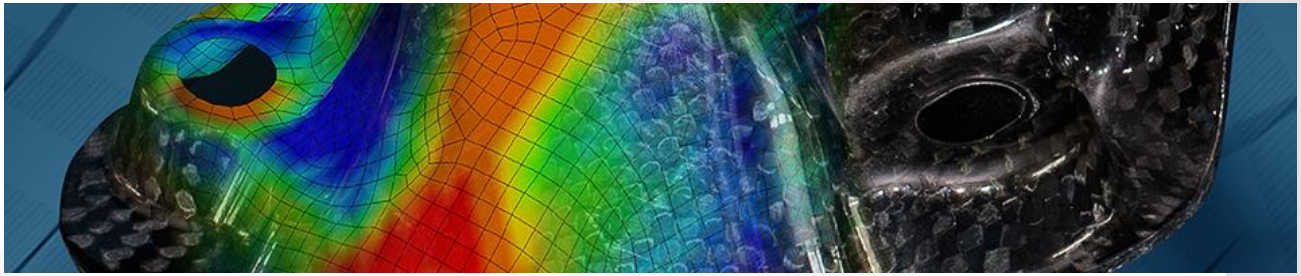
Composites „Seinerzeit“ Herausforderungen für die Zukunft

R. Hafellner, P. Reithofer, M. Pichler (4a technology GmbH)



4a Technologietag 2015

Leichtbau und Composites

5. - 6. März 2015

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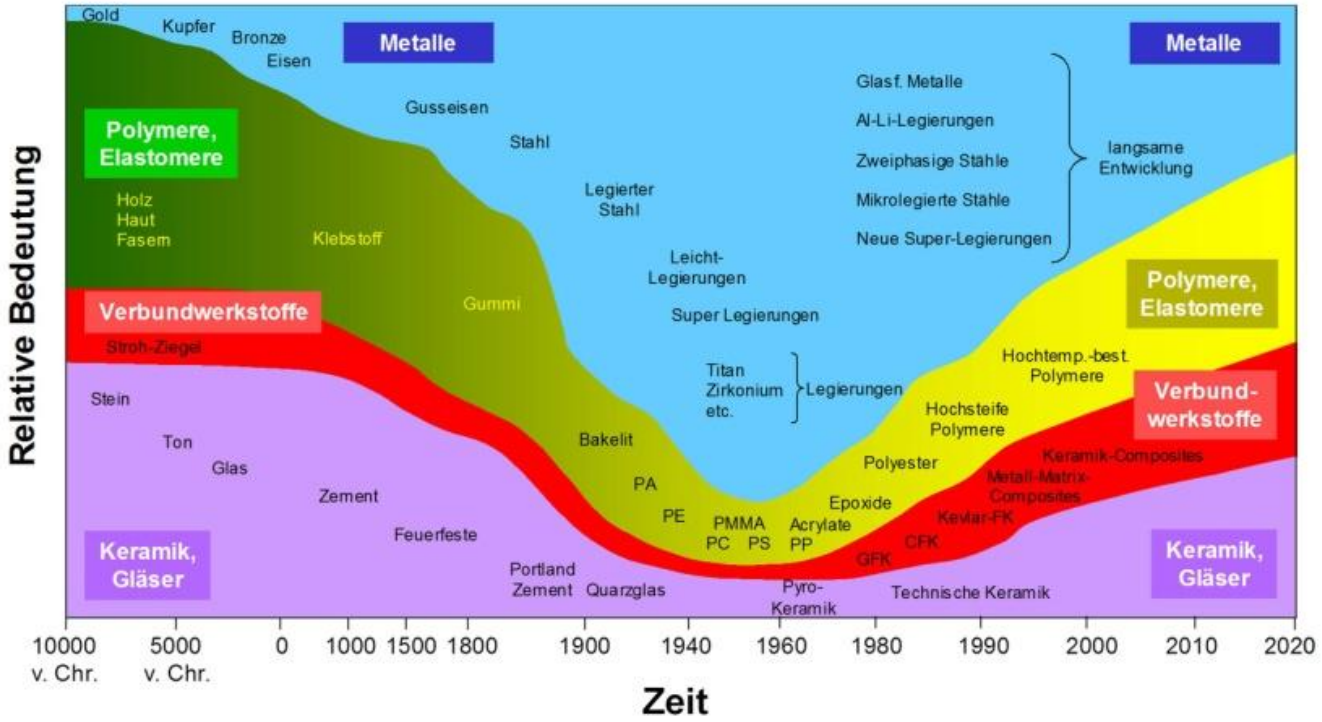
Entw. rel. Bedeutung von Werkstoffen n. Ashby
Vortrag Lang TT2005

Entwicklungsgeschichte der Werkstoffe

PCCL
Polymer Competence Center Leoben

Relative Bedeutung von Werkstoffklassen



[nach Ashby, 1999]

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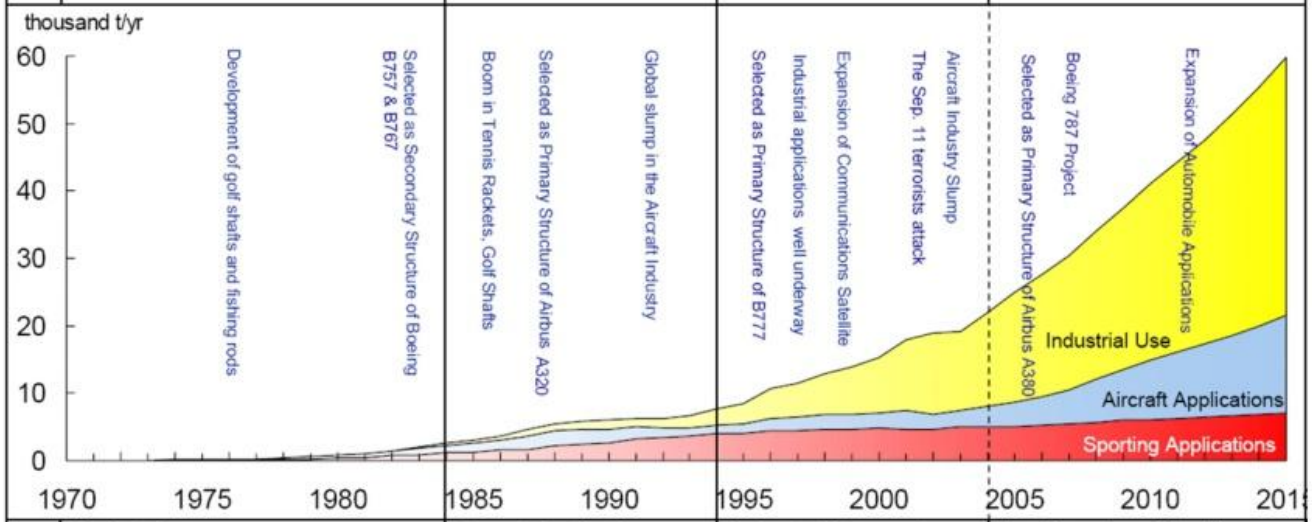
Marktentwicklung von Kohlenstofffasern n. Toray
Vortrag Lang TT2005

Marktentwicklung
Hochleistungsverbundwerkstoffe

PCCL Polymer Competence Center Leoben

Weltweite Marktentwicklung: Kohlenstofffasern



	Introduction Period (1971 – 1983)	Growth Period (1984 – 1993)	Expansion Period(1994–2003)	Full-scale Expansion Period (2004 -)
Applications	**Limited Area** Fishing rods ~~Secondary structure of~~ Aircrafts	**Expand Applications** Tennis rackets Golf shafts Primary structure of Aircrafts	**Industrial Uses under way** Pressure vessels Industrial machinery, Boats & Ships, Civil engineering and Construction, Repair and Reinforcement	**Huge Expansion of Aircrafts Automobiles under way** Significant Aircraft Program Wind-power Generation Automobile-related, Offshore Oil Field
Remarks	High-quality	Increase of products, Advancement in molding technology	Cost reduction Large structural material	Diversification of manufacturing methods Recyclability

Quelle: Toray, 2005.

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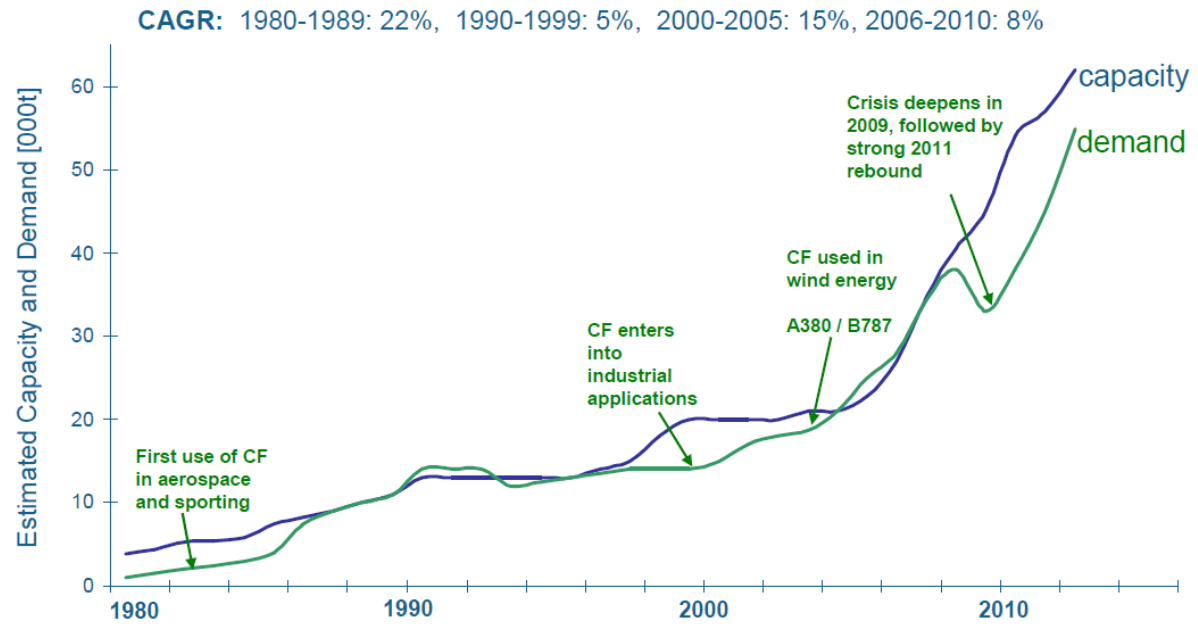
Marktentwicklung von Kohlenstofffasern
Vortrag SGL Goller TT2011

Global market for carbon fibres



Source: SGL Group

BROAD BASE. BEST SOLUTIONS.

SGL GROUP THE CARBON COMPANY

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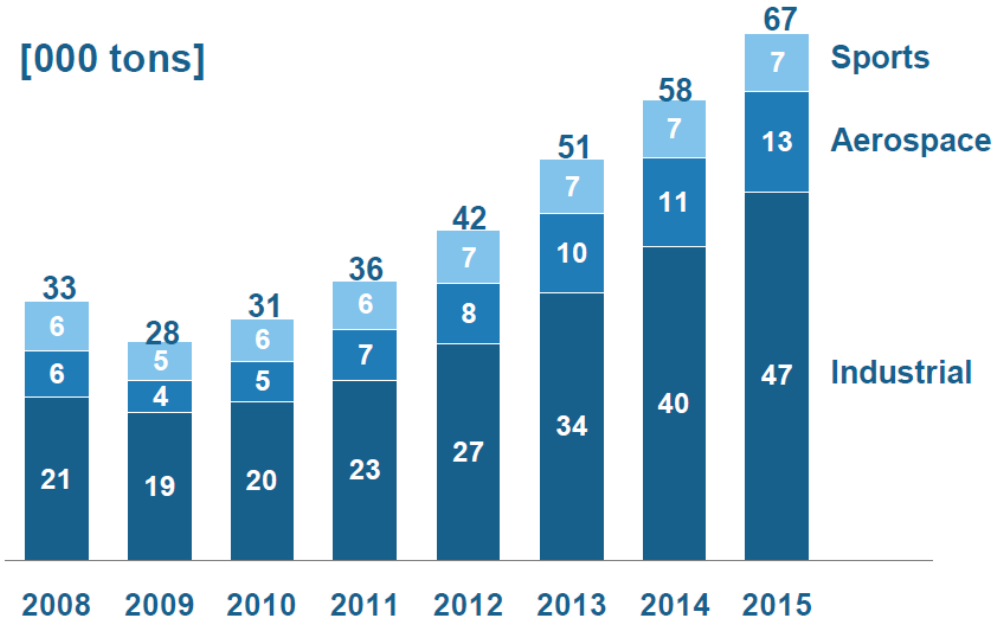
Marktentwicklung von Kohlenstofffasern
Vortrag SGL Goller TT2011

Annual carbon fiber consumption is dominated by industrial applications

- [000 tons]



	CAGR 2008-2015
Sports	2%
Aerospace	12%
Industrial	12%

- Growth is delayed due to the impacts from the financial crisis, but all growth drivers are still intact

Source: SGL Group market reserarch

BROAD BASE. BEST SOLUTIONS.

SGL GROUP THE CARBON COMPANY

Technologietag 2015

Jahresproduktion von Carbonfasern in kt/yr;
Schwarz: Ist, Rot: Prognose

	2005	2011	2014	2018
Technologietag 2005	24	44	55	
Technologietag 2011		36	58	
Technologietag 2015			50	71..80

Aus den Quellen Lang (2005), Goller (2011), Carbon Composites und SGL (2015)

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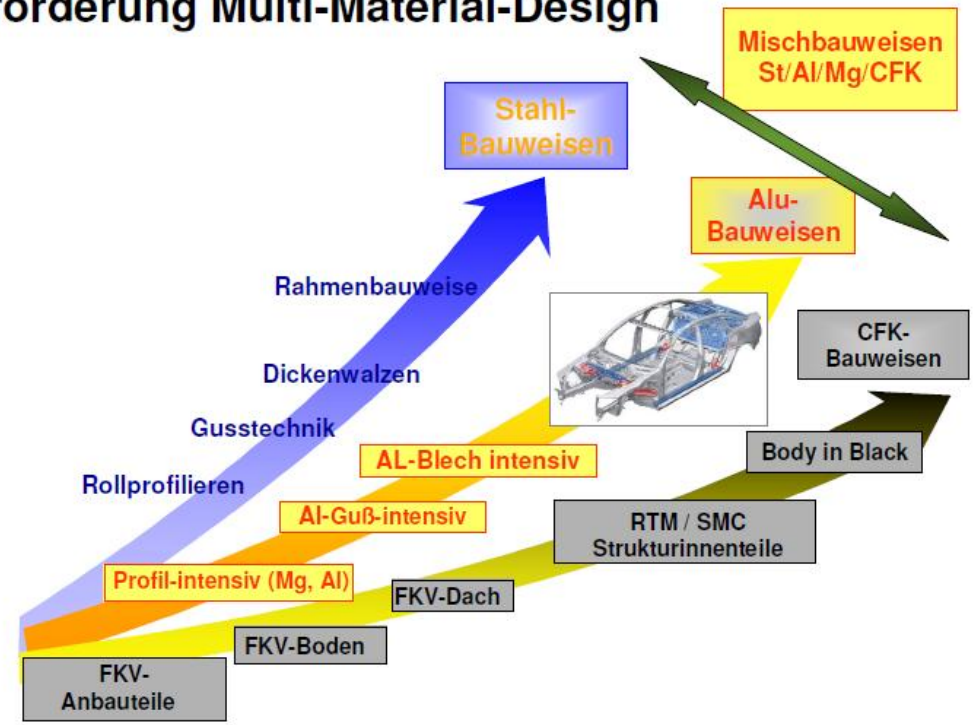
Fazit

Leichtbaukompetenz für morgen

Herausforderung Multi-Material-Design



25 Thomas Hambrecht, N/EK-L12, Leichtbau - Herausforderungen und Ziele bei AUDI, 26. März 2009

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Automobile Hybridanwendungen im Trend
Stock, Egger TT2009

4a ENGINEERING GmbH

4a Leichtbau auf dem Prüfstand

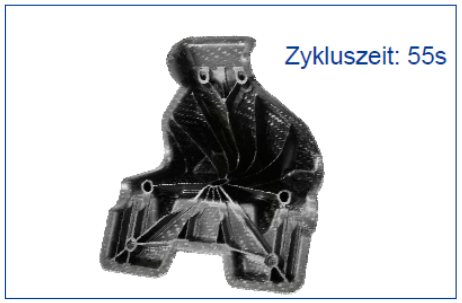
ENGEL organomelt-Technologie

> Vorformen und Hinterspritzen eines Organoblechs in einer vollautomatisierten Fertigungszelle

DFG

LKT Lehrstuhl für Kunststofftechnik Prof. Dr.-Ing. Dietmar Drummer

Dräxlmaier



Neue Materialien Fürth

SIEBENWURST

LANXESS

BOND LAMINATES

HANS VON DER HEYDE

→ Verbesserte Leichtbaueigenschaften bei wirtschaftlicher Fertigung

ENGEL be the first.

Alexander Stock 03/03/2011 19

Hybridtechnik

Gewicht: 18,9 kg

Gewichtsreduktion: 6,0 kg

9,2 kg Strukturteil
2,7 kg Blende
1,0 kg Befestigung, Dichtung Versteifung
12,9 kg Summe

Stahlheckklappe vs. Hybridkonzept (Fa. Rehau)

ENGEL be the first.

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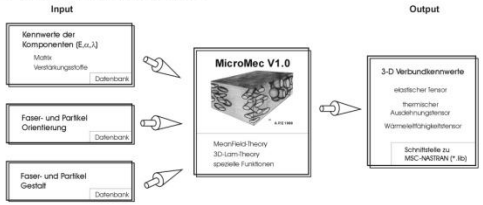
Berechnung / Simulation

Materialmodellierung (Schulung 2002)

ape - advanced polymer engineering
Peter Tunner Str.4
8700 Leoben - Austria

3D Werkstoffdaten



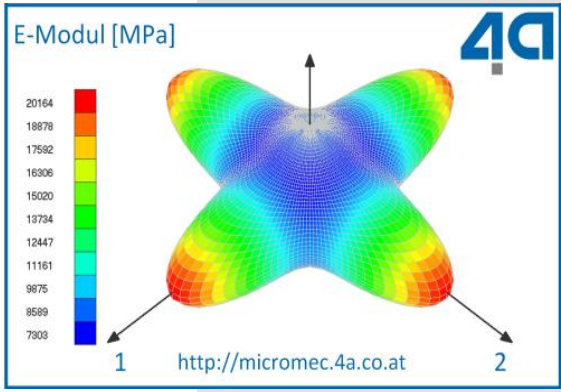
2D-3D Problematik

Echte 3-D Probleme mit LA-Elementen nicht lösbar z.B. Lasteinleitungen, Übergänge bei Wickelbehältern usw.

- Geeignetes Postprocessing mit 3D-Hypothesen

Besondere Problemstellungen

$$C^{-1} = \begin{bmatrix} \frac{1}{E_1} & -\frac{\nu_{21}}{E_2} & -\frac{\nu_{31}}{E_3} & 0 & 0 & 0 \\ -\frac{\nu_{12}}{E_1} & \frac{1}{E_2} & -\frac{\nu_{32}}{E_3} & 0 & 0 & 0 \\ -\frac{\nu_{13}}{E_1} & -\frac{\nu_{23}}{E_2} & \frac{1}{E_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{G_{23}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{G_{31}} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{G_{21}} \end{bmatrix}$$



ape - advanced polymer engineering
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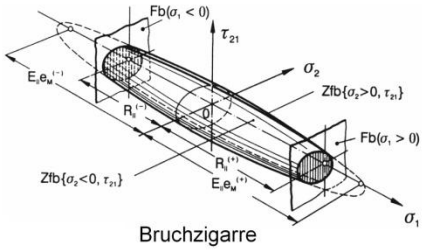
8700 Leoben - Austria

Kombinierte Bruchkriterien nach Puck

- Faserbruch - Zwischenfaserbruch
- Reserve Faktoren für FB und ZFB



Bruchzigarre

Versagenshypothesen

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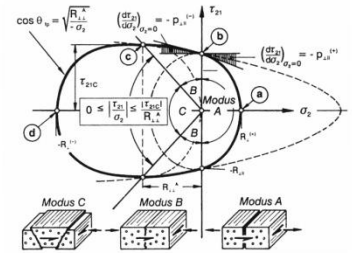
Kombinierte Bruchkriterien nach Puck

- Bruchmodi für ZFB:
  Zug-Bruch
  Scherbruch
  Sprengbruch !!



- auch für 3-dimensionalen Spannungszustand verwendbar

Versagenshypothesen

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Berechnung / Simulation
Idealisierung (Schulung 2002)

ape - advanced polymer engineering
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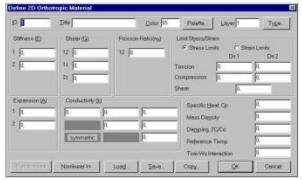
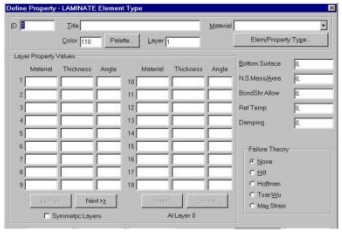
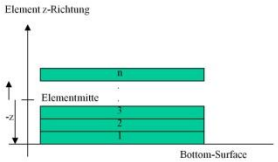
- INPUT

Material: orthotropic 2D
+ 2 Schubkennwerte
Materialkennwerte
der UD-Schicht

Property: Aufbau des Verbundes
Art der
Versagenshyp.







Umsetzung in MSC-Nastran

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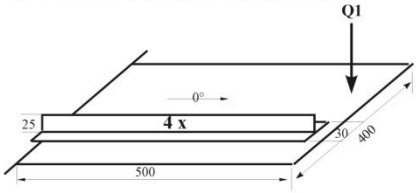
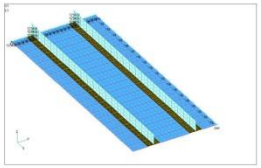
- **Beispiel 2: Stringer verstärkte Platte**





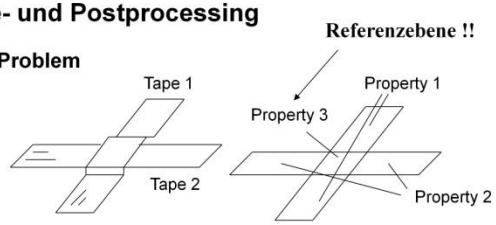
Aufbau	Belastung	Kommentar
CFK-HT Schichtdicke 0,125 mm Grundplatte 0°/45°/-45°/90° symm. Stringer: bestehend aus 2 L mit je 0°/0°/0°/45°/-45° symm	Q1 = 200 N / an Stringern angreifend	

Beispiele

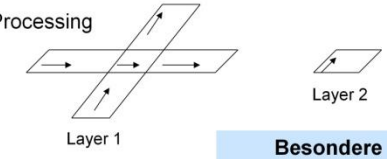
ape - advanced polymer engineering
Peter Tunner Str.4
8700 Leoben - Austria

- **Pre- und Postprocessing**

Tape-Problem



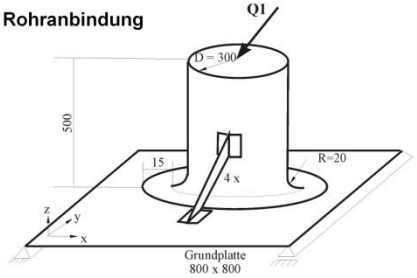
Post-Processing



Besondere Problemstellungen

ape - advanced polymer engineering
Peter Tunner Str.4
8700 Leoben - Austria

- **Beispiel 5: Rohranbindung**



Aufbau	Belastung	Kommentar
CFK-HT Schichtdicke 0,125 mm Grundplatte 0°/45°/-45°/90° symm. Rohr 0°/45°/-45° symm. Ges.?: Aufbau der Abstützungen	Q1x = - 200 N Q1z = - 300 N	

Beispiele

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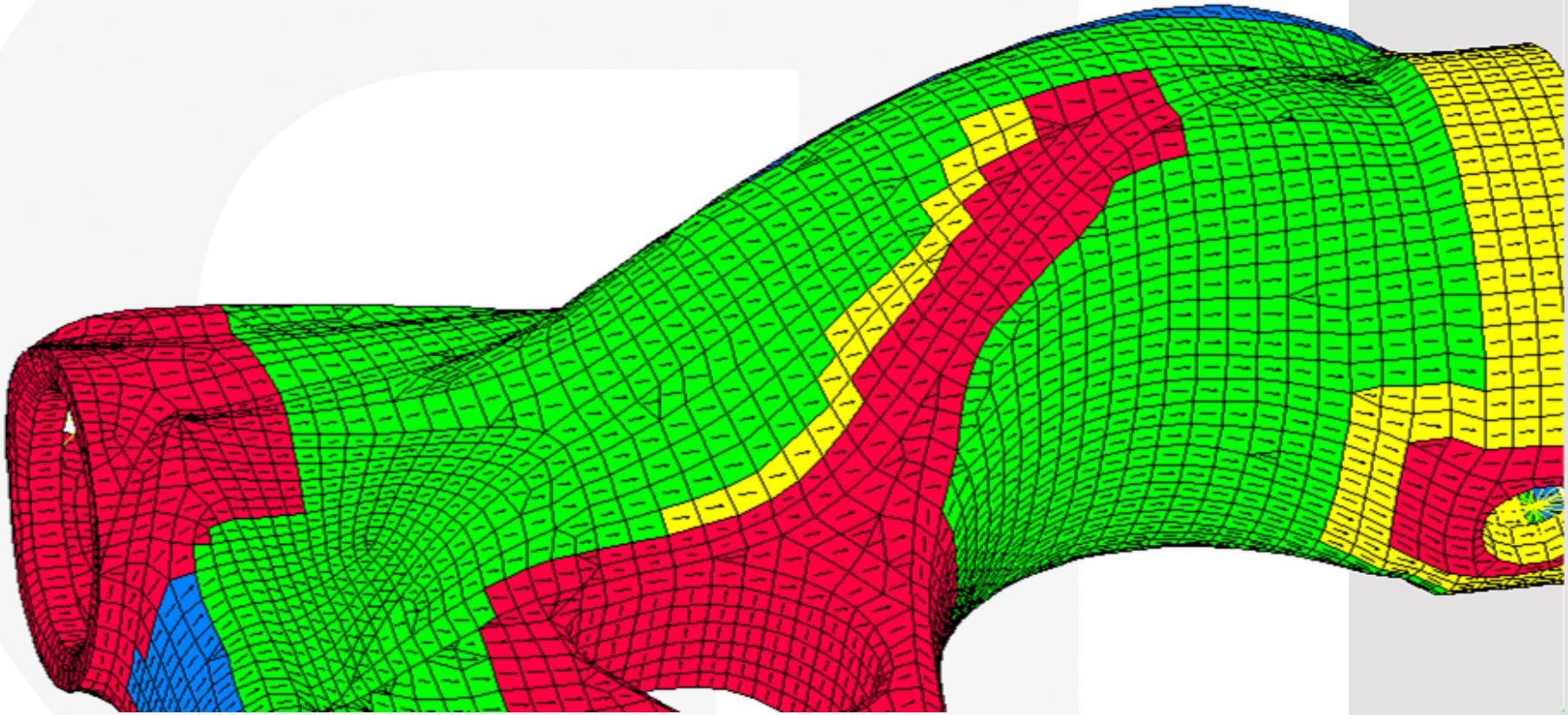
Berechnung / Simulation
Idealisierung (Beispiel 2002)



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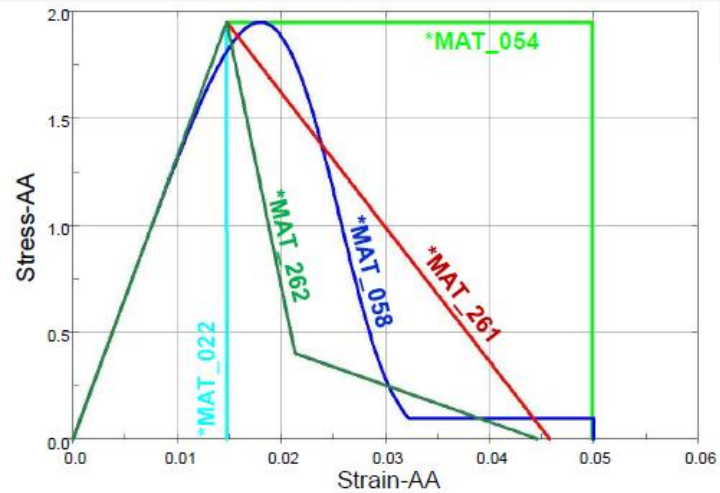
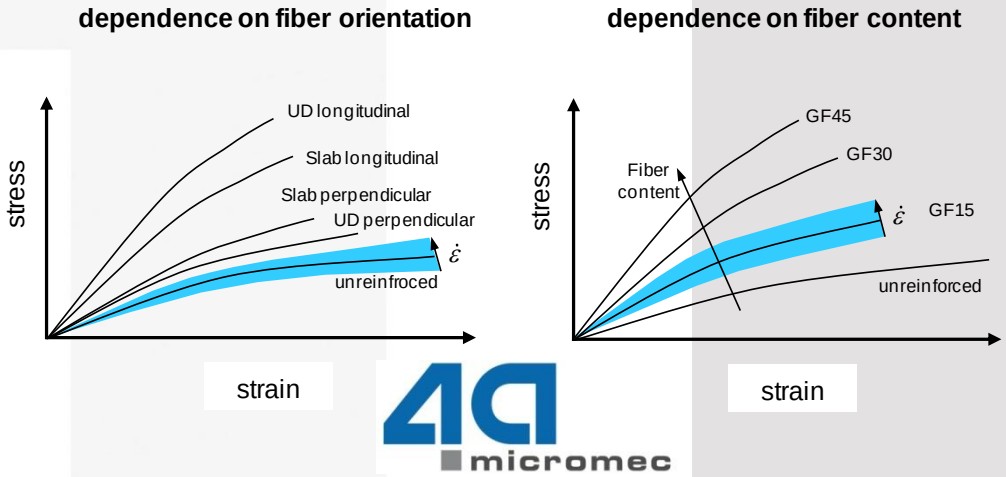
Berechnung / Simulation
Materialmodellierung 2010-2014

Postfailure / Energieaufnahme



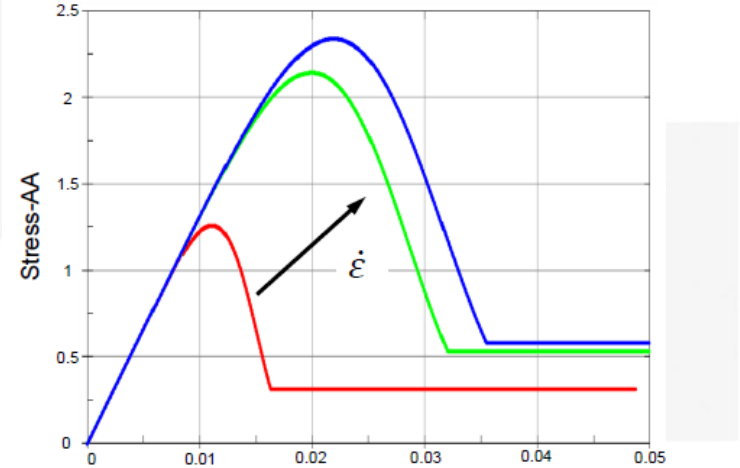
Quelle: Dynamore GmbH

Materialmodelle Mikromechanik



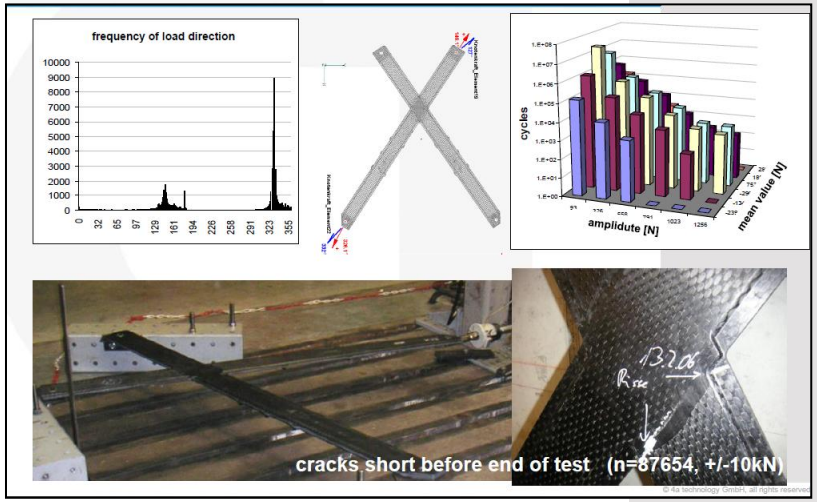
Quelle: Reithofer, TT2011

Dehnrate



Quelle: Dynamore GmbH

Lebensdauer



Quelle: Fritz, TT2011

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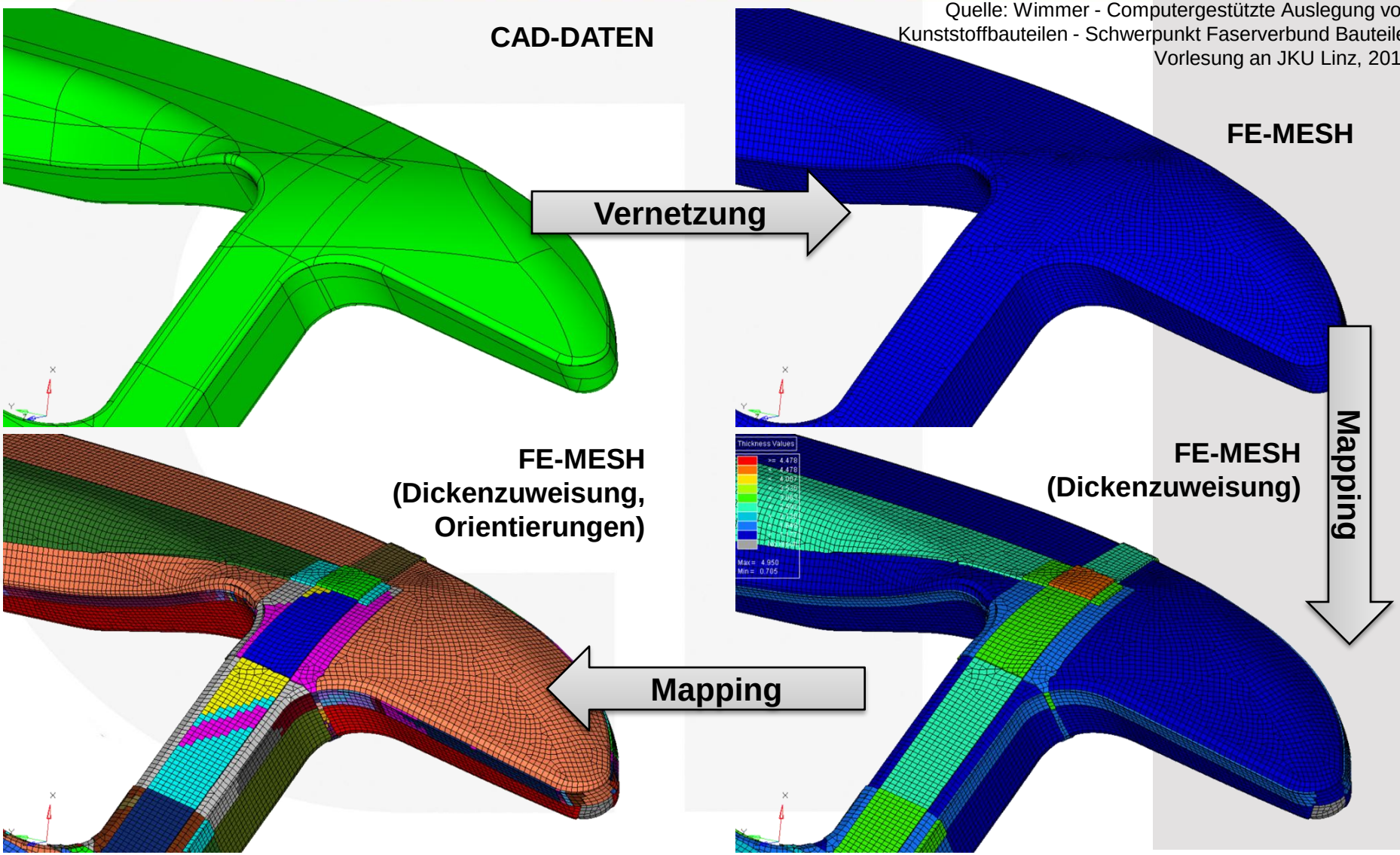
Berechnung / Simulation

Prozessablauf 2010-2014

Quelle: Wimmer - Computergestützte Auslegung von Kunststoffbauteilen - Schwerpunkt Faserverbund Bauteile; Vorlesung an JKU Linz, 2012



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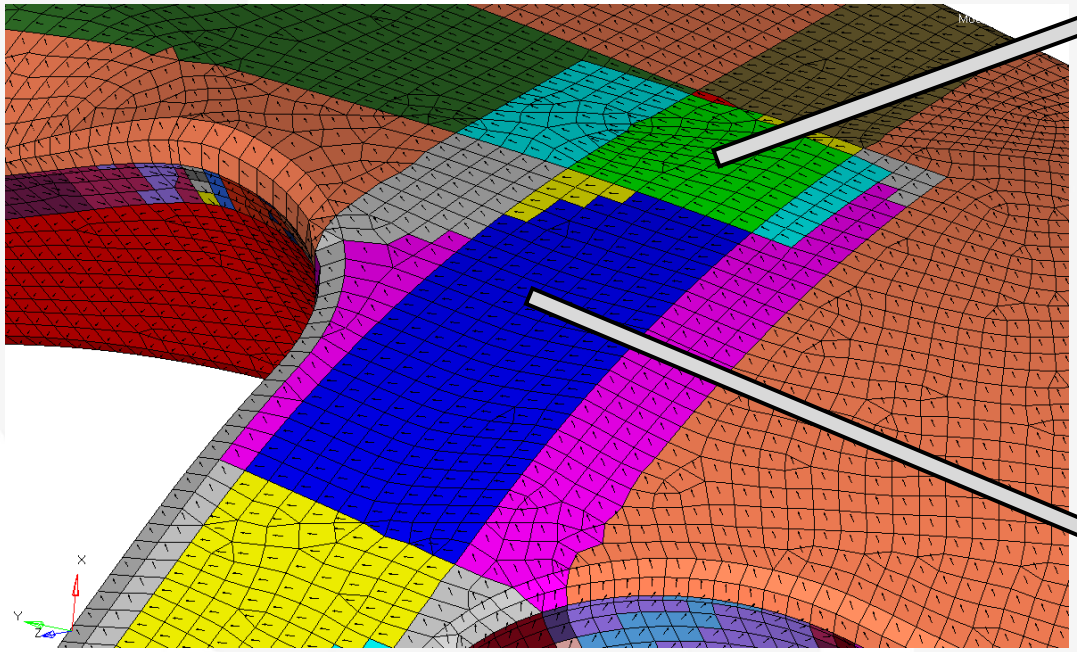
Berechnung / Simulation
Prozessablauf 2010-2014

- Vielzahl an unterschiedlichen Properties
- Händische Zuweisung sehr aufwändig bzw. nicht möglich
- Einsatz von entsprechenden Methoden nötig (Drapiersimulationen, Mapping-Tools,…)



Ply lay-up: PCUMPG_542
Total number of plies: 6
Total thickness: 4.242

Ply	Material	Thickness T1	Orientation Degrees
1	MAT8_2	0.708	0.0
2	MAT8_2	0.708	29.999
3	MAT8_2	0.708	0.0
4	MAT8_2	0.708	29.999
5	MAT8_1	0.705	-29.999
6	MAT8_1	0.705	-40.0

Ply lay-up: PCUMPG_543
Total number of plies: 4
Total thickness: 2.826

Ply	Material	Thickness T1	Orientation Degrees
1	MAT8_2	0.708	0.0
2	MAT8_2	0.708	0.0
3	MAT8_1	0.705	-70.0
4	MAT8_1	0.705	-70.0

Quelle: Wimmer - Computergestützte Auslegung von Kunststoffbauteilen - Schwerpunkt Faserverbund Bauteile; Vorlesung an JKU Linz, 2012

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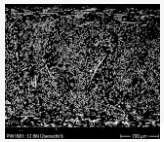
Berechnung / Simulation
Prozessablauf 2010-2014

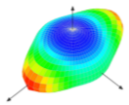
Injection molding (Moldflow, Moldex, ...)



$$a_{ij} = \begin{bmatrix} 0{,}66 & 0 & 0 \\ 0 & 0{,}32 & 0 \\ 0 & 0 & 0{,}02 \end{bmatrix}$$

fiber orientation

micromechanic modeling (4a micromec, ...)

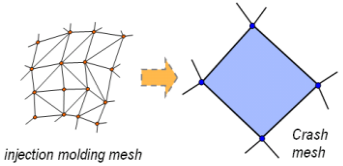


$$\mathbf{C} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} & C_{15} & C_{16} \\ & C_{22} & C_{23} & C_{24} & C_{25} & C_{26} \\ & & C_{33} & C_{34} & C_{35} & C_{36} \\ & & & C_{44} & C_{45} & C_{46} \\ & & & & C_{55} & C_{56} \\ & & & & & C_{66} \end{bmatrix}$$

anisotropy

Mapping (4a fibermap, ...)

In plane mapping



Mapping in thickness direction

Crash Simulation (LS-DYNA)

orientations

*ELEMENT_SHELL_BETA

*ELEMENT_SHELL_COMPOSITE

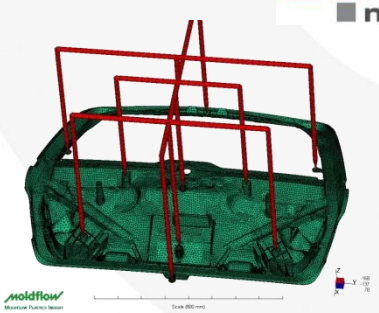
*INITIAL_STRESS_SHELL(SOLID)

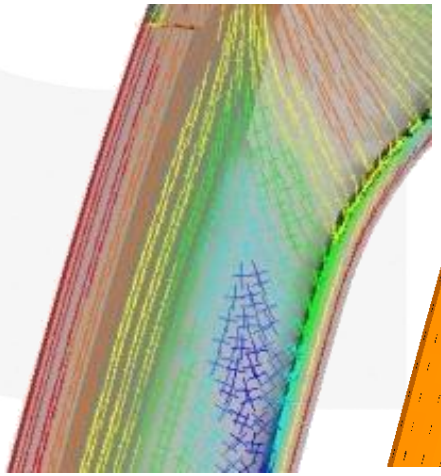
*ELEMENT_SOLID_ORTHO

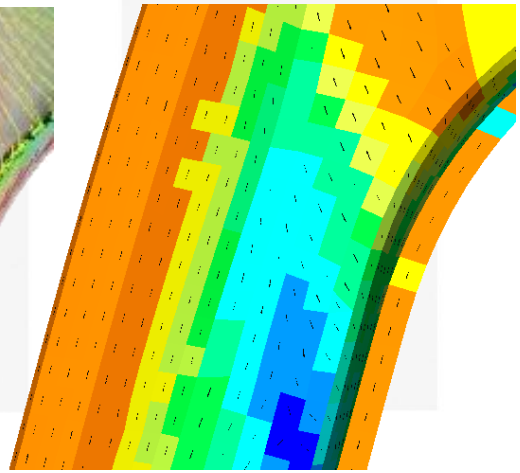
standard material models

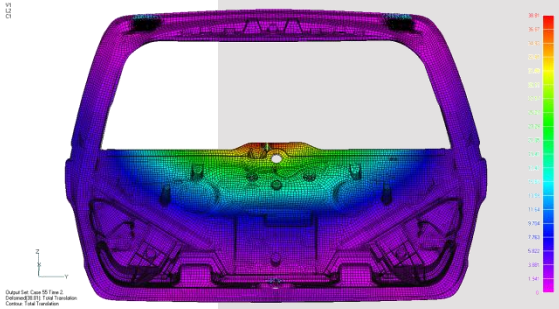
*MAT_(ANISO)TROPIC_ELASTIC

*MAT_ANISOTROPIC_ELASTIC_PLASTIC









Quelle: Reithofer , TT2011

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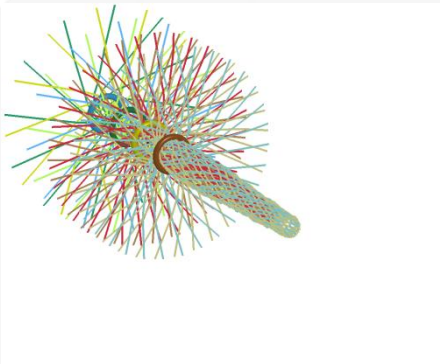
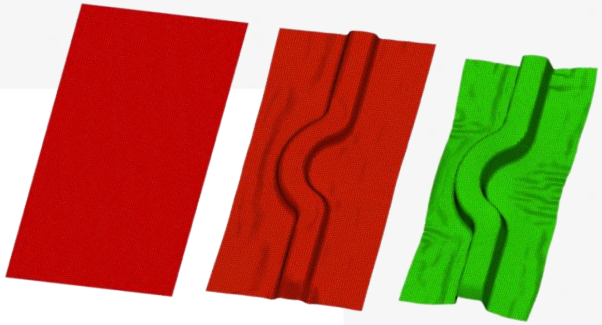
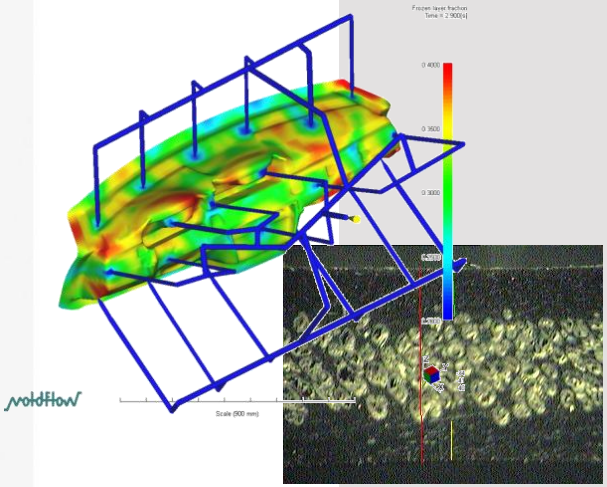
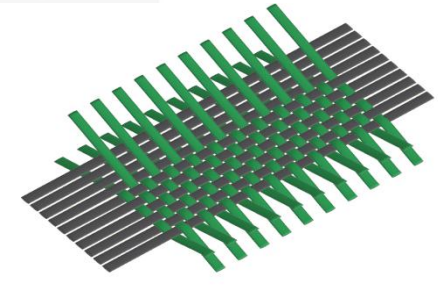
Berechnung / Simulation
Prozesssimulation 2010-2014

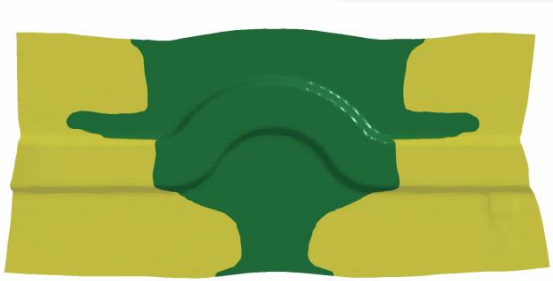




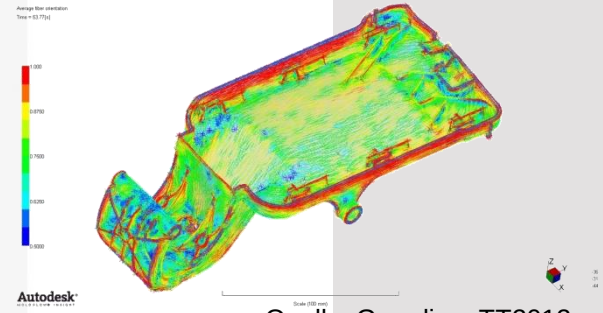


Quelle: Wimmer, TT2010

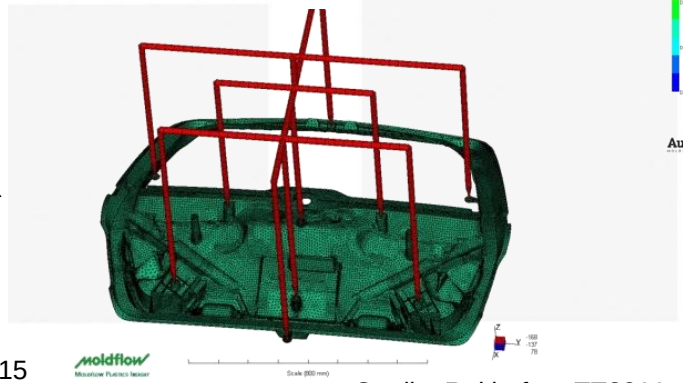




Quellen: Haufe, TT2014 bzw. Hartmann, TT2015



Quelle: Gramling, TT2012



Quellen: Haufe, TT2014 bzw. Hartmann, TT2015

Quelle: Reithofer , TT2011

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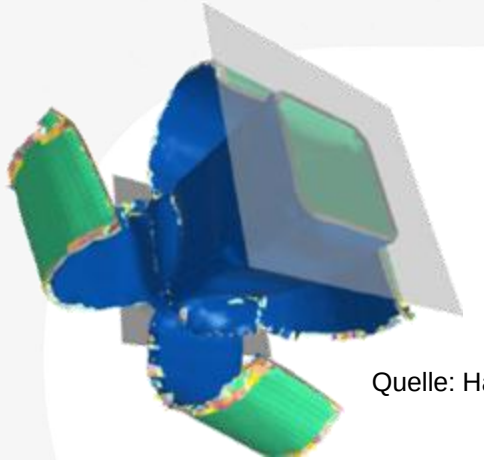
Berechnung / Simulation
Ausblick

- **Postfailure / Energieaufnahme**

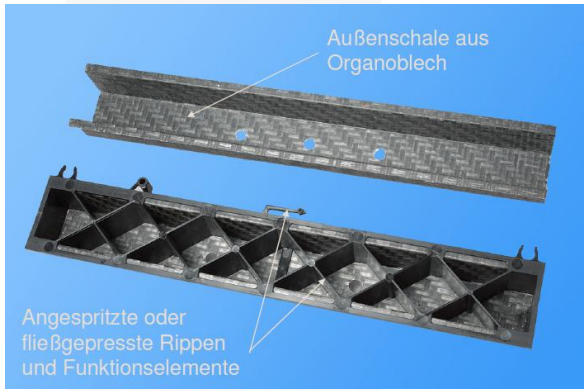


Quelle: Hartmann, TT2015

- **Integrative Simulation Prozess berücksichtigen**
  - Vereinfachung
  - Vielzahl an Prozessen

- **Materialcharakterisierung**
  - Effizienter Zugang für komplexe Modelle
  - Prozesssimulation

- **Multimaterial Ansatz / Verbindungstechnik**



Quelle: Egger, TT 2009

Quelle: Stock, TT2011

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Materialmix „Seinerzeit“ - Beispiele

1886: Benz Patent-Motorwagen
Quelle: www.daimler.com

1941: Ford Soybean Car
Sojafaserverstärkte Karosserie
Quelle: http://content.usatoday.com

1939: DKW F8, Holz-Stahl-Mischbauweise
Quelle: http://commons.wikimedia.org

1964: Trabant, Naturfaserverstärkte Karosserieteile
Quelle: http://de.wikipedia.org/wiki/Trabant_(Pkw)

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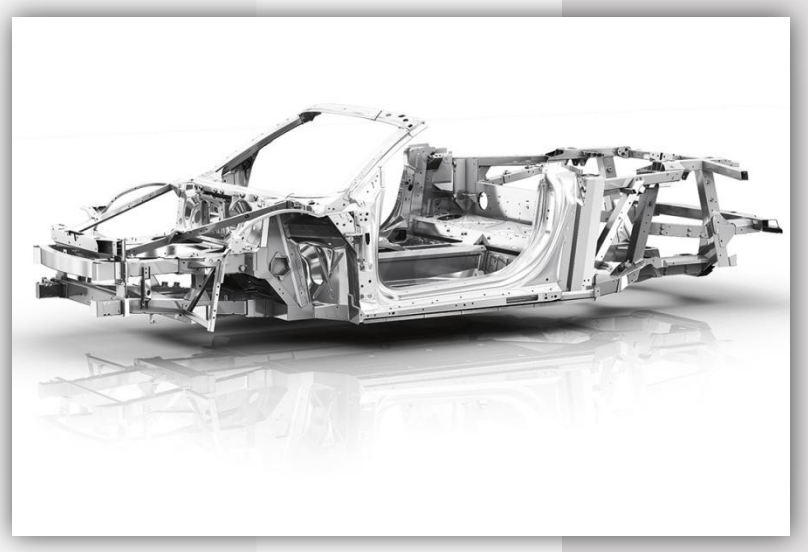
Materialmix - Beispiele

Quelle: http://www.motortrend.com



Quelle: http://www.audi.de

Quelle: http://www.audi-technology-portal.de

Quelle: http://www.autozeitung.de

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CULT- Cars Ultra Light Technologies

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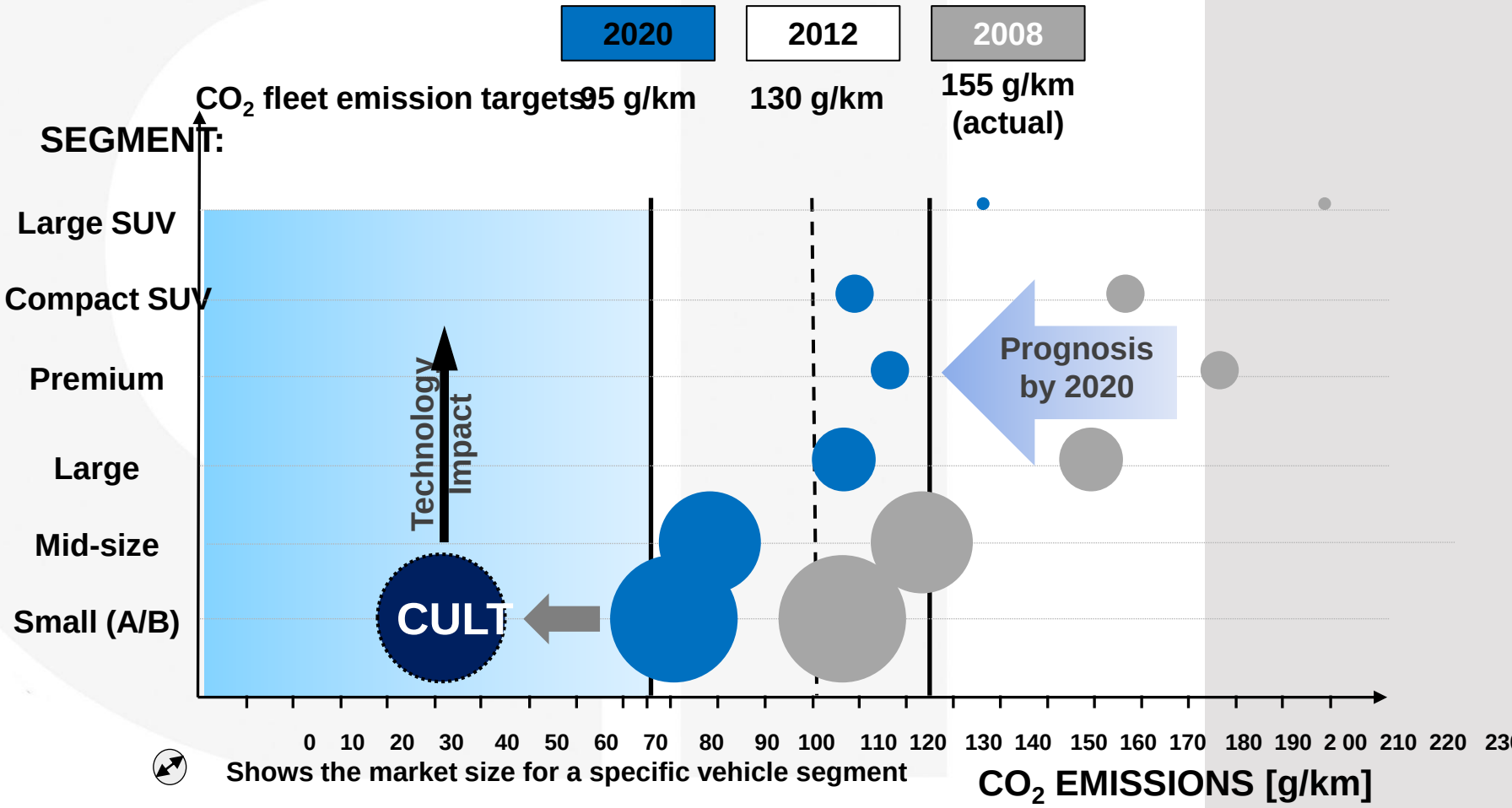
European CO_2 Fleet Emissions Today and Forecast

Scalability of CULT technologies



Source: J.D. Power, Roland Berger

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Maximization of Customer Benefit

CULT - Cars Ultralight Technologies

modern, efficient, minimalistic lifestyle vehicle

- **CO_2 target < 50 g/km**
- **A- Segment (e.g. Fiat 500)**
- **highly customer benefit (4 Seats)**

Adjusting lever in the complete vehicle development for CO_2 reduction

CO_2 reduction potential

3%	• Aerodynamics
3%	• Rolling resistance
9%	• Efficiency increase
10%	• Lightweight
30%	• (alternative) powertrain

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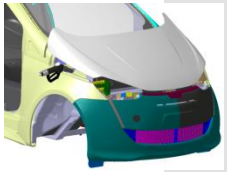
Holistic Lightweight Concept

Base 900 kg

ca. -80kg

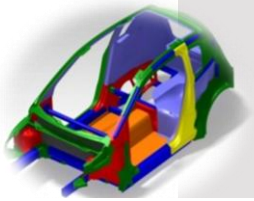
- **Integration of functions**
  (cancellation of parts)



Integrated fuel door

ca. -100kg

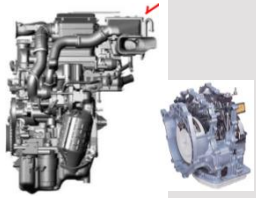
- **New materials**
  (selective usage of lightweight materials)



Multimaterial body

ca. -120kg

- **Downsizing**
  (& use of secondary effects)



engine: 660 cm³ instead of 1l

Weight reduction up to 300 kg

Target weight 600 kg

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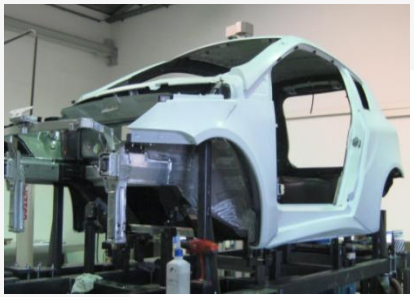
Selective Usage of Lightweight Materials



Multi material body in white

Fiber composite door and hood

Composite floor

Fire wall made of sandwich material

Composite axle module

Organo-Frontcrashsystem

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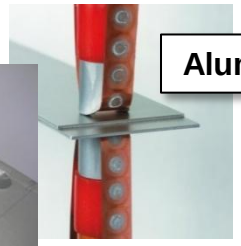
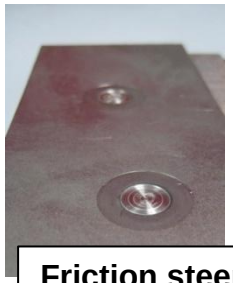
Joining technology

Metallic lightweight materials



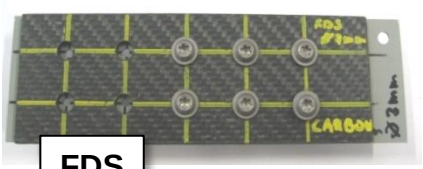
Aluminium-spotwelding

CMT-welding for Steel-Aluminium-joinings



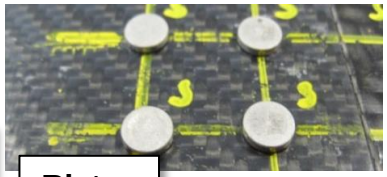
Friction steer welding for joining of Aluminium und Magnesium

Composite materials



FDS

Semi hollow-punch rivets



Rivtac

Blind rivetings

glue

Fixation elements

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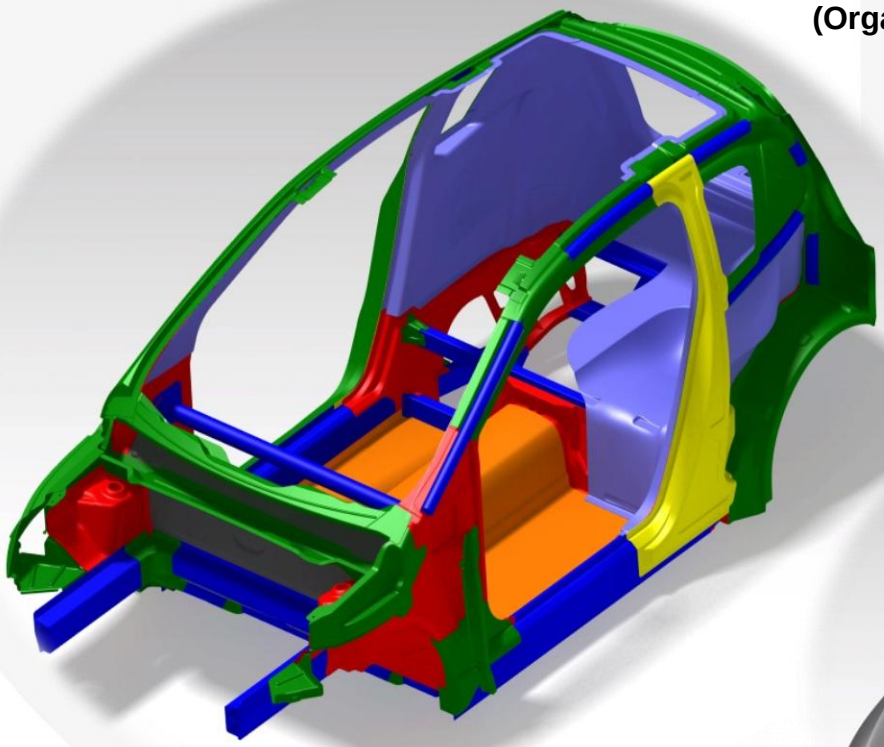
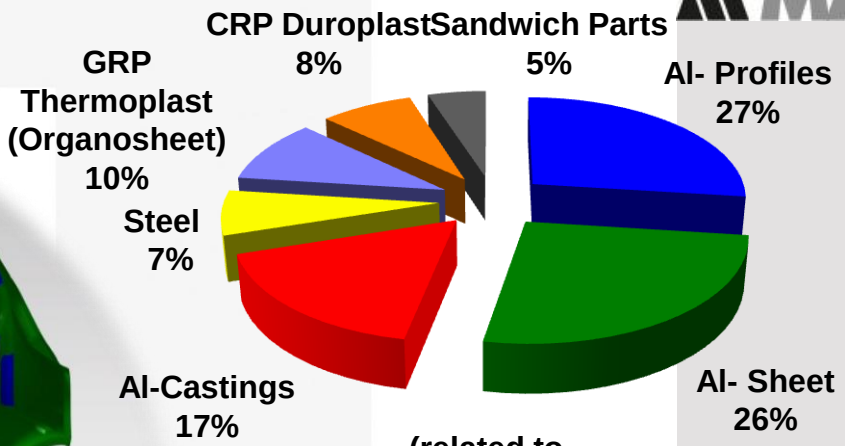
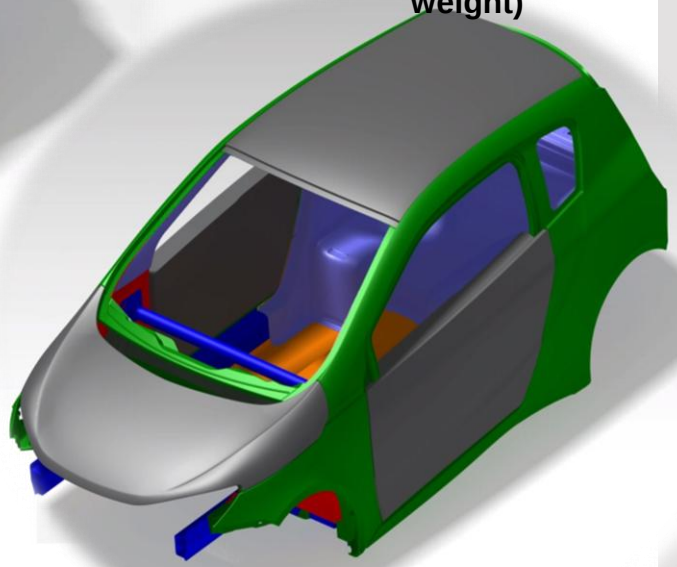
Material Concept





(related to weight)



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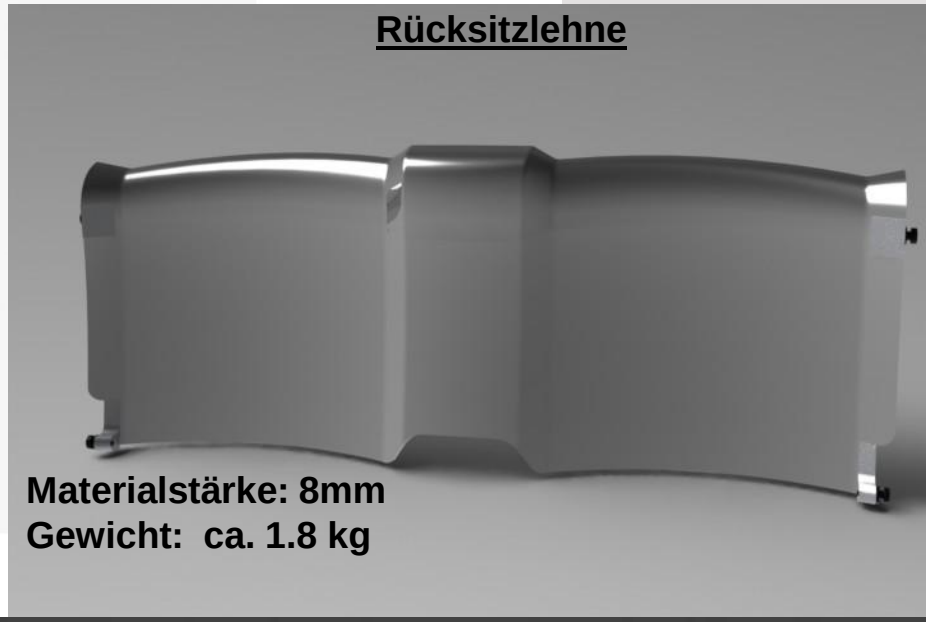
CULT- Cars` UltraLight Technologies

Stirnwand

Materialstärke: 3mm
Gewicht: ca. 1.6 kg
Gewichtseinsparung - 45%

Rücksitzlehne



Materialstärke: 8mm
Gewicht: ca. 1.8 kg

BIW incl. Doors & Hood

Weight comparison (without Doors & Closures):
CULT: 147kg (measured incl. Paint)
Benchmark veh.1 : 240 kg
Benchmark veh.2 : 222 kg

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Staatspreis
Mobilität 2013