countermeasures
- Inner Structure
  - Long Beams
  - Cross Beams
  - Plates







Drivers for Pultrusion (Continuous Fiber Solutions) for Battery Applications

- Strength to Weight
- Non-Metallic or Non-Conductive Structural Solutions
- V-0 compliance OEM driven
- Thermal Runaway
  - Flame ~1000C for 20 minutes
  - Initial Cell Explosion

- 2-4:1 depending on fiber loading and orientation
- Non-Conductive with High CTI with glass fiber
- V-1 compliant without any development
- Method of Passing with Composites
  - Resin is not an accelerant
  - Highly Filled Structure remains intact
  - Char Layer Protection

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Flame Resistant PU Resins for e-Mobility Applications

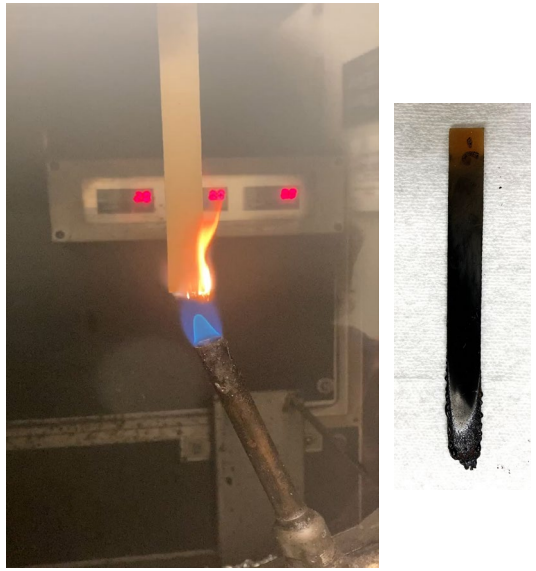
Halogenated

- Neat PU meets UL94 V0
- High line speed > 6 FPM
- Excellent fiber wetout
- Low pull force < 4 kN

Halogen free

- Neat PU meets UL94 V0
- High line speed > 6 FPM
- Excellent fiber wetout
- Low pull force < 4 kN

Typical burn test



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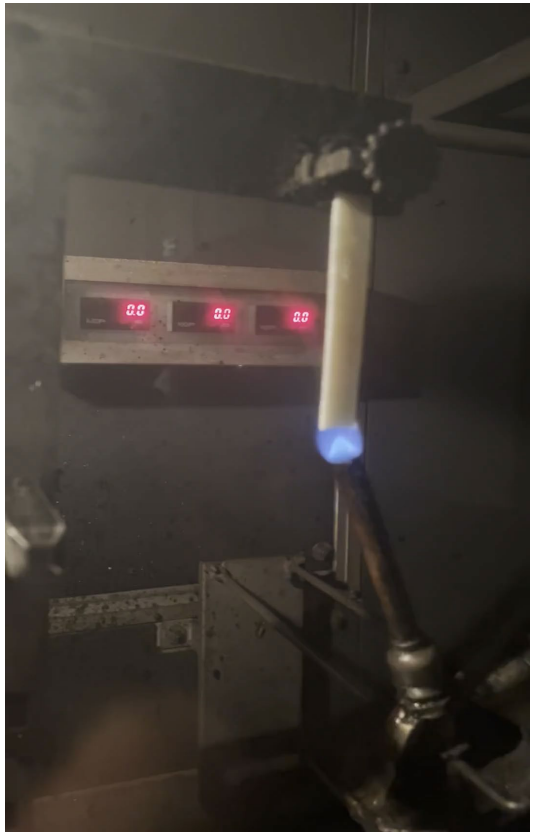
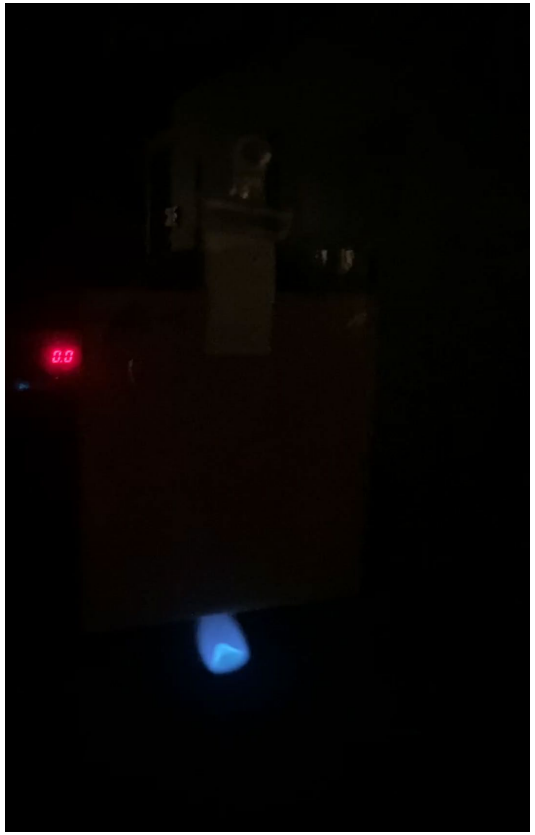
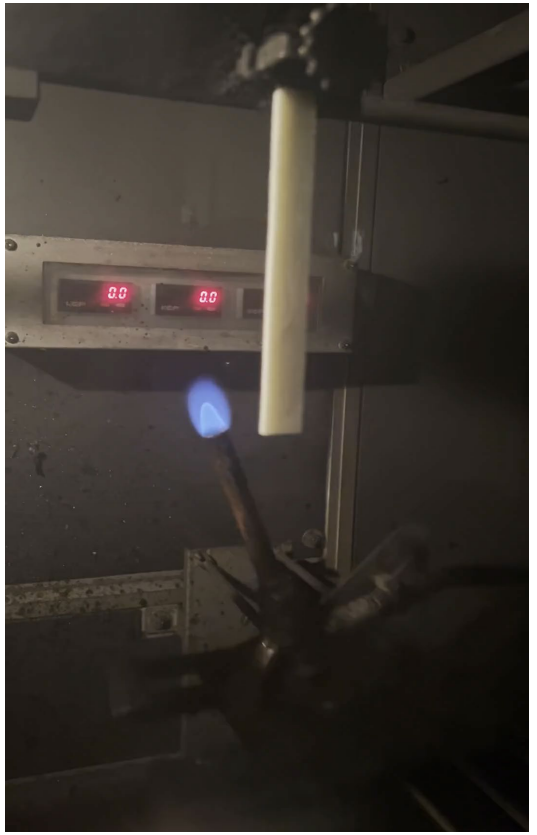
UL94 Flame test – Pultruded Samples

Transverse direction	Part edge	Parallel to fiber direction
		
UL94 V0	UL94 V0	UL94 V1

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Flexural Properties

System	Flex Modulus (GPa)	Flex Strength (GPa)
Regular PU system Pultruded 3 mm	50.9	1.54
Halogenated FR system Pultruded 3 mm	54.8	1.45
Halogen-free FR system Pultruded 3 mm	50.2	1.17

A Note on Sustainability
The driving Mega Trend

- Multifaceted
  - GHG reduction/elimination
  - Circular Economy
  - Transparency
- Polyurethane (Thermoset)
  - Lighter weight
    - lower in use GHG
    - Less resources utilized
  - High Glass Fiber Content
    - Low System PCF (LCA is being verified)
    - Glass Fiber reclamation possible

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