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Lightweight Development on Semi Structural Parts for Automotive Applications

4a Technologietag

Pichl bei Schladming, February 2018

4a impetus

Olaf Herd
Global Account Manager Automotive

Contents

- Celanese Short Introduction
- Semi Structural Parts for Automotive Applications
- How to create Data Cards vs 4 a Impetus
- Crash Data Cards for Structural Parts
- Summary

Celanese Short Introduction

Celanese: Ein Technologieführer bei der Produktion von differenzierten Chemieprodukten und Spezialmaterialien

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- Das Unternehmen mit Sitz in Dallas (Texas, USA)
- beschäftigt weltweit rund 7000 Mitarbeiterinnen und Mitarbeiter
- Mehr als 35 Produktionsstandorte in 18 Länder (Übernahme von So.F.teR nicht beinhaltet)
- erwirtschaftete 2016 einen Umsatz von 5,47 Milliarden US$.

Materials Solutions

2.4 MRD. US$ UMSATZ

Kombiniert **Chemie, Werkstoffkunde** und **Verständnis kundenspezifischer Bedürfnisse** zur Entwicklung maßgeschneiderter, wertschöpfender Lösungen

- **Technische Hochleistungskunststoffe** finden Verwendung in Automobil- und Elektronikindustrie, in Medizinprodukten und ästhetischen Anwendungen
- **Acetatflocken, -kabel und -folien**, z.B. für den Einsatz in Filtermaterialen und Spezialfolien
- **Lebensmittelzusatzstoffe**, einschließlich Süßstoffe und Konservierungsmittel

Acetyl Chain

3.07 MRD. US$ UMSATZ

Nutzt **Technologie**, unser **globales Produktions Netzwerk**, und ein profundes Verständnis **globaler Handelsströme** zur Wertschöpfung

- **Essigsäure, Vinylacetatmonomer** und weitere chemische Zwischenprodukte
- **Polymerdispersionen** finden Verwendung z.B. in Anstrichfarben und Klebstoffen
- **EVA Polymers** kommen bei flexiblen Verpackungen und medizinischen Lösungen zum Einsatz

Product Pyramid
after So.F.teR & Nilit Acquisition

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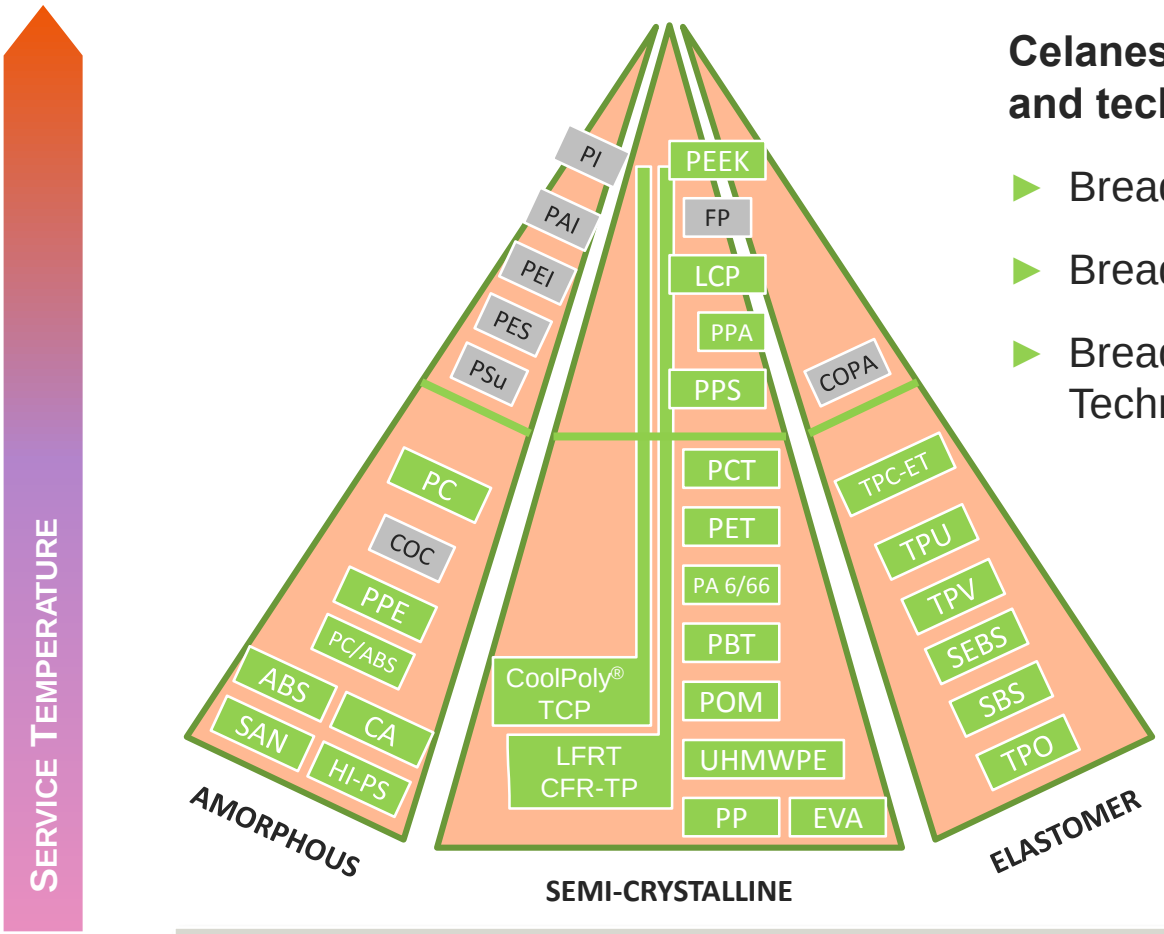

Celanese's broad materials portfolio and technical expertise offer…

- Breadth in Functionality
- Breadth in Form Factors
- Breadth in Customer Conversion Technologies

Celanese has one of the **broadest portfolios** spanning all thermoplastic classes

Semi Structural Parts for Automotive Applications

Manufacturing Process – Pultrusion

stands for Quality

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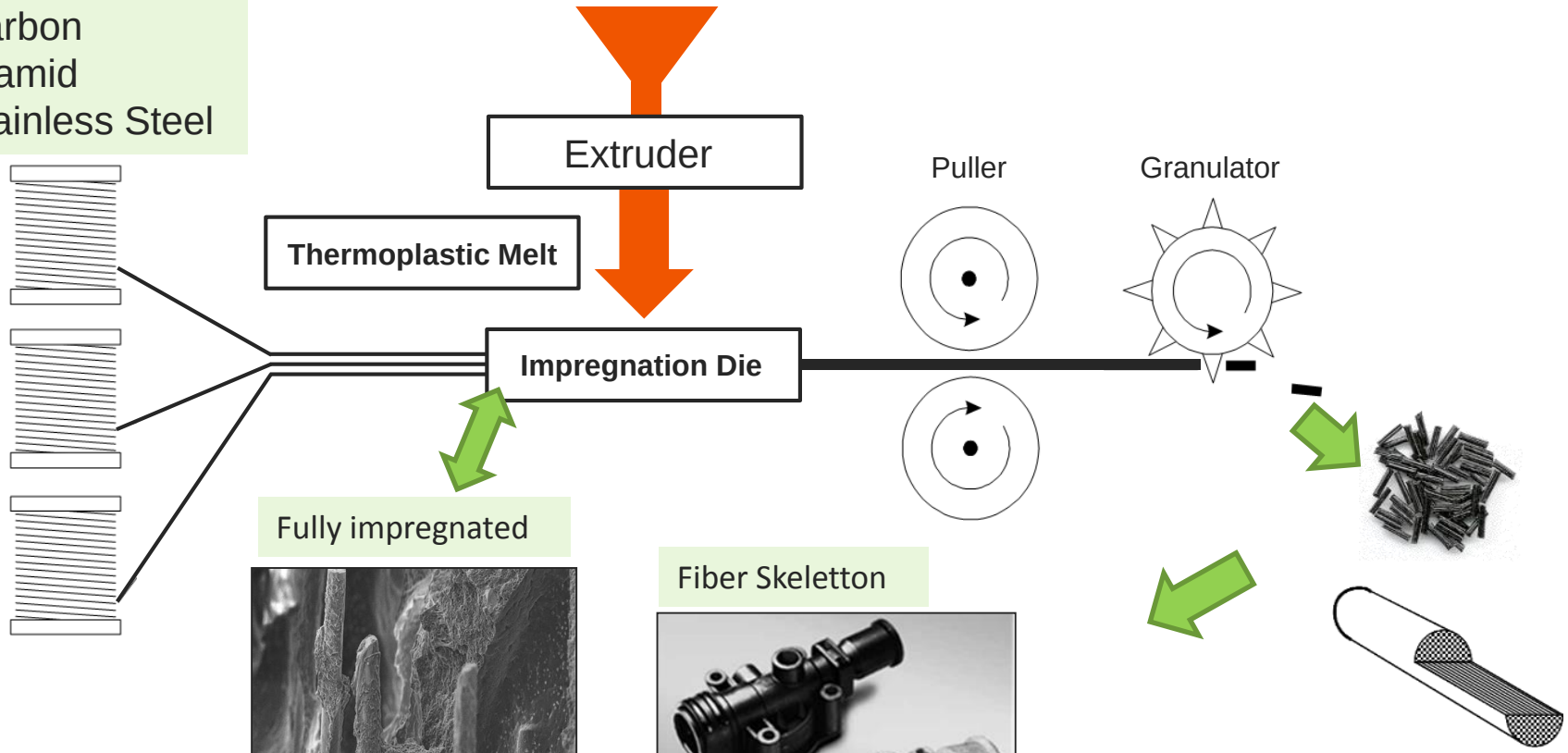
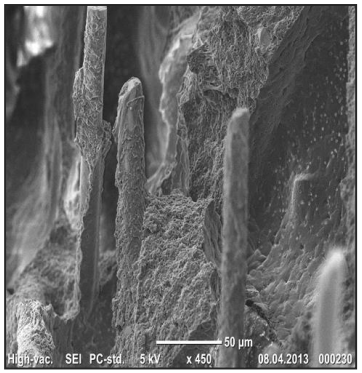
Glass Fiber
Carbon
Aramid
Stainless Steel

Polymer
PP, PA, POM, PBT, PPS etc. + additives



Fully impregnated



Fiber Skeletton

LFrT Pellets:
10 mm length for Celstran
25 mm length for Compel

Semi Structural Parts
in development with Long Glass Fiber reinforced TPs

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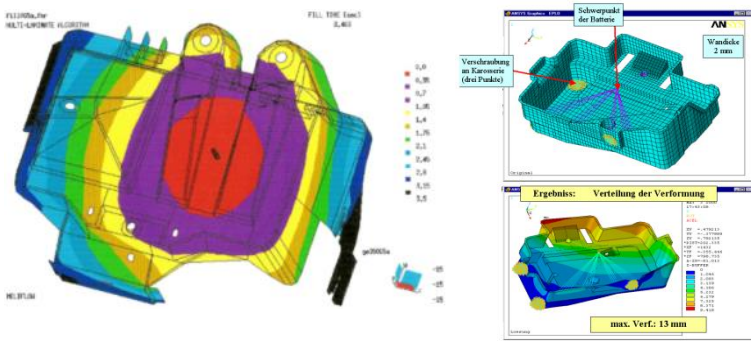
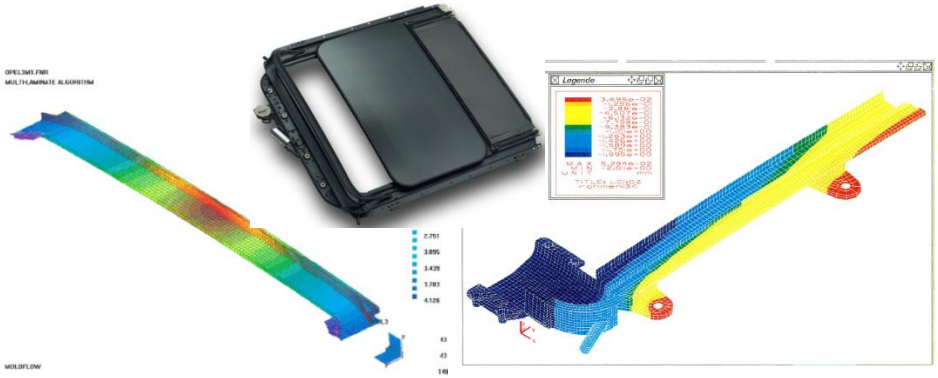
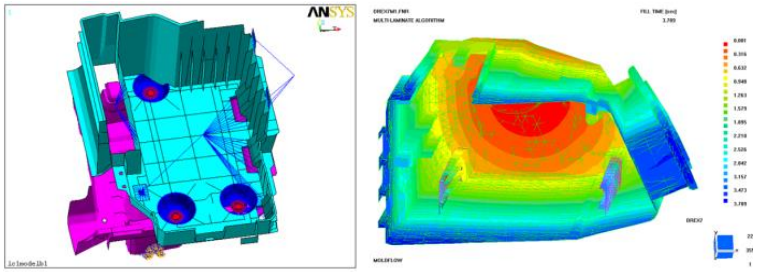


Battery Trays - 1995



Sunroof Parts - 1994



Control Units,
Management Systems - 1999

Semi Structural Parts
in development with Long Glass Fiber reinforced TPs

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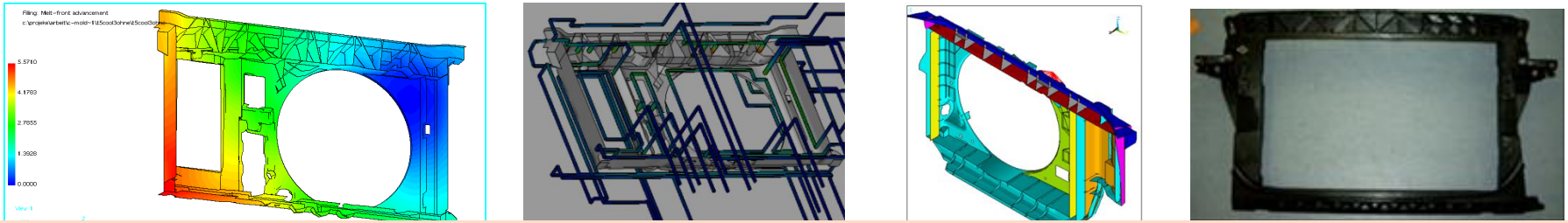
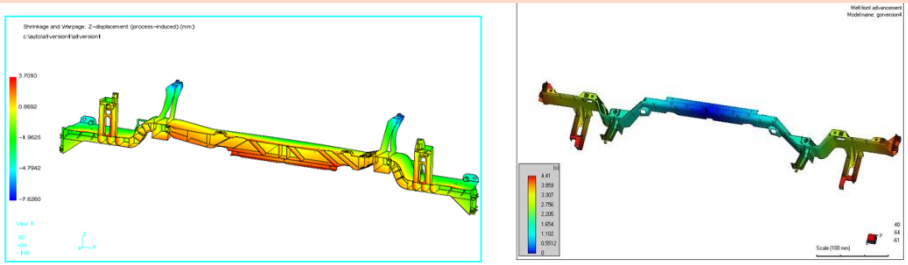
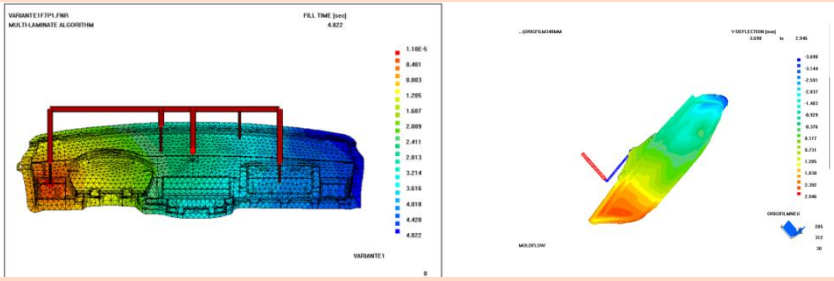


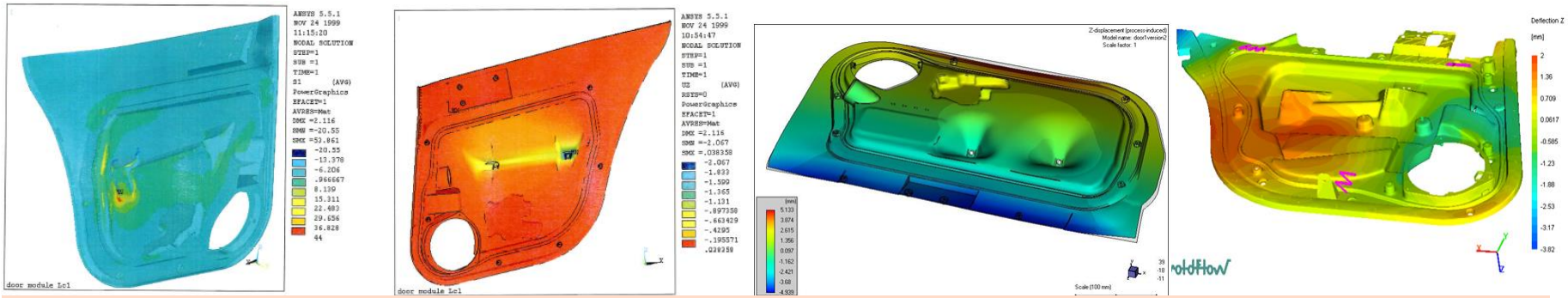
Front Ends - 1997



Grill Opening Retainers - 1999



Instrument and Dash Panels - 1999



Door Modules - 1999

…for excellent project development

in cooperation with OEM / Tier 1, 2… as project tracking

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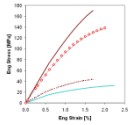
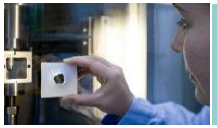
Ideation

Component Design



Material Data Cards

Filling Simulation, Tooling, Production



Testing

Component Validation

OEM Specification

Cars
Trucks
Electrification

Specification – as requirements for a global process

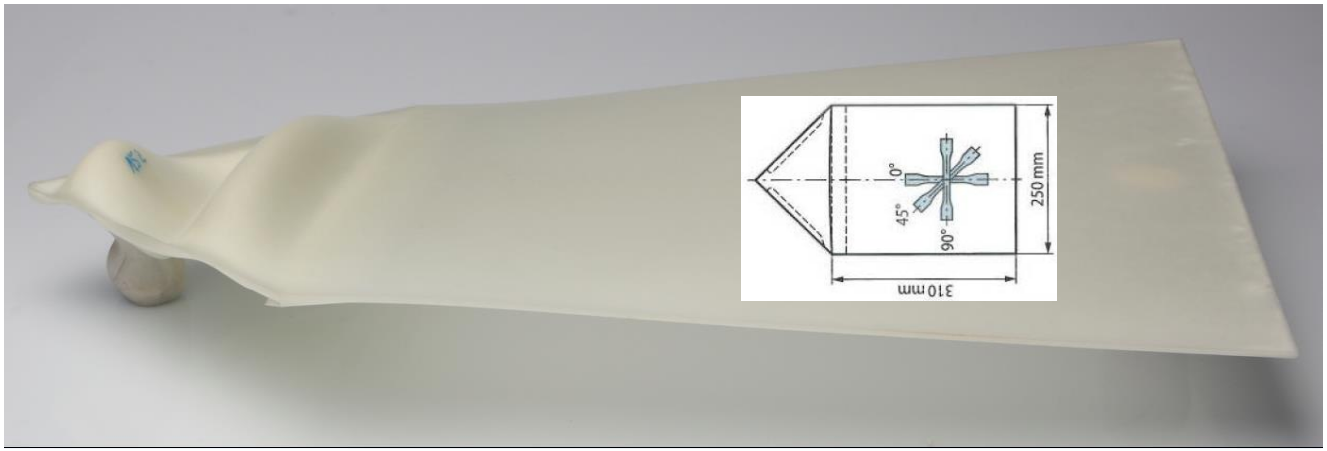
Valuable cooperation – right from the start.

How to create Data Cards vs 4 a Impetus

4a impetus

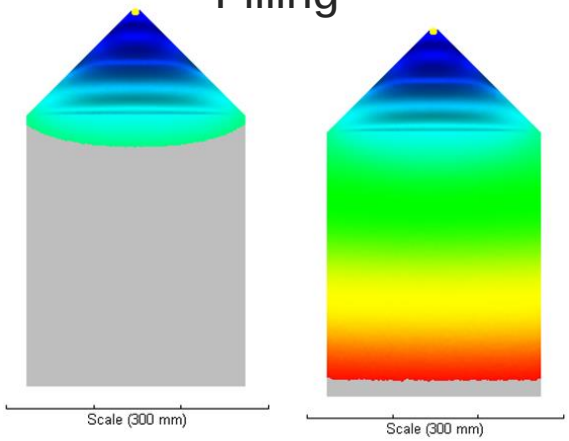
Moldflow Simulation of LFT

Filling study on 2.5 mm plaque



Filling

Celstran PP GF30



Celstran PP GF50

Short fiber GF30

Different flow fronts depending on fiber content.
Filling behaviour (flow front) can not be simulated correctly.

Moldflow Simulation of LFT

Filling study on 2.5 mm plaque

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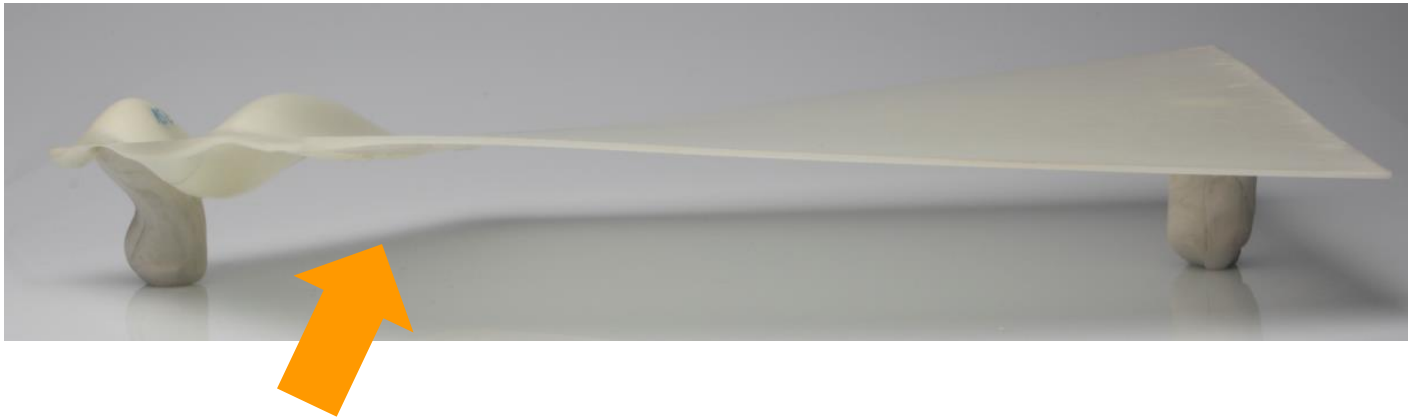
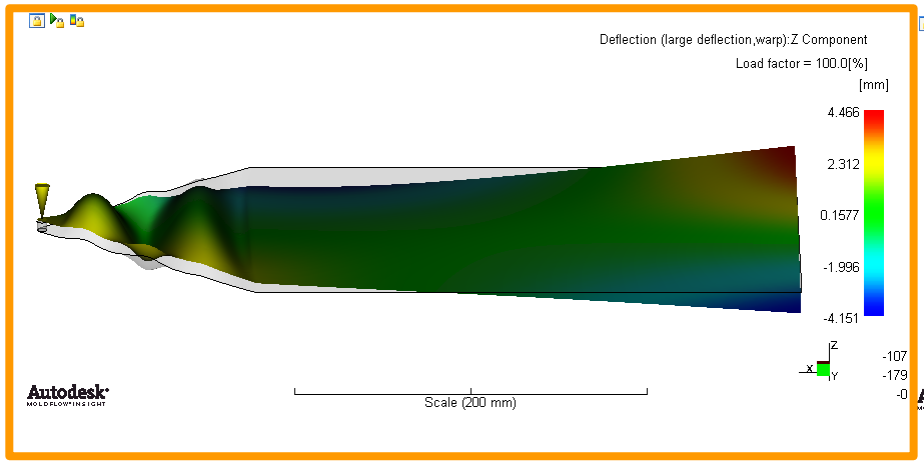
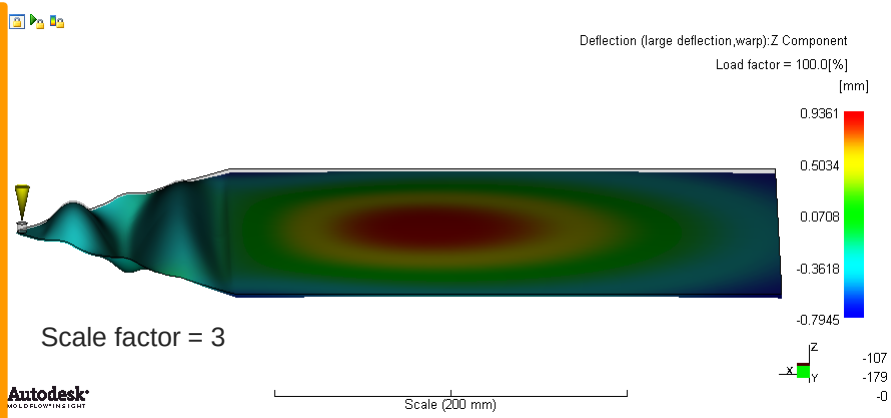






Calculate fiber orientation using

Moldflow model with auto-calculated Ci and Dz values

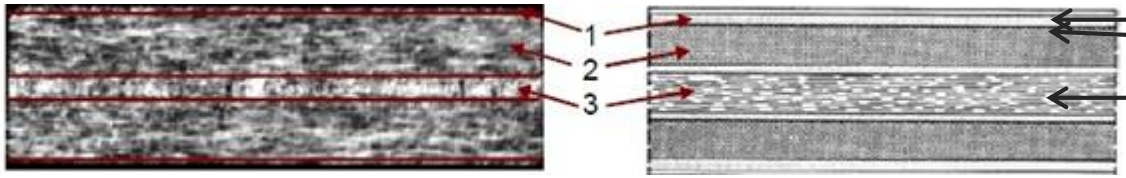
Calculate fiber orientation using

RSC or ARD-RSC model (determined by length)

ARD RSC: **A**nisotropic **R**otary **D**iffusion – **R**educed **S**train **C**losure)

CT Analyzes: Fiber Length

Distribution and Orientation over Thickness



cross section

schematic layer structure

Skin layer

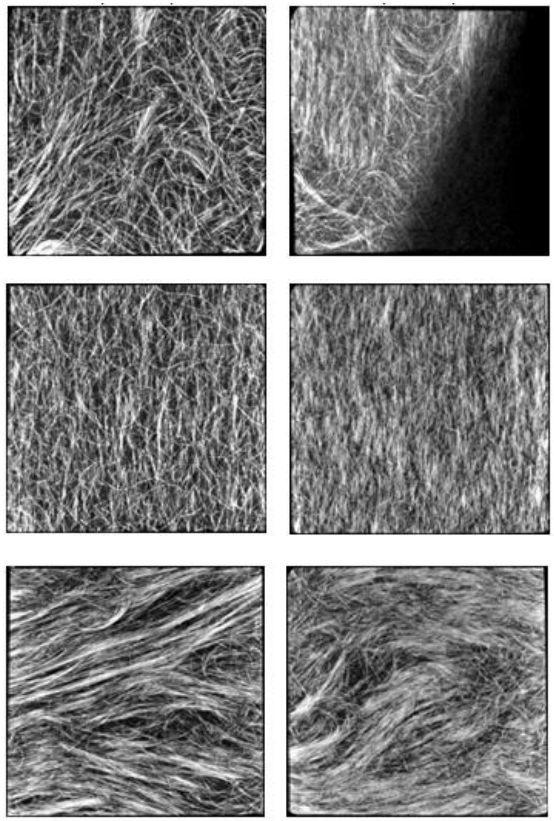
Shear layer

Core layer

Celstran PP GF20 blend

Celstran PP GF50

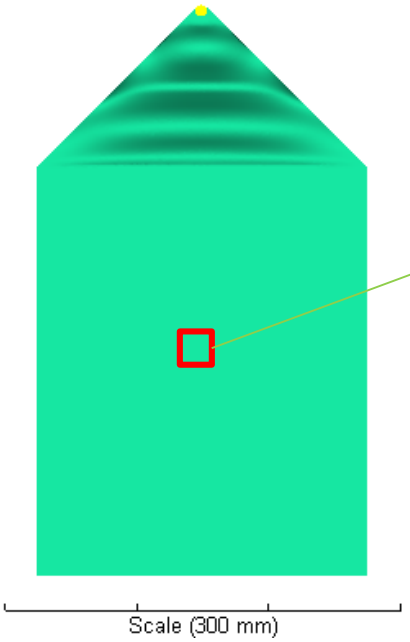
Flow direction

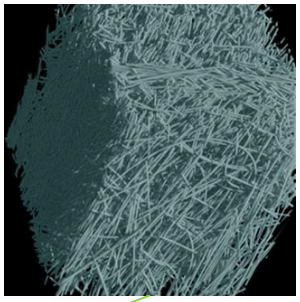


Skin layer (1)

Shear layer (2)

Core layer (3)





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3-point bending test for creating LS Dyna, Mat 24
on 2.5 mm plaque – PP-LGF30 – 3 directions

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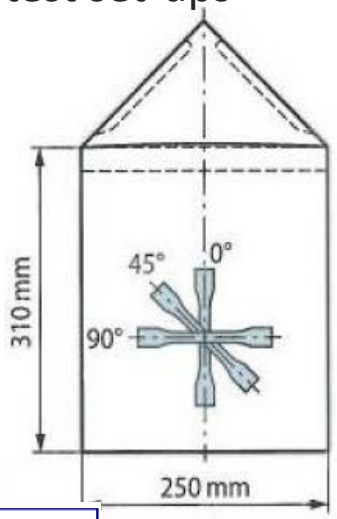
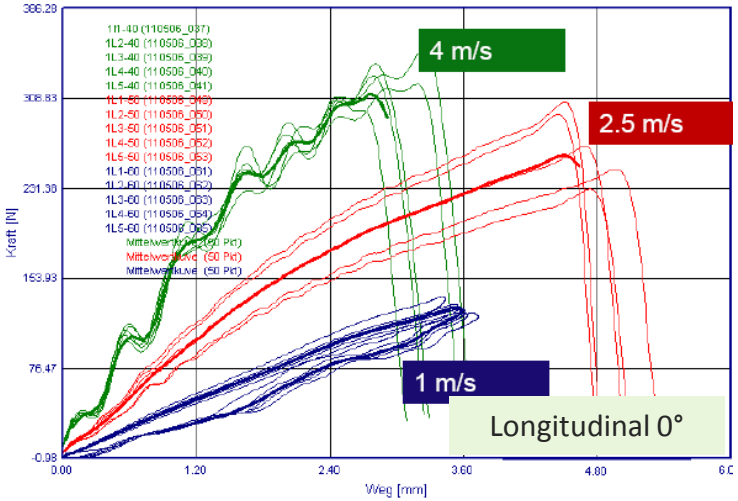
3-point bending test

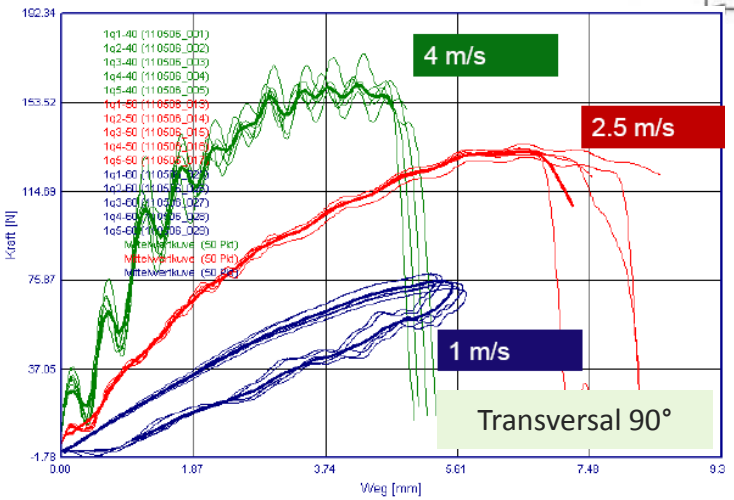
- Analytical estimation of the range of strain rates leads to the following test set-ups

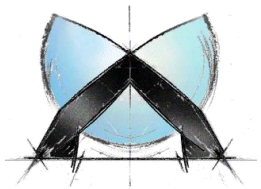
Distance between Supports l_w [mm]	Velocity of Pendulum v [m/s]	Strain Rate epsilon_pkt [1/s]
50	1	0 - 10
40	2.5	10 - 20
30	4	60 - 100



- The strain rate is not of constant value (see given range).
- Each test configuration is repeated three times.







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Crash Data Cards for Structural Parts

Reference vs 2,5 mm wall thickness

Cockpit Structural Parts

Celstran PP-GF20-05 53 blk & Celstran PP-GF30-05 51 blk

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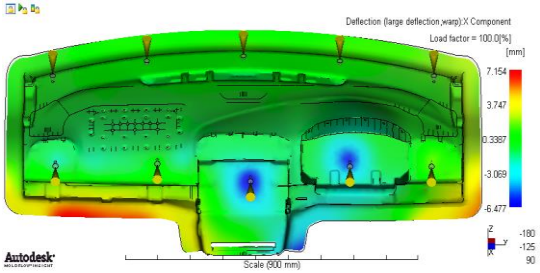
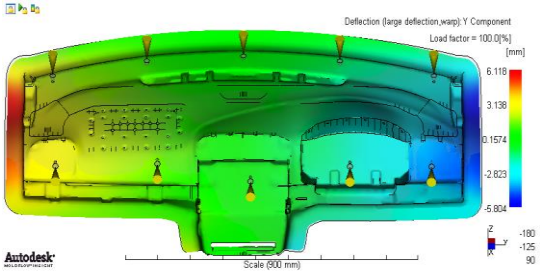
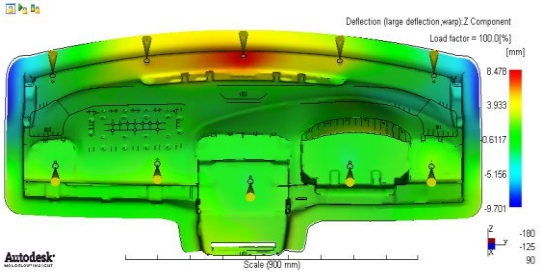


Deflection in X direction

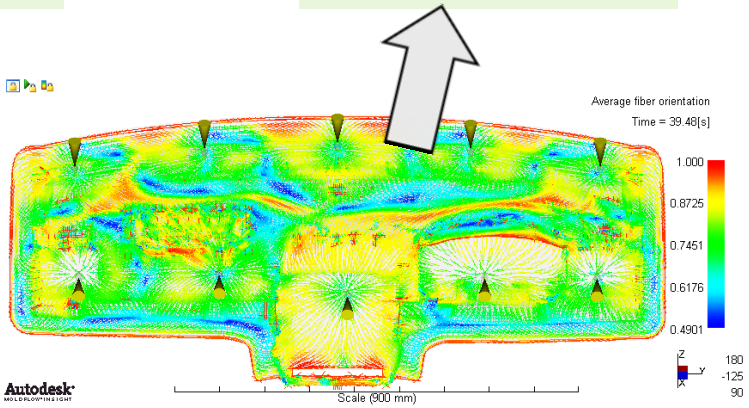


Deflection in Y direction



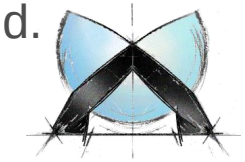
Deflection in Z direction

Finished IP: low warpage / homogenous surface



Average fiber orientation in flow direction

- Recommended a single cavity tool with a 10-drop hot runner manifold.
- Warpage range was predicted to be less than 7 mm
- Average wall thickness: approx. 2 mm
- Mat 24 as LS Dyna created



4a impetus

Cockpit Structural Parts

Celstran PP-GF20-05 53 blk

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REQUEST

Material data preparation (LS-Dyna *MAT024)

- **at 3 temperatures**
- **at 3 orientations**

by using a quasi-static device and 4a impetus device.

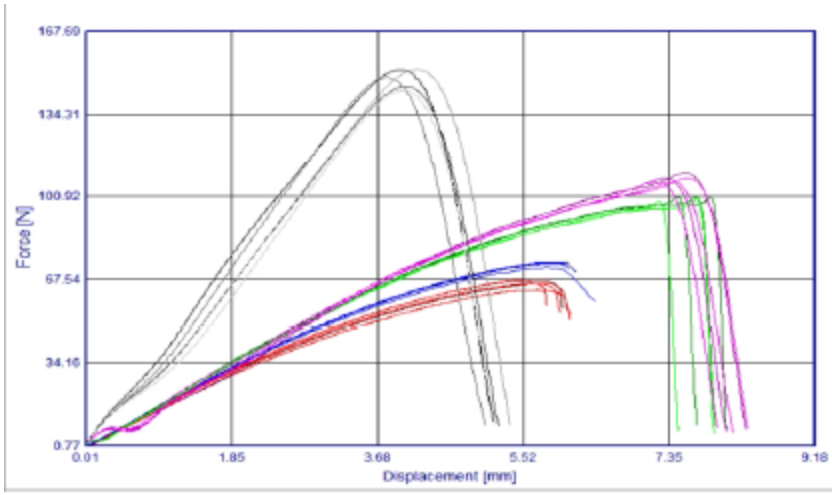
Calculated Values

23°C	Linear Modulus (MPa)	Yield Stress (MPa)	Stress Hardening Plateau (MPa)	Tangent Modulus (MPa)	Strain Rate Scale	Plastic Failure Strain	Failure Strain Scale
0°	4216	34.9	80.0	2654	7.93	0.018	-0.050
45°	3286	25.5	60.0	2221	6.62	0.027	-0.077
90°	2794	23.1	45.7	500	6.33	0.038	-0.085

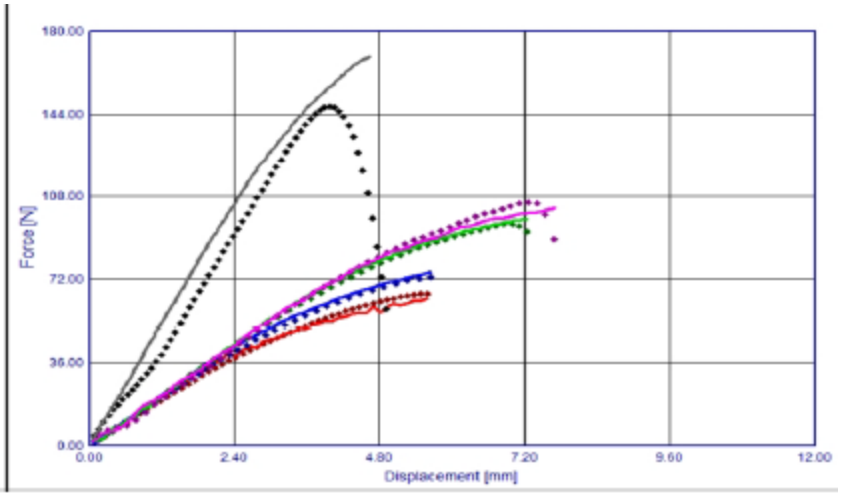
Please get in contact with Celanese, before using those data sets, optimization programs are still working

Reverse Engineering with Celstran PP-GF20-05 53 blk

23°C, 0° Orientation- no failure



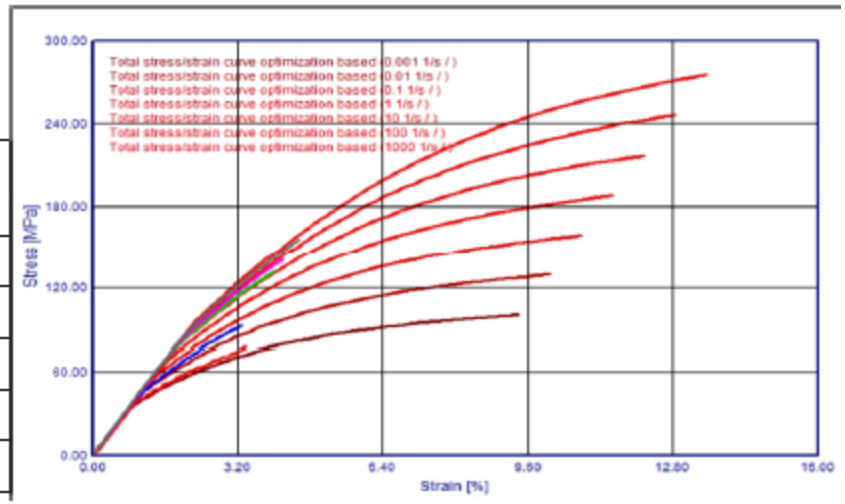
Test Curves - Force vs. Displacement



Simulation Curves - Force vs. Displacement

Model 170424_004
Solver: LS DYNA, Metamodell: *MAT_PIECEWISE_LINEAR_PLASTICITY (*MAT_024)
Element type:16: Fully integrated shell element (very fast), Number of layers: 5, Element size: 5mm
Assumptions: Poisson's number: 0.3, Friction coefficient: 0.1

Case name	v_0 [m/s]	l_w [mm]	$m_{Pendulum}$ [g]	b [mm]	t [mm]	l [mm]
3PBST_0g_0p1mmps_lw40mm	0.0001	40	0.000	10.1	1.88	55.2
3PBST_0g_1p2mmps_lw40mm	0.0012	40	0.000	10.1	1.88	55.3
3PBEP_1454g_1mps_lw40mm	1	40	1454	10.1	1.87	55.2
3PBEP_960g_2p5mps_lw40mm	2.5	40	960.0	10.1	1.87	55.1
3PBEP_453g_4p3mps_lw30mm	4.3	30	453.3	10.0	1.88	45.0



Simulation Curves on Material Curves - Stress vs. Strain

Cockpit Structural Parts

Celstran PP-GF30-05 51 blk

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Material data preparation (LS-Dyna *MAT024)

- **at 3 temperatures**
- **at 3 orientations**

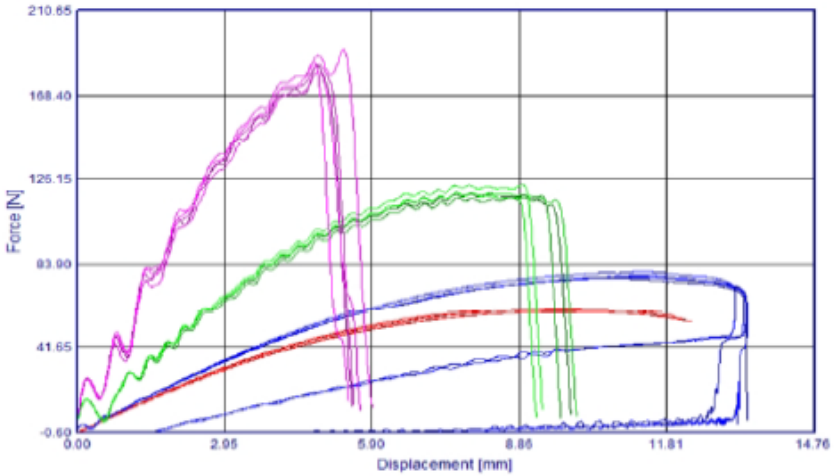
by using a quasi-static device and 4a impetus device.

Calculated Values

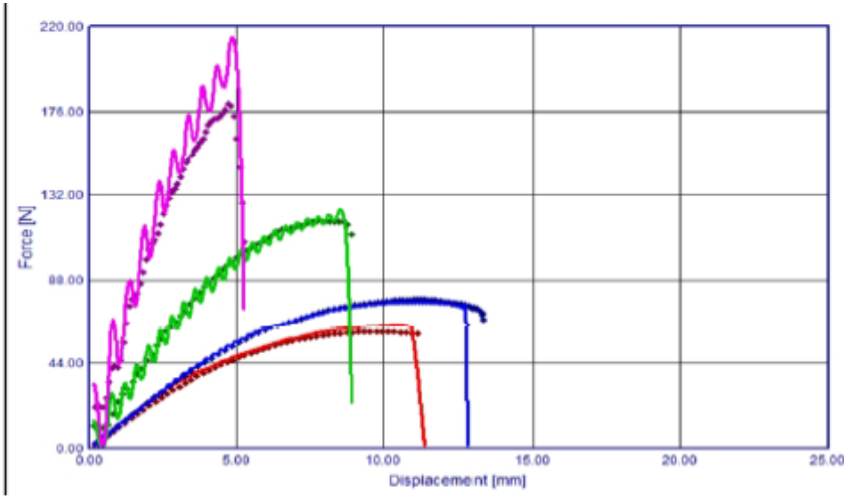
23°C	Linear Modulus (MPa)	Yield Stress (MPa)	Stress Hardening Plateau (MPa)	Tangent Modulus (MPa)	Strain Rate Scale	Plastic Failure Strain	Failure Strain Scale
0°	5484	33.4	93.1	2170	8.54	0.029	-0.043
45°	3951	22.6	64.2	1000	8.55	0.034	-0.028
90°	3235	19.7	58.2	1782	8.94	0.037	-0.003

Reverse Engineering with Celstran PP-GF30-05 51

23°C, 0° Orientation- no failure



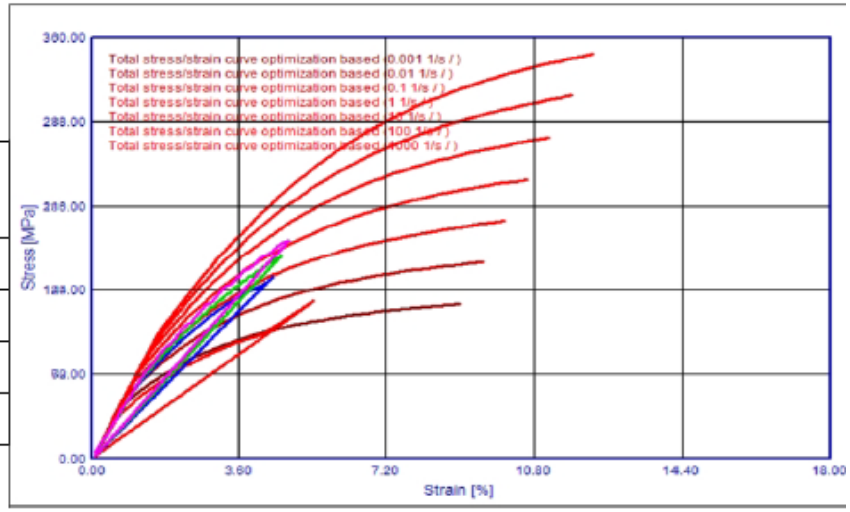
Test Curves - Force vs. Displacement



Simulation Curves - Force vs. Displacement

Model 170523_004
Solver: LS DYNA, Metamodell: *MAT_PIECEWISE_LINEAR_PLASTICITY (*MAT_024)
Element type:16: Fully integrated shell element (very fast), Number of layers: 5, Element size: 5mm
Assumptions: Poisson's number: 0.3, Friction coefficient: 0.1

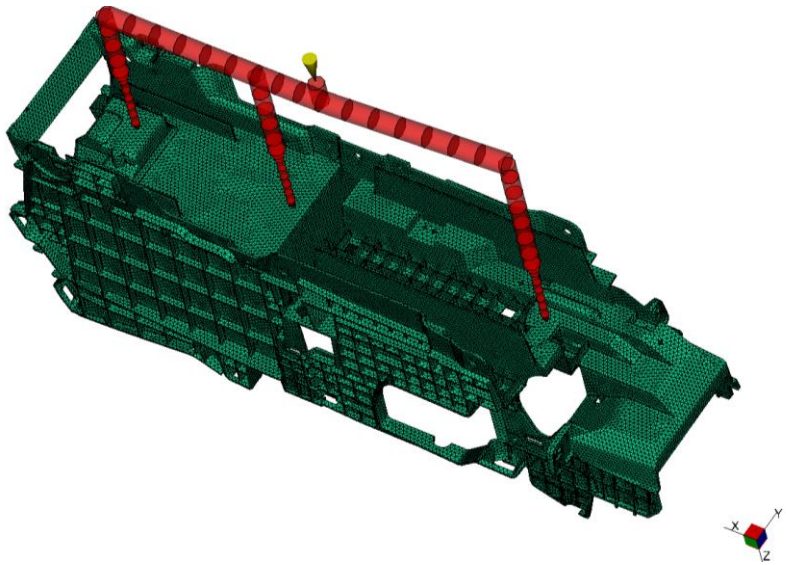
Case name	v_0 [m/s]	l_w [mm]	$m_{Pendulum}$ [g]	b [mm]	t [mm]	l [mm]
3PBST_0g_1mmps_lw50mm	0.001	50	0.000	10.1	1.87	64.7
3PBEP_1454g_1mps_lw50mm	1	50	1454	10.1	1.87	64.9
3PBEP_960g_2p5mps_lw40mm	2.5	40	960.0	10.1	1.86	49.8
3PBEP_960g_4p3mps_lw30mm	4.3	30	960.0	10.1	1.86	39.7

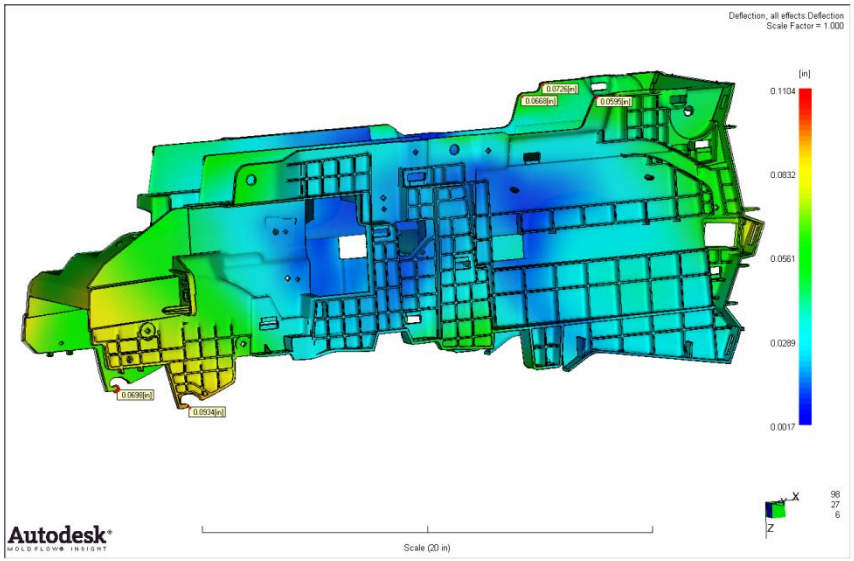


Simulation Curves on Material Curves - Stress vs. Strain

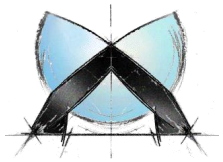
Center Console – Structural Parts

Celstran PP-GF40-04 53 blk





- Recommended a single cavity tool with a 3-drop hot runner manifold.
- Minimized hot spots from excess shearing or cold spots where the flow front has hesitated.
- Warpage range was predicted to be to 2.6 mm
- Mat 24 as LS Dyna created



4a impetus

Center Console – Structural Parts

Celstran PP-GF40-04 53 blk

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REQUEST

Material data preparation (LS-Dyna *MAT024)

- **at 3 temperatures**
- **at 3 orientations**

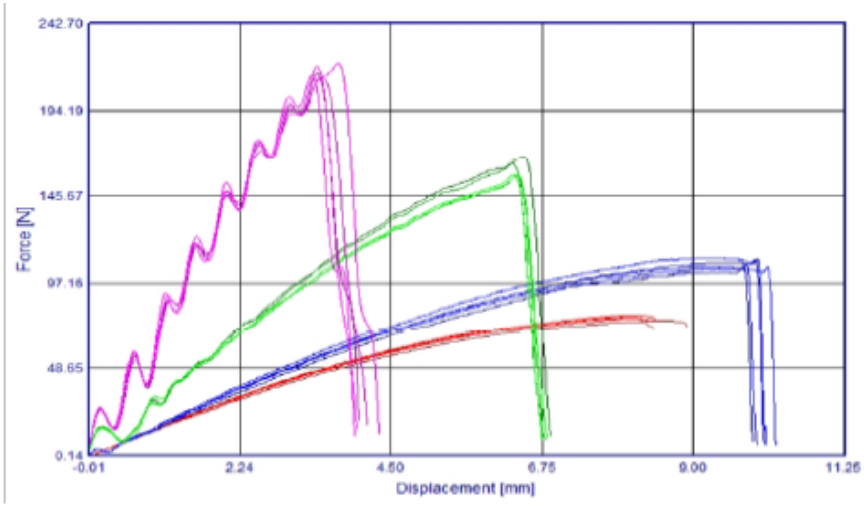
by using a quasi-static device and 4a impetus device.

Calculated Values

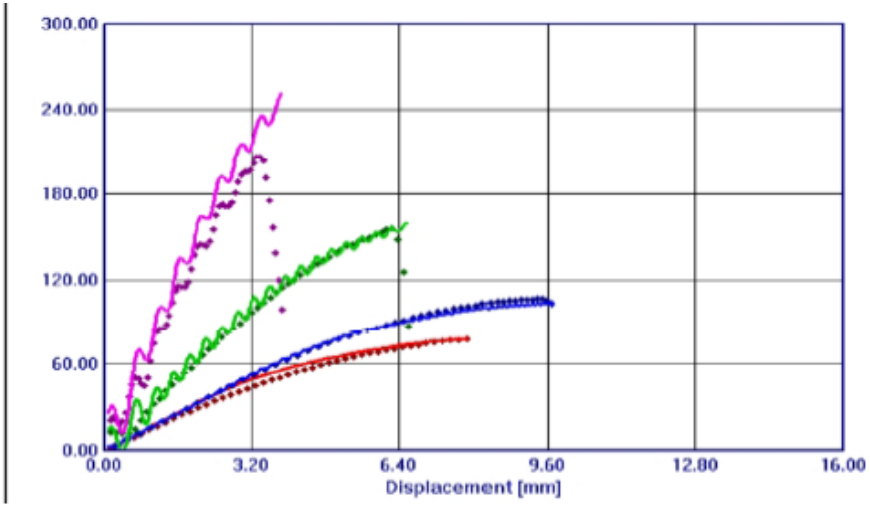
23°C	Linear Modulus (MPa)	Yield Stress (MPa)	Stress Hardening Plateau (MPa)	Tangent Modulus (MPa)	Strain Rate Scale	Plastic Failure Strain	Failure Strain Scale
0°	7888	56.3	100.0	3628	10.08	0.015	-0.017
45°	5190	33.3	90.0	2261	8.59	0.020	-0.055
90°	4347	25.3	70.7	2288	8.04	0.037	-0.069

Center Console – Structural Parts

Celstran PP-GF40-04 53 blk



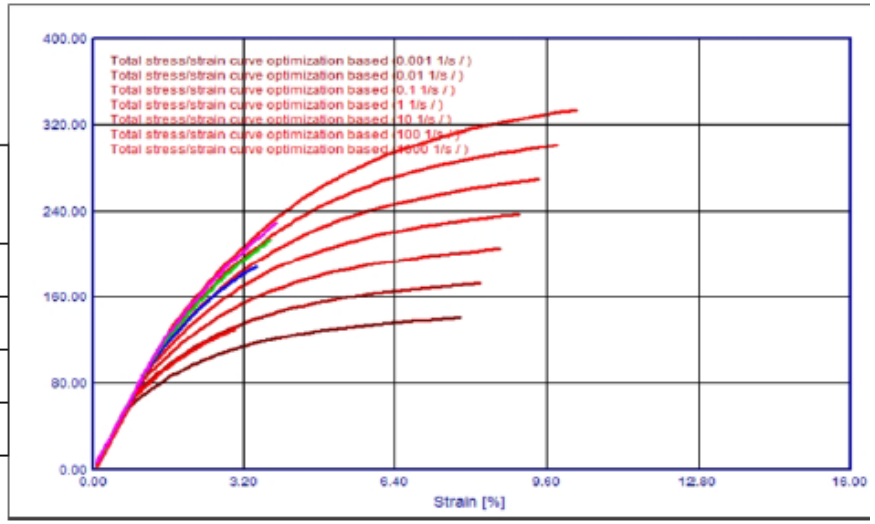
Test Curves - Force vs. Displacement



Simulation Curves - Force vs. Displacement

Model 170224_005
Solver: LS DYNA, Metamodell: *MAT_PIECEWISE_LINEAR_PLASTICITY (*MAT_024)
Element type:16: Fully integrated shell element (very fast), Number of layers: 5, Element size: 5mm
Assumptions: Poisson's number: 0.3, Friction coefficient: 0.1

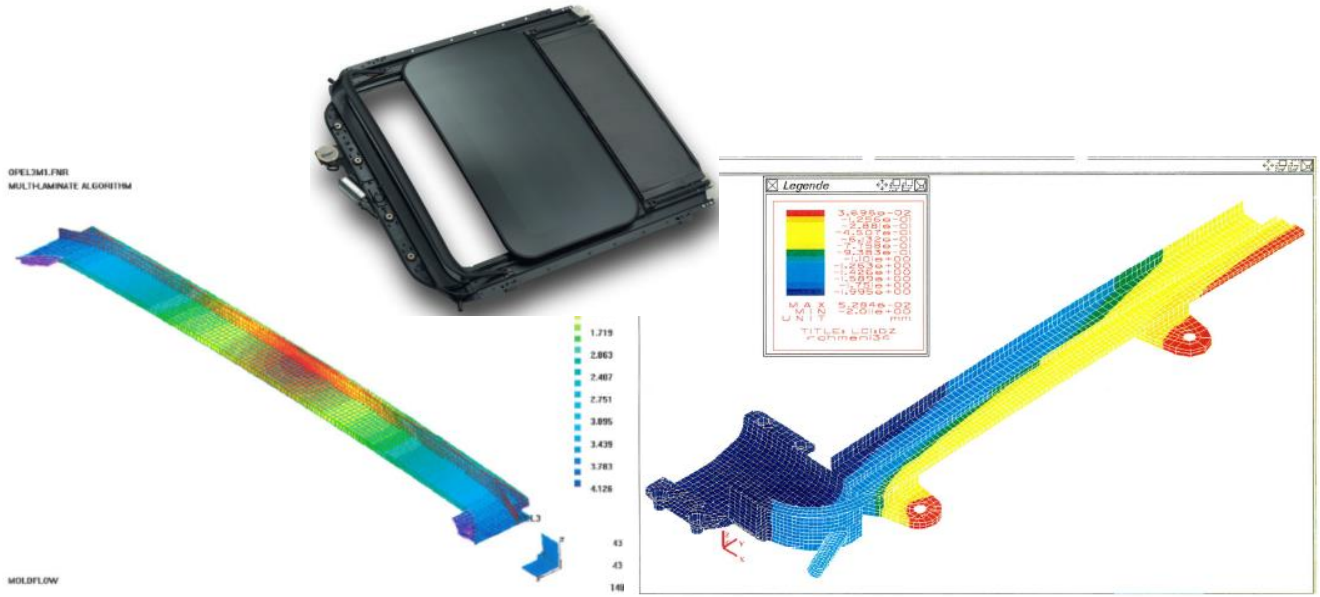
Case name	v_0 [m/s]	l_w [mm]	$m_{Pendulum}$ [g]	b [mm]	t [mm]	l [mm]
3PBST_0g_1mmps_lw50mm	0.001	50	0.000	10.1	1.85	66.3
3PBEP_1454g_1mps_lw50mm	1	50	1454	10.1	1.85	65.9
3PBEP_960g_2p5mps_lw40mm	2.5	40	960.0	10.1	1.85	50.1
3PBEP_960g_4p3mps_lw30mm	4.3	30	960.0	10.1	1.85	40.4



Simulation Curves on Material Curves - Stress vs. Strain

Roof Frame– Structural Parts

Celstran PP-GF50-04 53 blk



- Recommended a single cavity tool with a 1-drop hot runner manifold.
- Minimized hot spots from excess shearing or cold spots where the flow front has hesitated.
- Warpage range was predicted to be less than 3 mm
- Mat 24 as LS Dyna created

4a impetus

Center Console – Structural Parts

Celstran PP-GF50-04 53 blk

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Material data preparation (LS-Dyna *MAT024)

- **at 3 temperatures**
- **at 3 orientations**

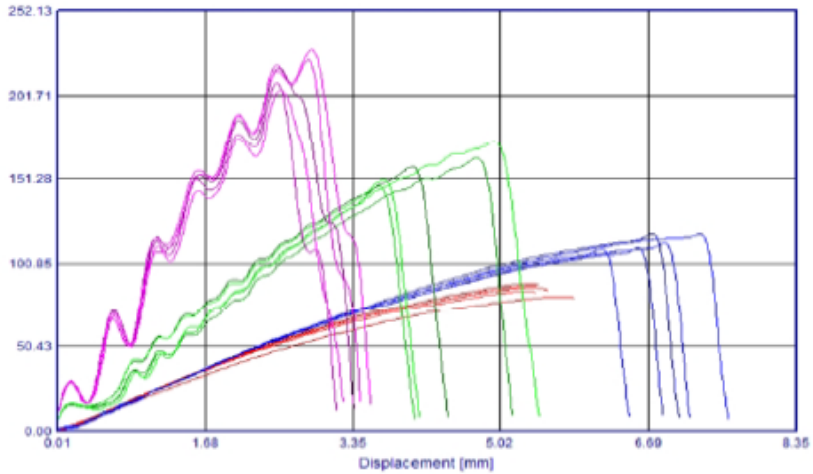
by using a quasi-static device and 4a impetus device.

Calculated Values

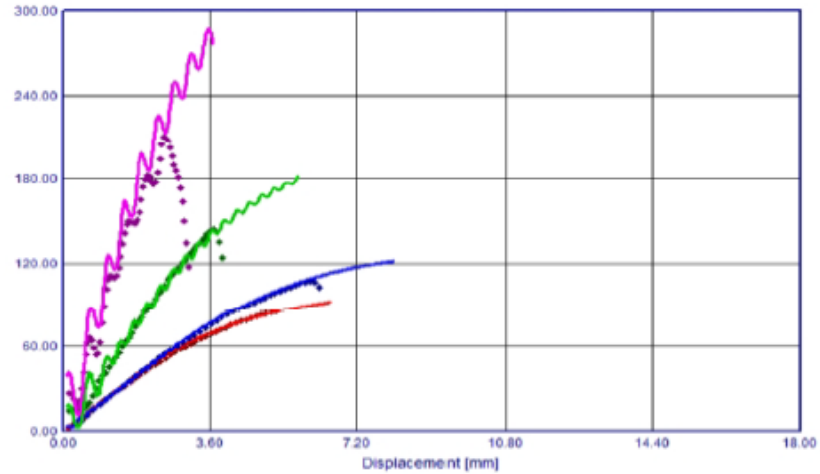
23°C	Linear Modulus (MPa)	Yield Stress (MPa)	Stress Hardening Plateau (MPa)	Tangent Modulus (MPa)	Strain Rate Scale	Plastic Failure Strain	Failure Strain Scale
0°	10234	70.1	110.0	5028	13.88	0.009	-0.010
45°	5748	34.6	75.0	3667	11.06	0.022	-0.040
90°	4823	19.1	58.7	777	8.59	0.038	-0.050

Center Console – Structural Parts

Celstran PP-GF50-04 53 blk



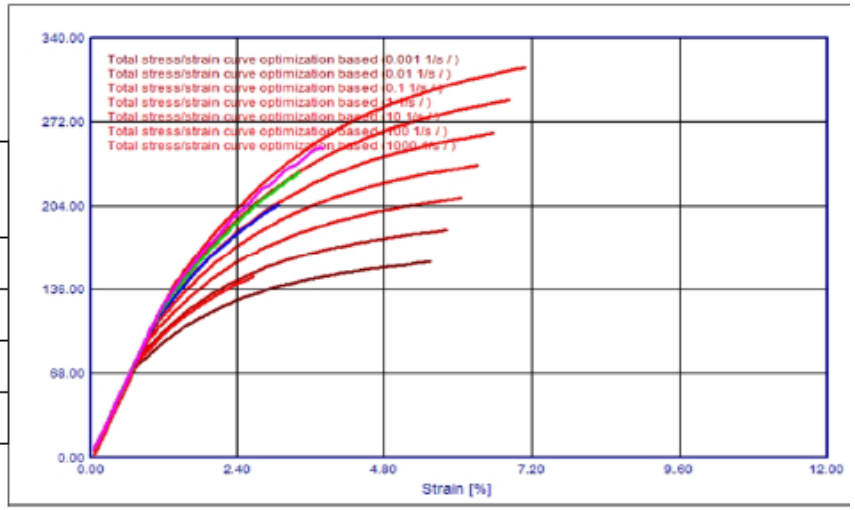
Test Curves - Force vs. Displacement



Simulation Curves - Force vs. Displacement

Model 170830_007
Solver: LS DYNA, Metamodell: *MAT_PIECEWISE_LINEAR_PLASTICITY (*MAT_024)
Element type:16: Fully integrated shell element (very fast), Number of layers: 5, Element size: 5mm
Assumptions: Poisson's number: 0.3, Friction coefficient: 0.1

Case name	v_0 [m/s]	l_w [mm]	$m_{Pendulum}$ [g]	b [mm]	t [mm]	l [mm]
3PBST_0g_1mmps_lw50mm	0.001	50	0.000	10.1	1.87	65.3
3PBEP_1982g_1mps_lw50mm	1	50	1982	10.0	1.87	65.2
3PBEP_960g_2p5mps_lw40mm	2.5	40	960.0	10.0	1.87	50.3
3PBEP_960g_4p3mps_lw30mm	4.3	30	960.0	10.0	1.86	40.5



Simulation Curves on Material Curves - Stress vs. Strain

Summary

Summary

- PP Long Glass Fiber reinforcement in use for Semi Structural Parts
- Continuously Data Development for Simulation and Structural Analyses
  - Simulation approach (Midplane, Dual Domain, 3D)
  - Moldflow material data
  - Mesh quality
  - Used Moldflow release
  - Fiber orientation model
  - Simulation parameters
  - Material Data Packs as LS Dyna – Mat 24, Digimat as reference requested

Ongoing Procedure

Experience – Measurements → Correlation between simulation and experiment

Stronger Automotive Requirements
Interior

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High heat aging resistance (long term performance)

Low Emission / Low Odor

- total C- emission as VDA 277 << 50 µg C/g
- low odor requirement ≤ 3, actual values 3-4,5
- low fogging as VW PV 3015 < 1 mg (limiting value < 2 mg)

Trends

- thin wall technology (≤ 2 mm)
- lower GF content (towards 30 and 20% LGF)
- Appearance, good surface finish
- increasing emission requirements (VDA 278)
- Recycling Concept
- Chemical and Physical Foaming
- **Material Data Cards**

Material PP-LGF

Odor (≤3) VDA270

Low Emission

VDA 277, 278 und BMW GS…

Injection Molding Parameter

Influence for Interiors

Application Automotive

- Pedal Application
- Door Module
- Front End
- Instrument Panel (Soft IP)
- Under Body Cover
- Head Rest Systems
- Seating Systems
- Etc….

THANK YOU

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