WoodC.A.R. - Nachhaltiger struktureller Leichtbau – Chancen & Herausforderungen für Holz im Automobilbau

Christian Kurzböck, Thomas Jost, Virtual Vehicle
Ulrich Müller, Institut für Holztechnologie und Nachwachsende Rohstoffe / Universität für Bodenkultur Wien
Florian Feist, Vehicle Safety Institute TUGraz

FFG - COMET K-Project
Wood - Computer Aided Research

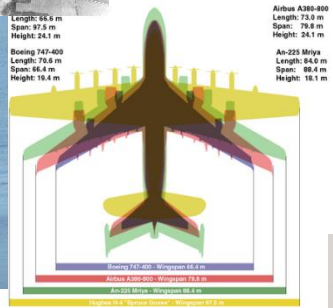
More than 70 Years of High-Performance Industrial Applications

De Havilland Mosquito bomber, Beechcraft AT-10, H-4 Hercules named the Spruce Goose, Giant Plane Comparison

Source: https://www.baesystems.com/en/heritage/de-havilland-mosquito

Source: https://www.wikipedia.org/

Source: https://commons.wikimedia.org/



Source: https://www.wikipedia.org/

Wooden bicycle frame

Source: https://www.my-esel.com/my-esel-urban/

Source: https://www.wikipedia.org/

2016 Toyota Setsuna EV Concept

Source: https://toyotadriver.com/toyota-setsuna-ev-concept/

Train bogie

Source: http://www.internationalsteam.co.uk/trains/norway05.htm

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Project Consortium

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Scientific Partner

Innovationszentrum W.E.I.Z.
BOKU
virtual vehicle
TU Graz
UNI GRAZ
FH JOANNEUM

Business Partner

AC STYRIA
doka
EJOT
DYNA MORE
FHP READER
VOLKSWAGEN AKTIENGESELLSCHAFT
MAN
MATTRO Driven By EcoLogic
MAGNA
Weitzer Parkett
Collano
IB STEINER
holzcluster steiermark gmbh
>LEAN

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WoodC.A.R. Vision

WoodC.A.R.
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New Production Technologies for Shaping, Joining and Bonding

Computer Aided Engineering (CAE) Models of Wooden Materials

Environmental and Economic Sustainable Materials

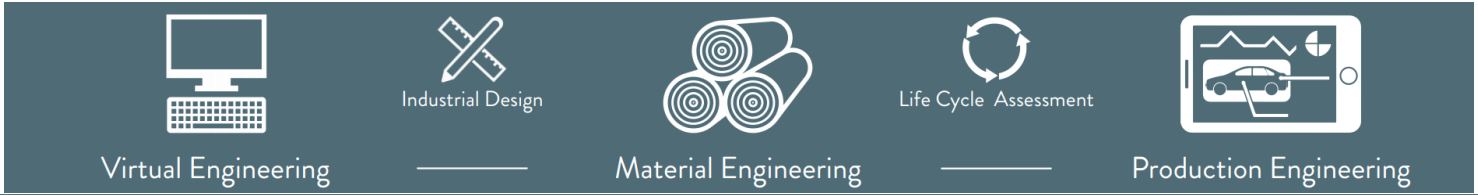
EWC to the Mobility Sector

Engineered Wood Products (EWP), Engineered Wood Components (EWC) and Wood-Based Materials

Life Cycle Assessment

Determination of Material Parameters

Noise Vibration Harshness



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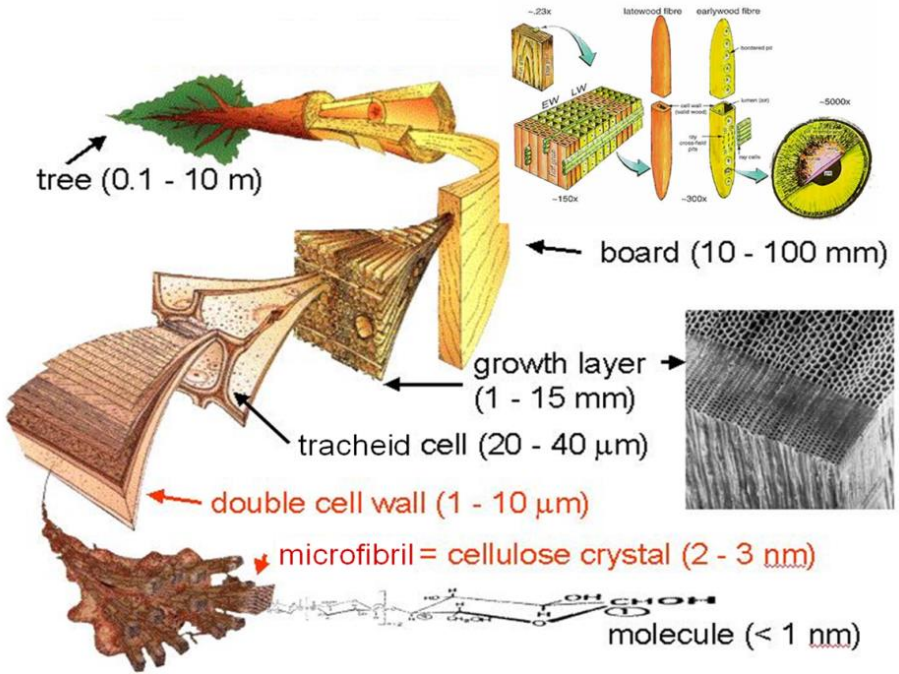
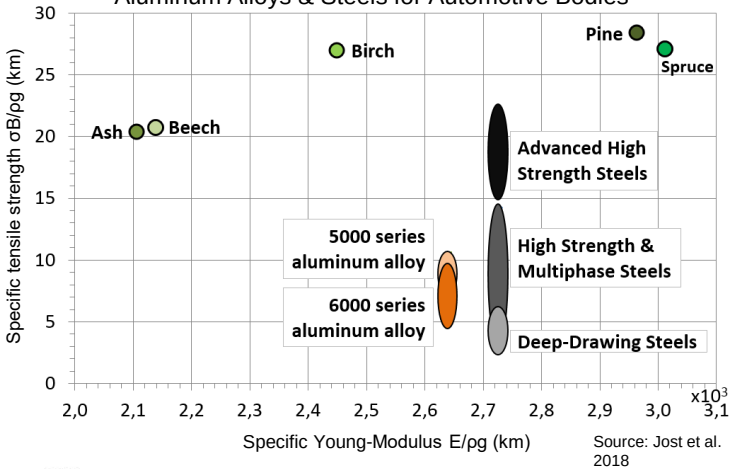
Wood – Chemistry, Structure & Mechanical Properties

Dealing with Wood Properties demands considering all Hierarchical Levels of Wood Structure

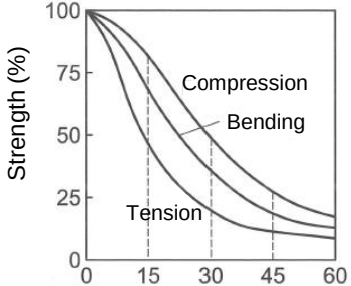


Source: The hierarchical structure of cellulose in wood. From an artwork by Mark Harrington, Copyright University of Canterbury, 1996.

Specific Young-Modulus and Strength Solid Wood (longitudinal), Aluminum Alloys & Steels for Automotive Bodies

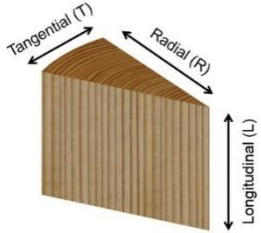


Source: Jost et al. 2018



Load distribution throughout the angle

Source: Holzphysik (Niemz)



Source: https://www.wikipedia.org/

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Effects of Wood Anatomy on Mechanical Properties

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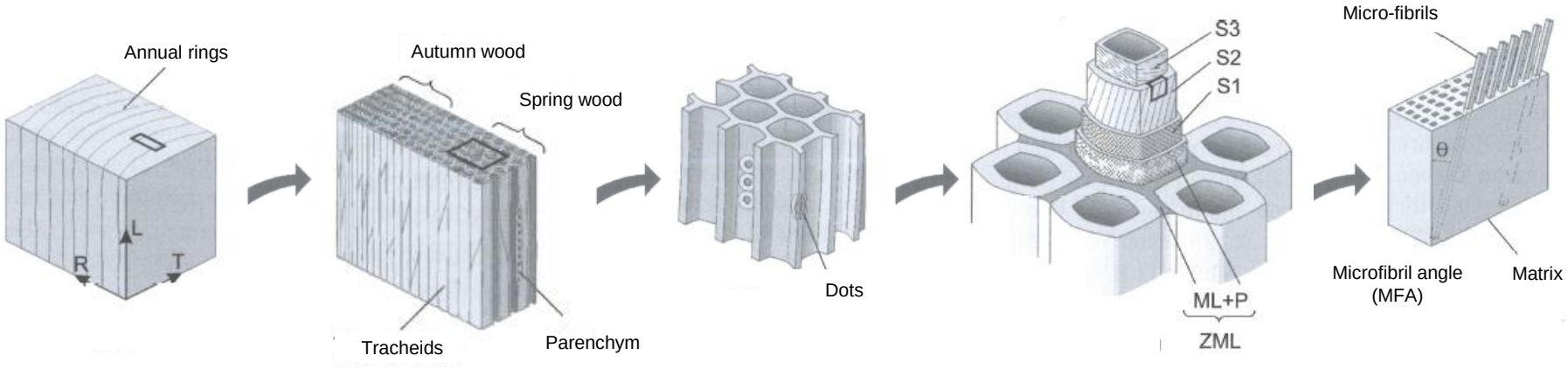
COMPUTER AIDED RESEARCH

Plywood	Annual rings	Cells	Cellwall	Cellwall-Layer



Laminate	Laminate	Structural composite	Composite Laminate	Fibre-reinforced composite

Source: Holzphysik (Niemz)

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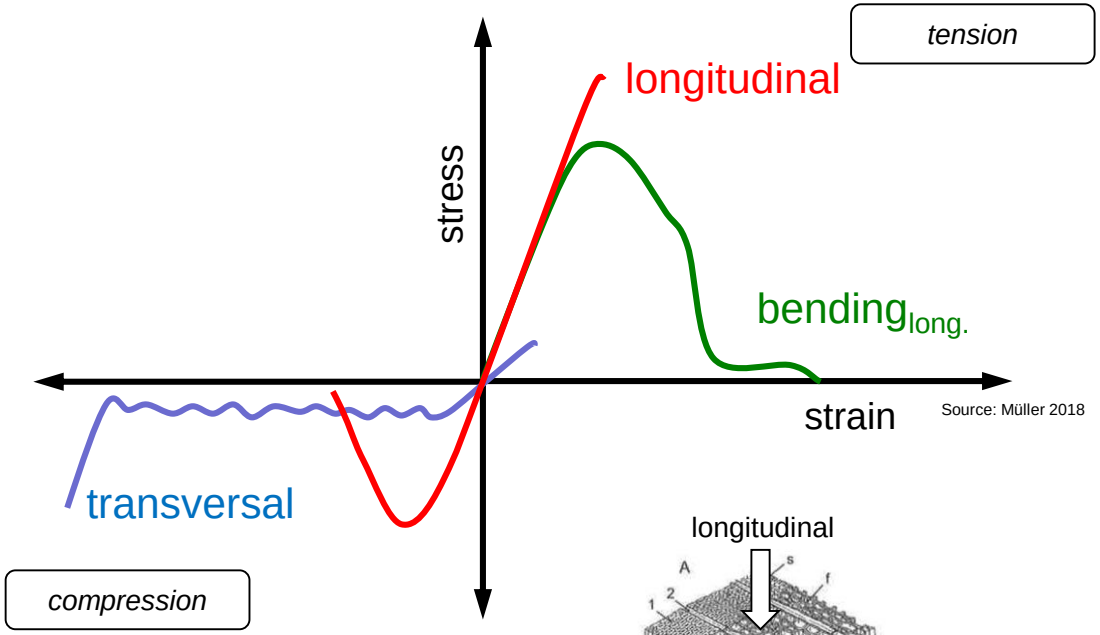
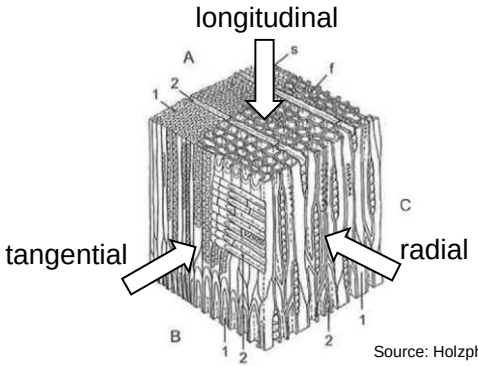
Elastic / Plastic Deformation and Fracture Behaviour of Wood



Source: Müller 2018



Source: Holzphysik (Niemz)

Tension:

- Brittle failure in longitudinal and
- Transversal direction

Compression:

- Ductile behaviour in longitudinal direction
- Highly plastic deformation in transversal direction
- Hardening effect in transversal direction
- Softening effect in longitudinal direction

Bending:

- Longitudinal: ductile behaviour until tensile strength is reached, than stepwise brittle failure
- Transversal: brittle failure due to low tensile strength perpendicular to grain

Shearing:

- Ductile failure in all directions

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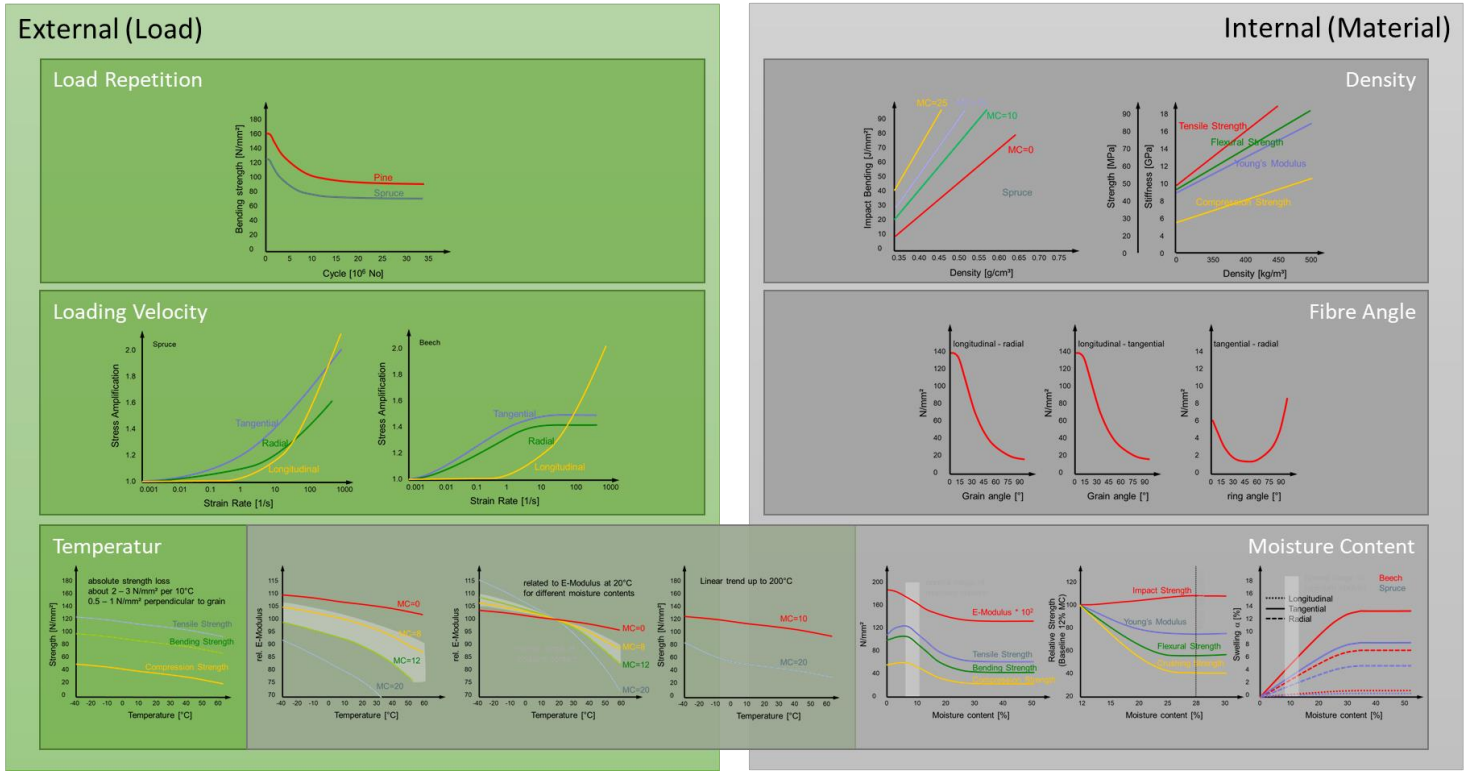
Material Characteristics and Influencing Factors



Source: Feist et al. 2018

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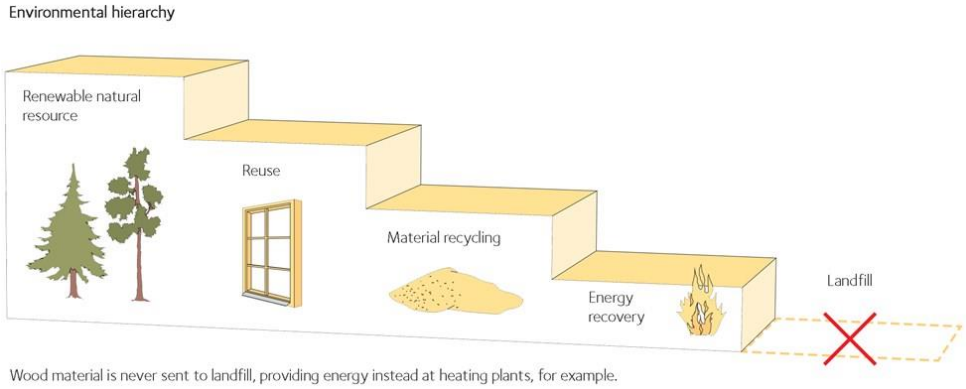
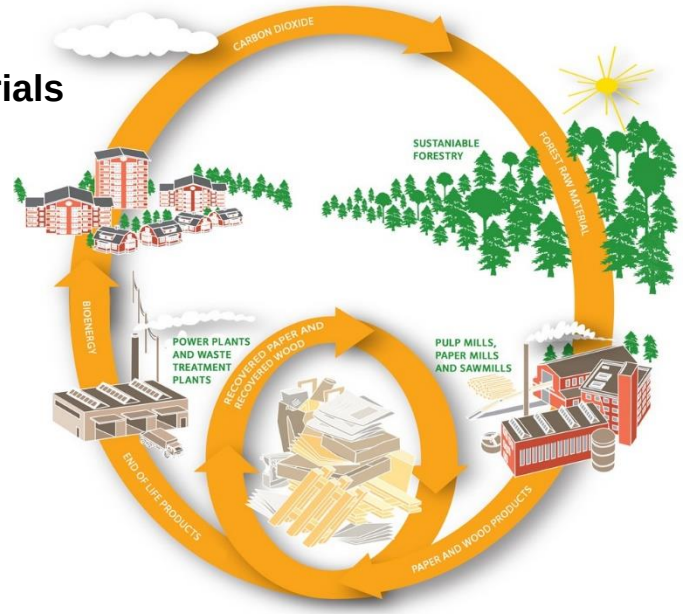
Renewable Domestic Raw Material

- **Reasonably priced, sustainable availability in Austria**
- **Short transport routes and entire supply chain in Styria**
- **Low energy consumption compared to conventional materials**
- **Possibility of waste recycling (Enviromental hierachy)**
- **Wood has two ecocycles compared to conventional materials**



Source: https://www.swedishwood.com/



Source: https://www.swedishwood.com/

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Materials Made of Wood

Solid Wood Materials	Veneer Materials	Chip Materials	Fiber Materials	Composites

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Opportunities and Challenges

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Figures of merit for the evaluation of lightweight suitability

Properties	Quality coefficient	Wood	Steel	AL-Leg	Mg-Leg.	CFK
Strength (Tens., Comp.)	$[\frac{R_m}{(g\rho)}]$	1,35	0,6	1	1,16	3,45
Stiffness long. (Tens., Comp.)	$[\frac{E}{(g\rho)}]$	0,93	1,03	1	1,00	3,09
Shear stiffness (Torsion)	$[\frac{G}{(g\rho)}]$	-	1,06	1	1,06	1,11
Buckling strength	$[\frac{\sqrt{E}}{(g\rho)}]$	0,96	1,02	1	1,00	1,76
Elastic work capacity	$[\frac{R_{p0.22}}{E}]$	0,47	2,08	1	1,55	2,29
Impact strength	[A]	0,2	2,50	1	2,50	0,20
Fatigue *R=-1* *N=10^6*	$[\frac{\sigma_{bw}}{(g\rho)}]$	1,2	1,30	1	1,20	2,80
Price	[€/t]	300-500	1.000-1.300	2.000-3.000	3.000-5.000	50.000-100.000

Source: Leichtbau-Konstruktion, Berechnungsgrundlagen und Gestaltung

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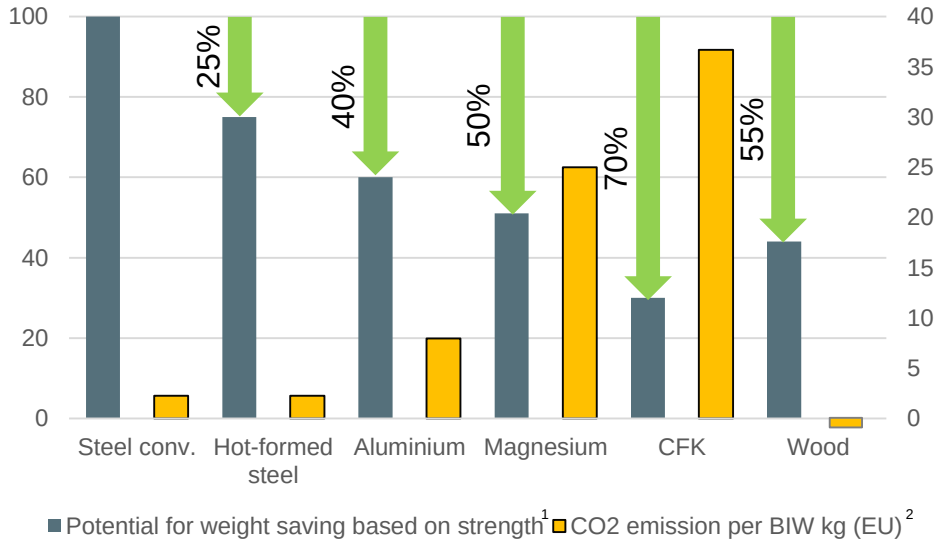
Lightweightpotential and CO_2 Balance of Selected Materials



Source: [1]Leichtbau-Konstruktion, Berechnungsgrundlagen und Gestaltung
[2]Life-Cycle Analyse von Leichtbaukonzepten für den Automobilbau

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Specification of Components

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Design

Manufacturability

Water absorption

Flammability

Strength

Use Case

Source: Mattro

ect.

Fatigue strength

Splinter protection

UV-resistant

Crash behavior

Chemicals resistant

Recyclability

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Computer Aided Engineering: Using Different Virtual Methods

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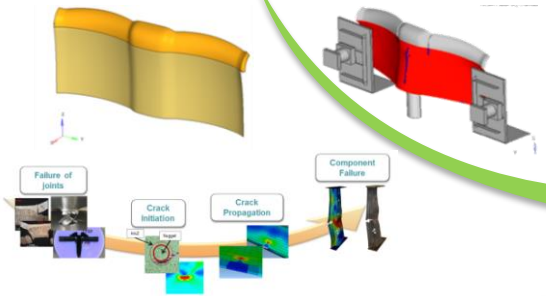
COMPUTER AIDED RESEARCH

Joining and Gluing Technology

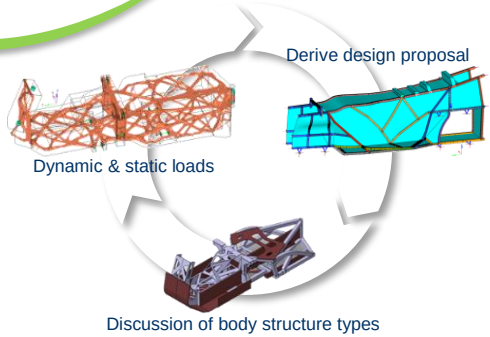
Methods Development for Wood in Vehicle Crash Simulation

Integrated Failure Assessment in Crash

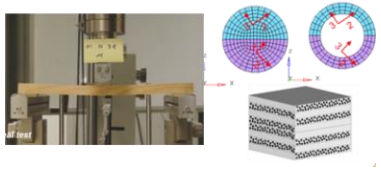


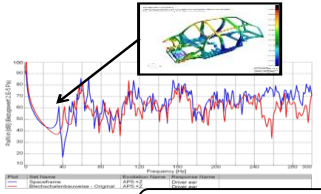
Source: Mattro

Efficient Derivation of Functional Lightweight Body Concepts



Material Characterization for Crash Simulation





NVH

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Integration in the Virtual Engineering Process

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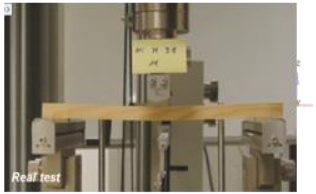
Material Testing

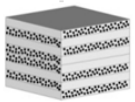
Material Modelling and Validation

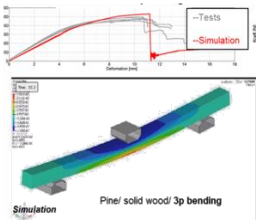
Component Testing

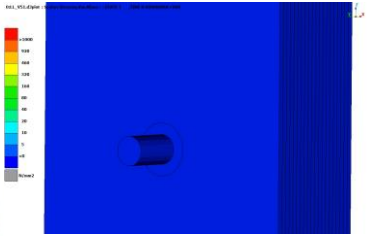
Component Modelling and Validation

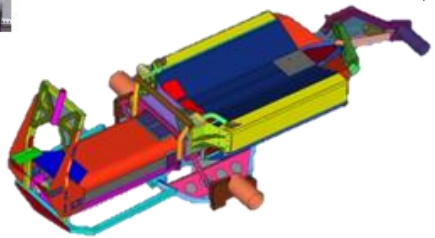
Functional Validation

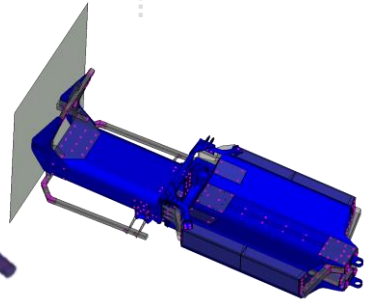












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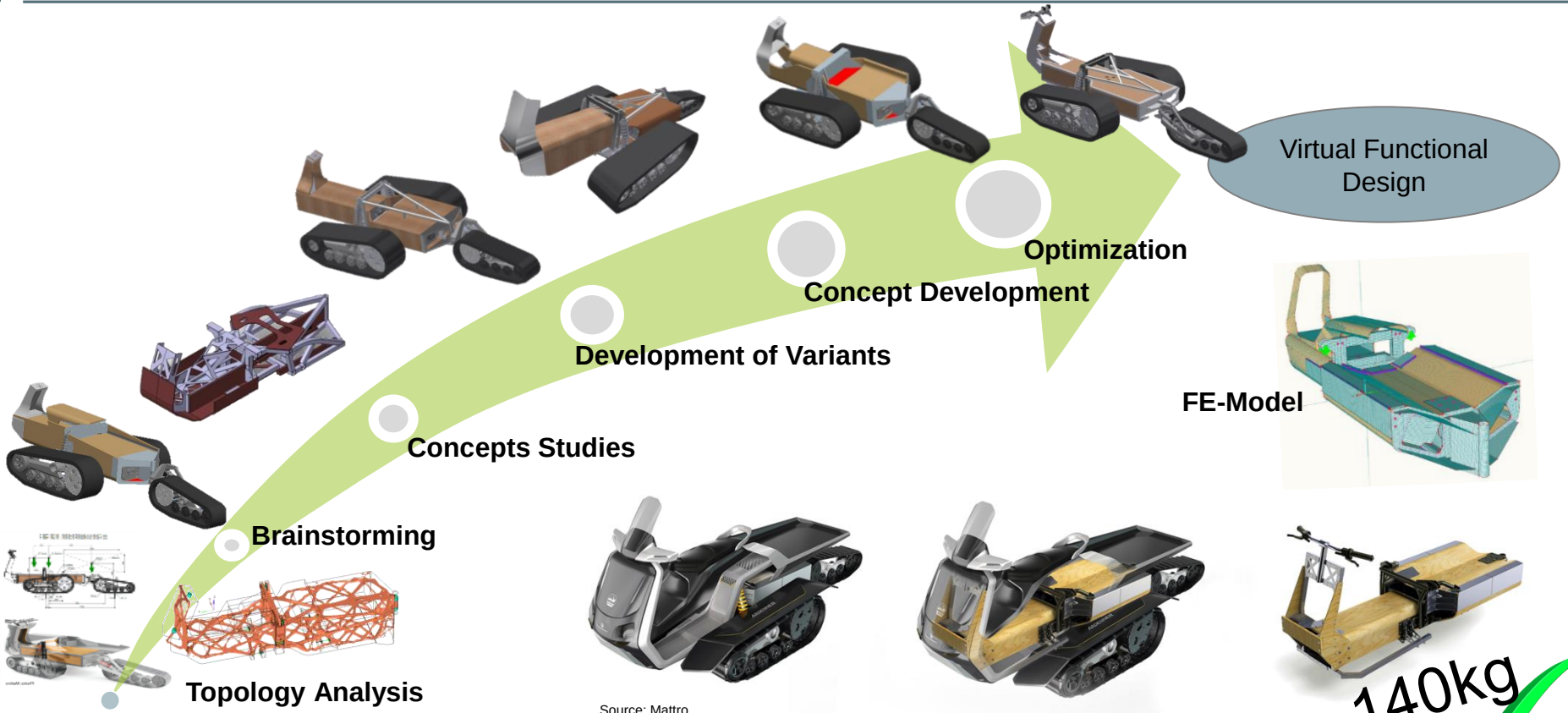
Implementation - Example Use Case Ardenner



Source: Mattro

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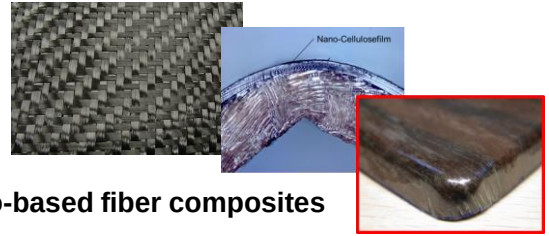
Challenges in the Production Process

Additive production technologies

CNC & Robotic



Bio-based fiber composites

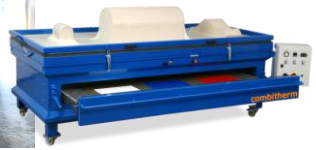
New gluing and bonding technologies

Source: Engel

Source: https://www.kunststoff-magazin.de/formen-schaeumen-fvk/bilder/naturfasern-im-automobilbau-hybrid-formpressen-fuer-innenraumkomponenten-1.htm

Injection molding (back injection, over molding etc.)

Connection, screwing and joining



3D moulding und non-cutting processing

… and additional (additive and generative) production technologies

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Conclusions

- **Use of wood and wood composites on selected structural components possible and expedient**
- **FE material simulation of wood and wood composites for complex structures under crash loading can be performed**
- **Functional structural components, in terms of basic function to the initial failure can be designed and evaluated in an early vehicle development phase**
- **Joining technology plays a major role and must be considered especially in plywood and wood composites**
- **Use-Cases reveal the potential of wood as a lightweight material, that is underrated in contemporary mechanical engineering**

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The K-Project WoodC.A.R. – Computer Aided Research is funded within the scope of COMET - Competence Centers for Excellent Technologies by BMVIT, BMDW and the federal states Styria and Tyrol. The program COMET is managed by the FFG.

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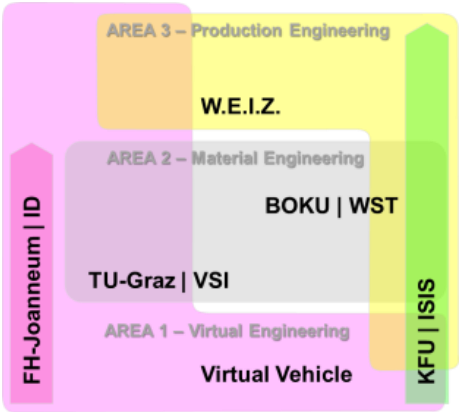
Scientific management



http://www.woodcar.eu/

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