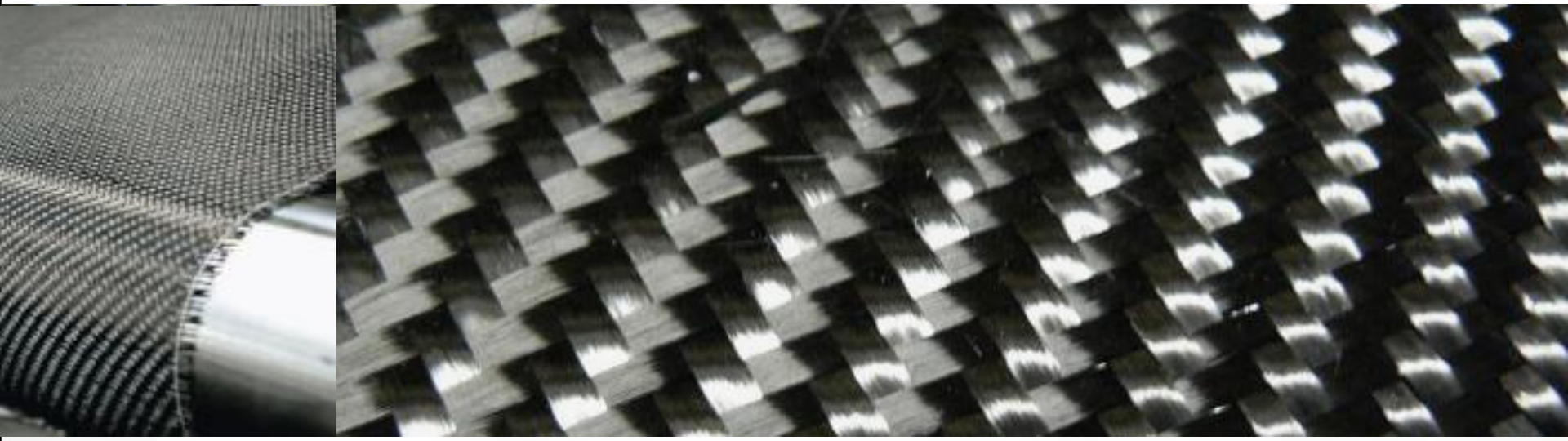


Modern multi-material cars: Challenges and methods to develop a cost efficient lightweight design

Dr. N. Feindler, Dr. H. Schluder, J. Döll, Audi Lightweight Design Centre, AUDI AG

4a-Technologietag 2013, 27.-28. Feb. 2013

- **Trend to Multi-Material-Design with CFRP applications**
- Challenges for the use of composite materials
- Weight and cost reduction using anisotropic material properties
- Optimized material properties using 3-d reinforced CFRP
- Conclusion

Trend to Multi-Material-Design with CFRP applications

Lightweight design as a keyfactor to future requirements

Enhanced vehicle dynamic	Reduction of emission	Reduction of operation costs
		
▶ Higher acceleration ▶ Improved handling ▶ Advanced safty ▶ Shorter braking distance ▶ Lower vehicle force	▶ Lower co_2–emission up to 11 g/km per 100kg reduce of weight	▶ Reduction up to 0,5 l/100km fuel per100kg reduce of weight

Lightweight design at Audi will be called ultra®

Lightweight design in bodywork allows…

…Downsizing engines and hence…

…secondary effects, as etc.: smaller breaks…

…

Evaluation of material concepts

The overall environmental balance benchmark

Input
- Power
- Raw materials

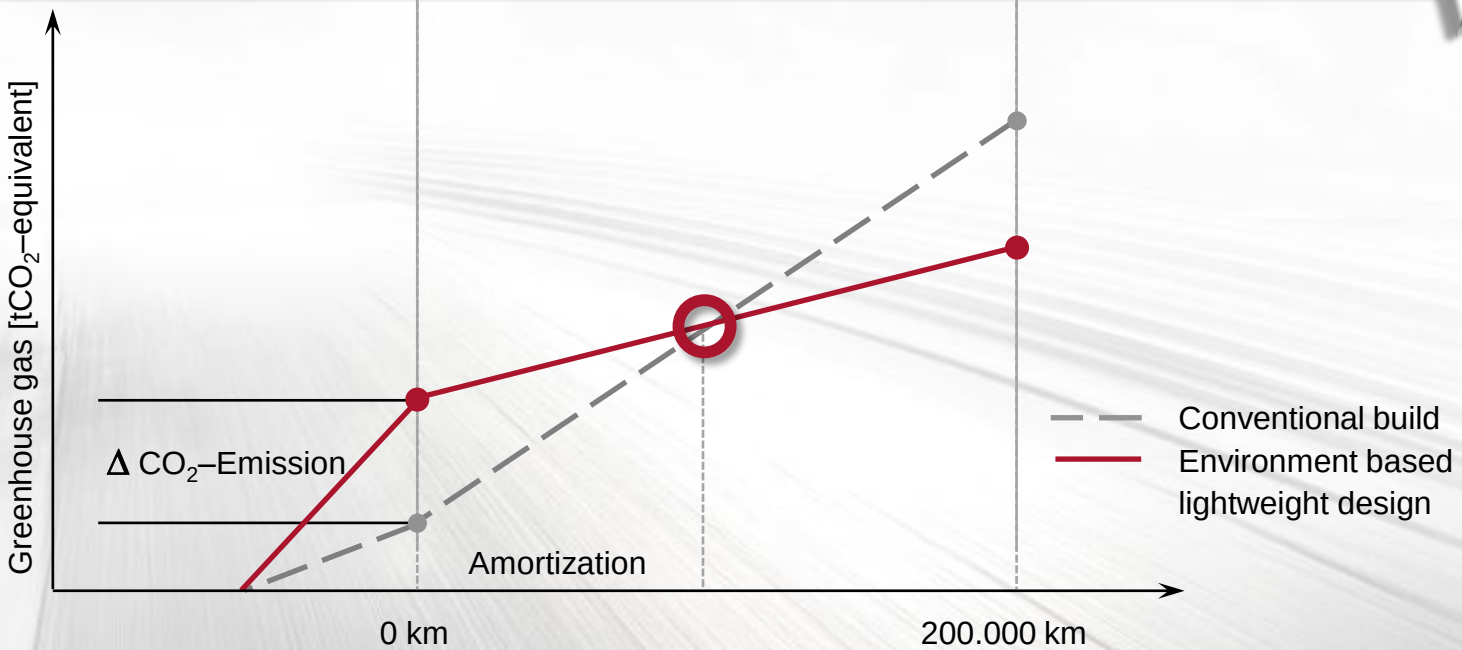
Manufacture

Production

Tank to wheel

Recycle

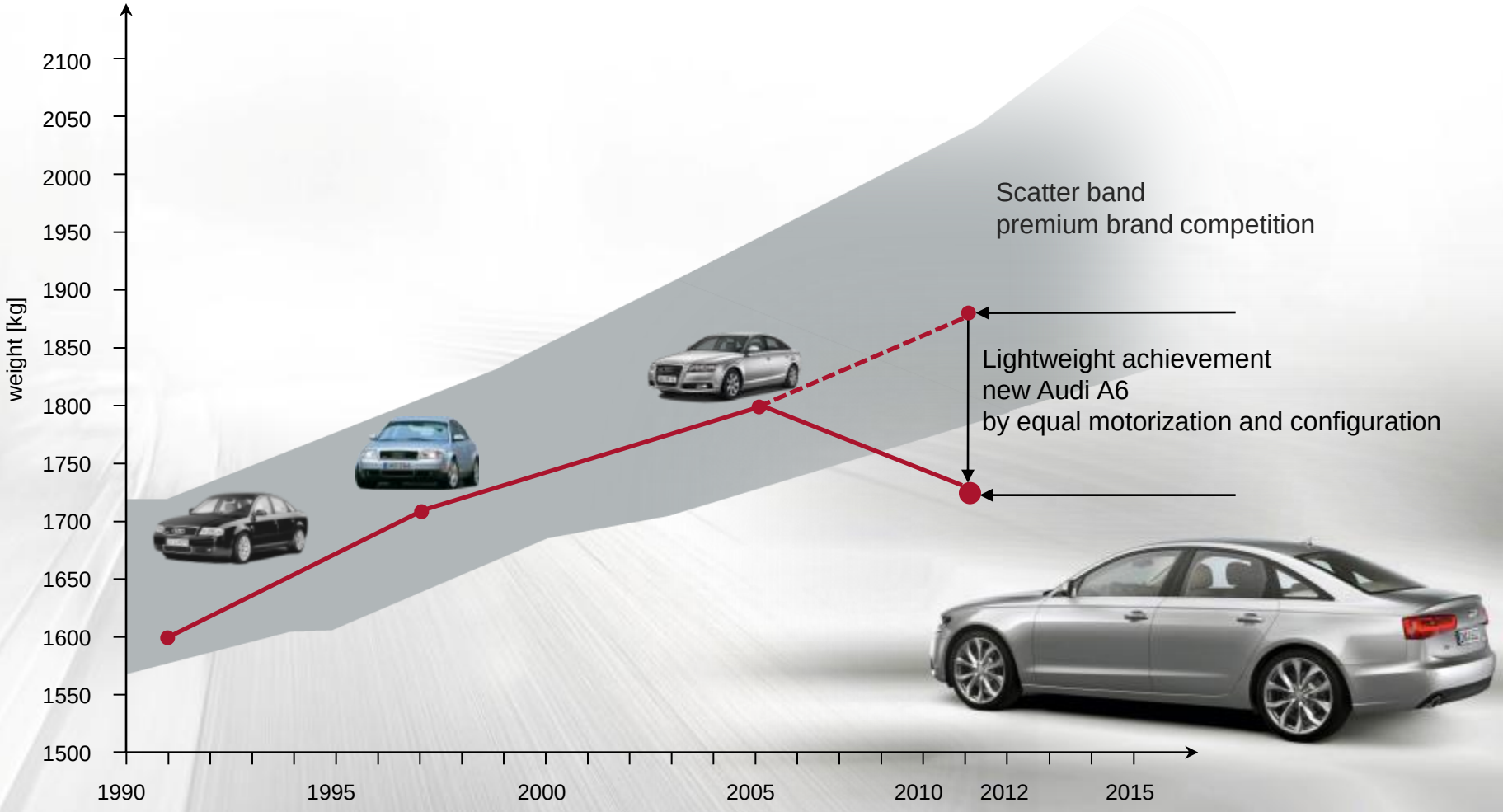
Output
- Emission
- Waste



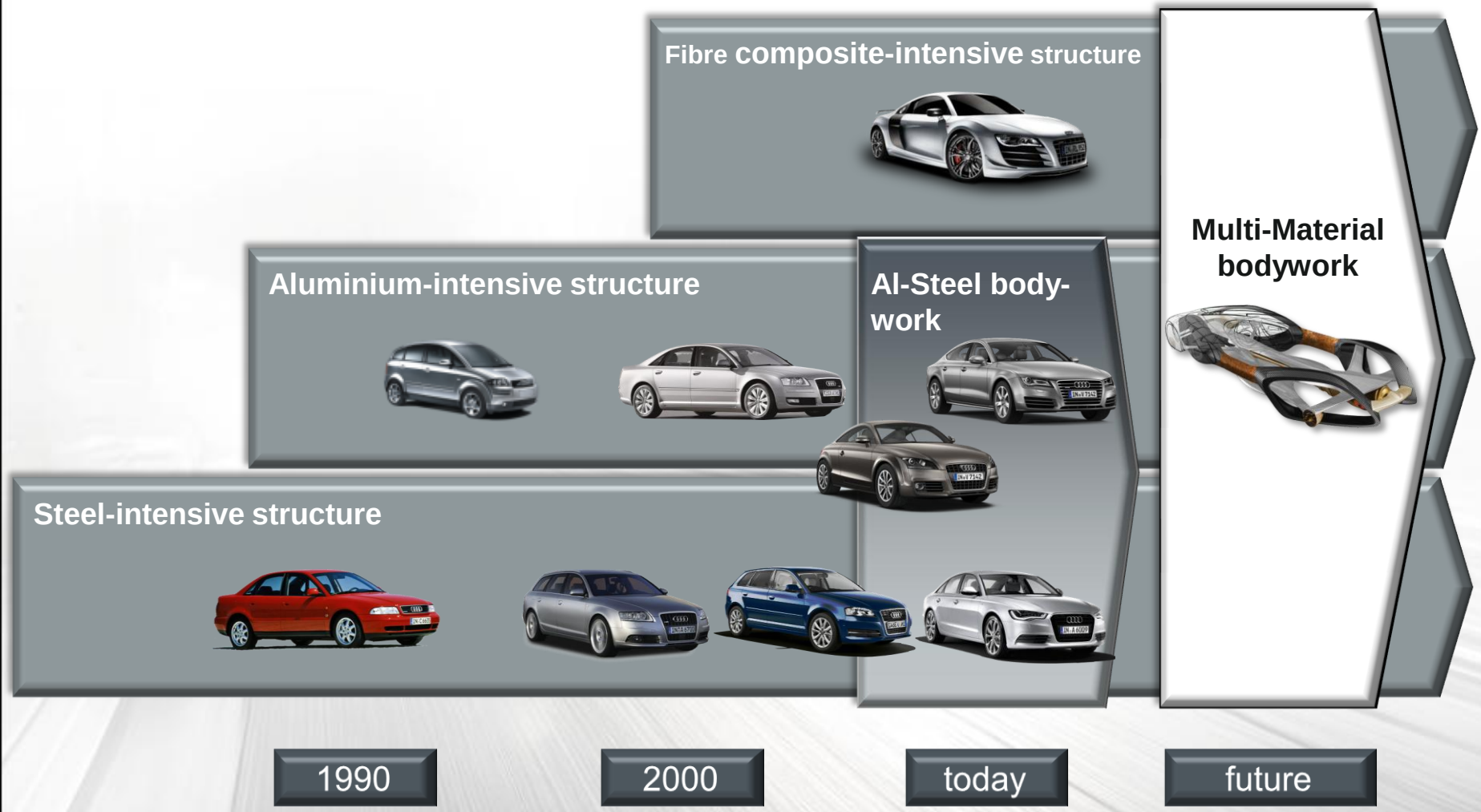
» For the analysis of the overlall enviromental balance the complete lifecycle is used

2011 Audi A6
Turning back the weight increase

- Reduction of the overall weight of the new Audi A6 about 80 kg confer to the volume model 3.0 TDI quattro



Multi Material as a key-factor for lightweight design



- Trend to Multi-Material-Design with CFRP applications
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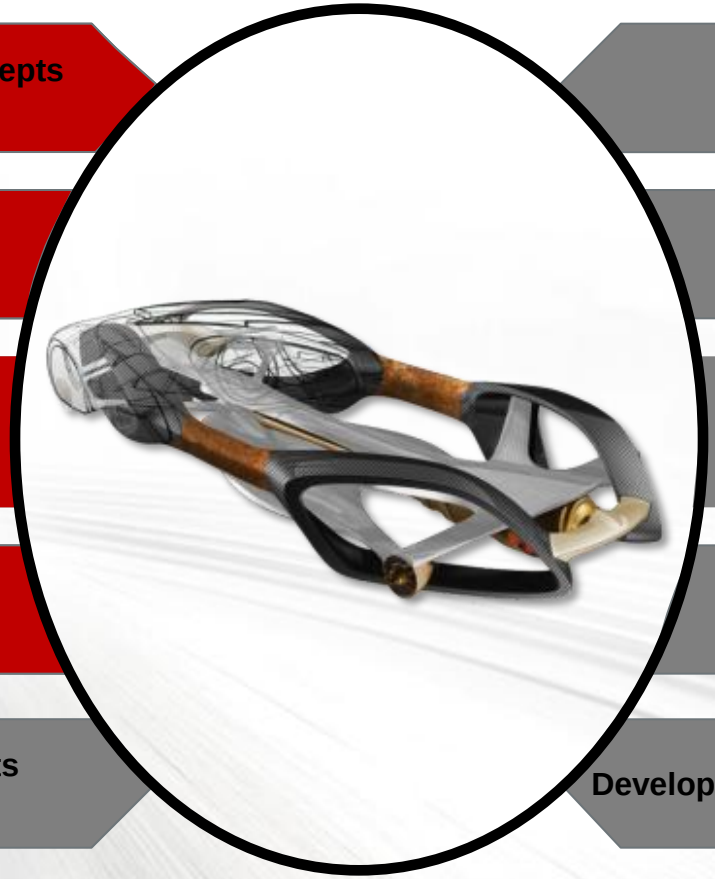
Challenges for the use of composite materials

New challenges for the development of composite car body structures

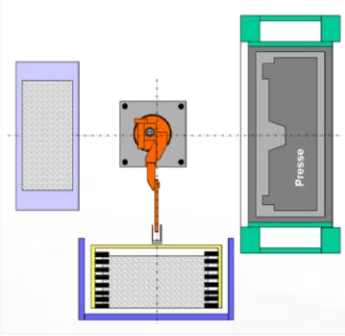
- Development of CFRP-specific concepts (Full use of lightweight potential)
- New material models for crash simulations and process simulation
- Improvement of material properties: cost reduction and increased lightweight potential
- Manufacturing technology: „mass production“ and cost reduction
- Joining technology: Al/CFRP – Joints and CFRP/CFRP – Joints



- Quality insurance: Processes and test methods to validate high quality standards
- CFRP-specific tools and processes
- Development of a CFRP-specific assembly process
- Recycling
- Development of repair and service concepts

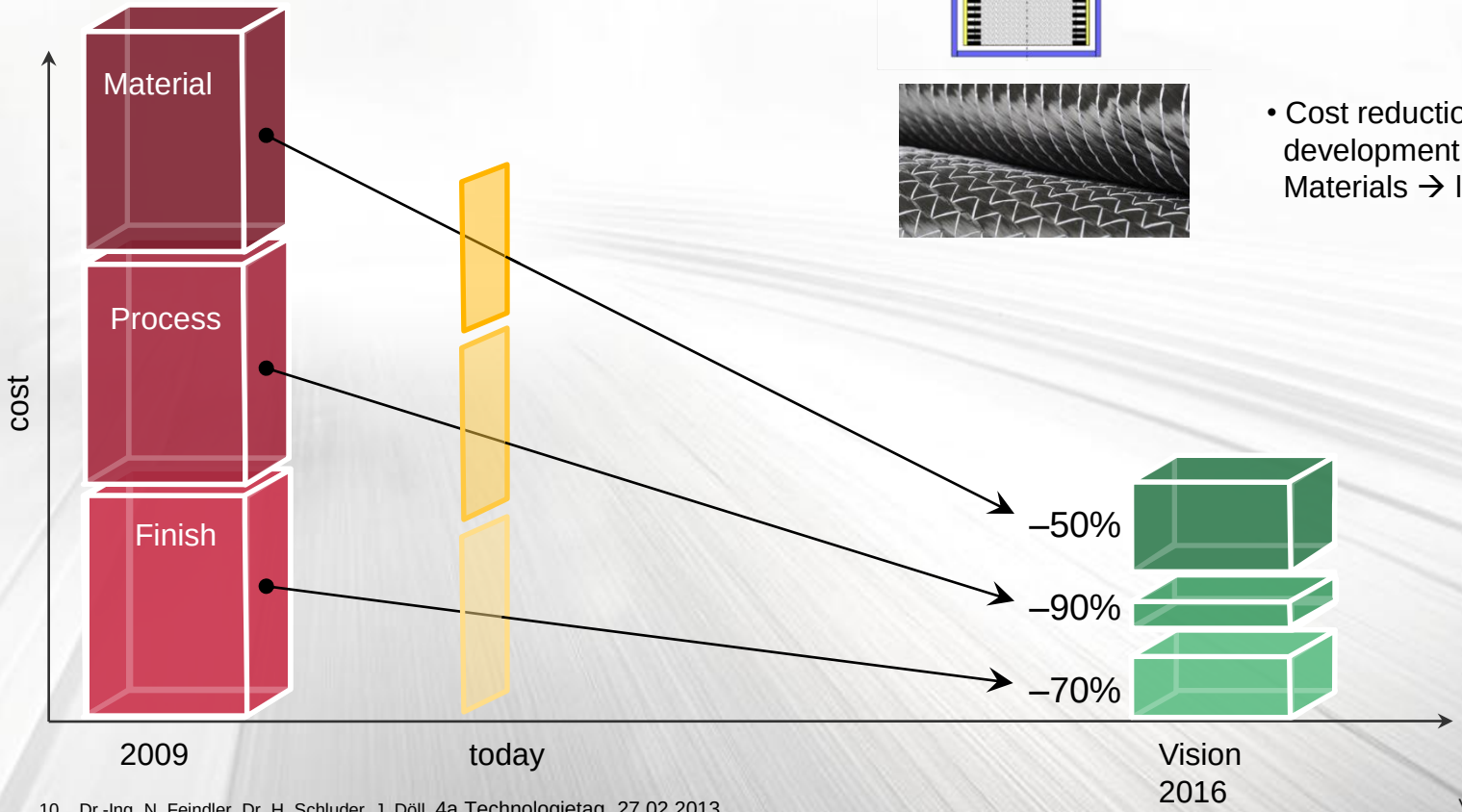
Main challenge for fibre reinforced plastics

- Cost reduction by optimized process costs

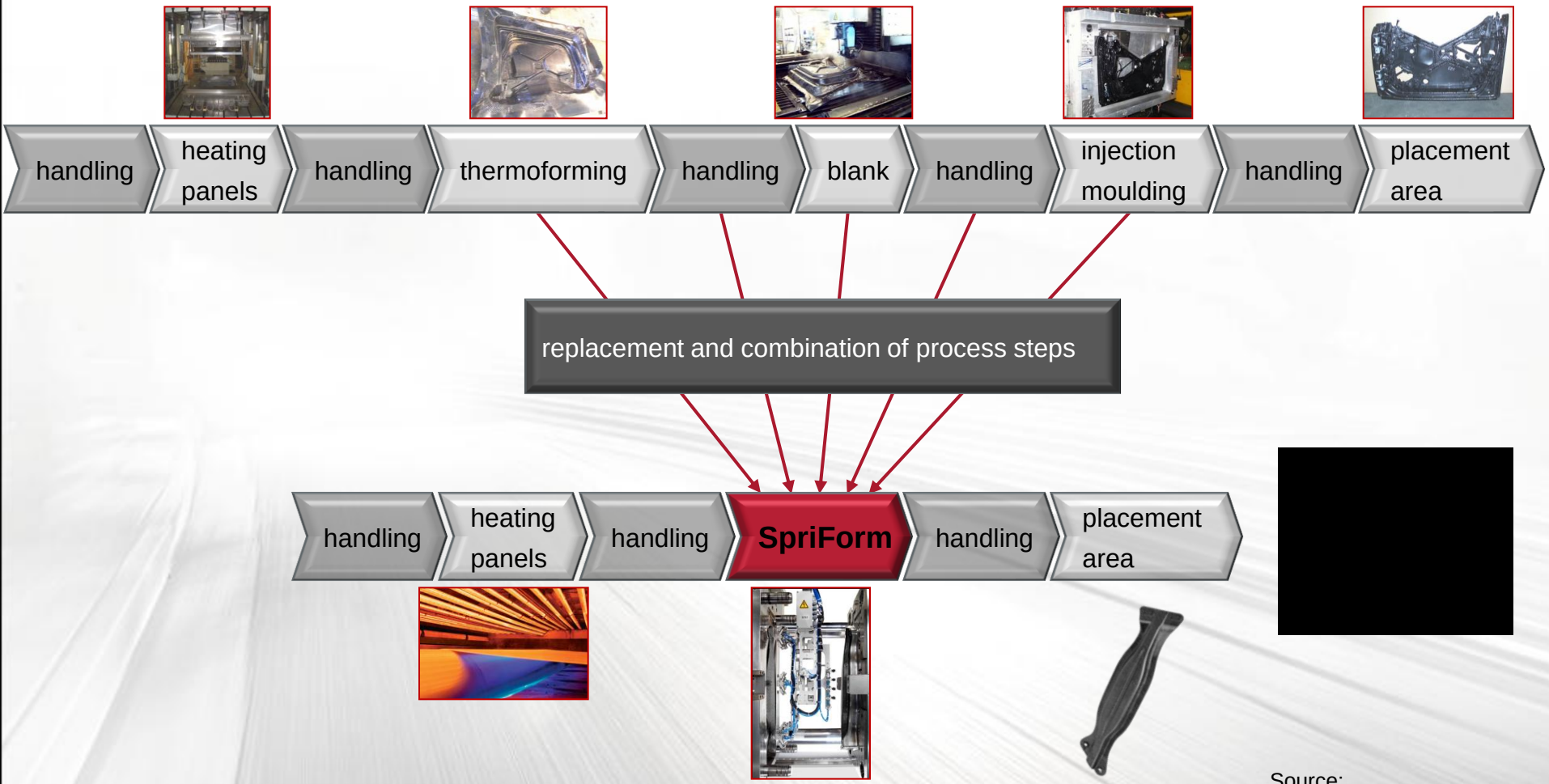


- highly automated manufacturing processes

- Cost reduction requires a further development of:
  Materials → low-cost carbon fibre for automotive



Example: cost efficient process chain for thermoplastic composites (SpriForm)

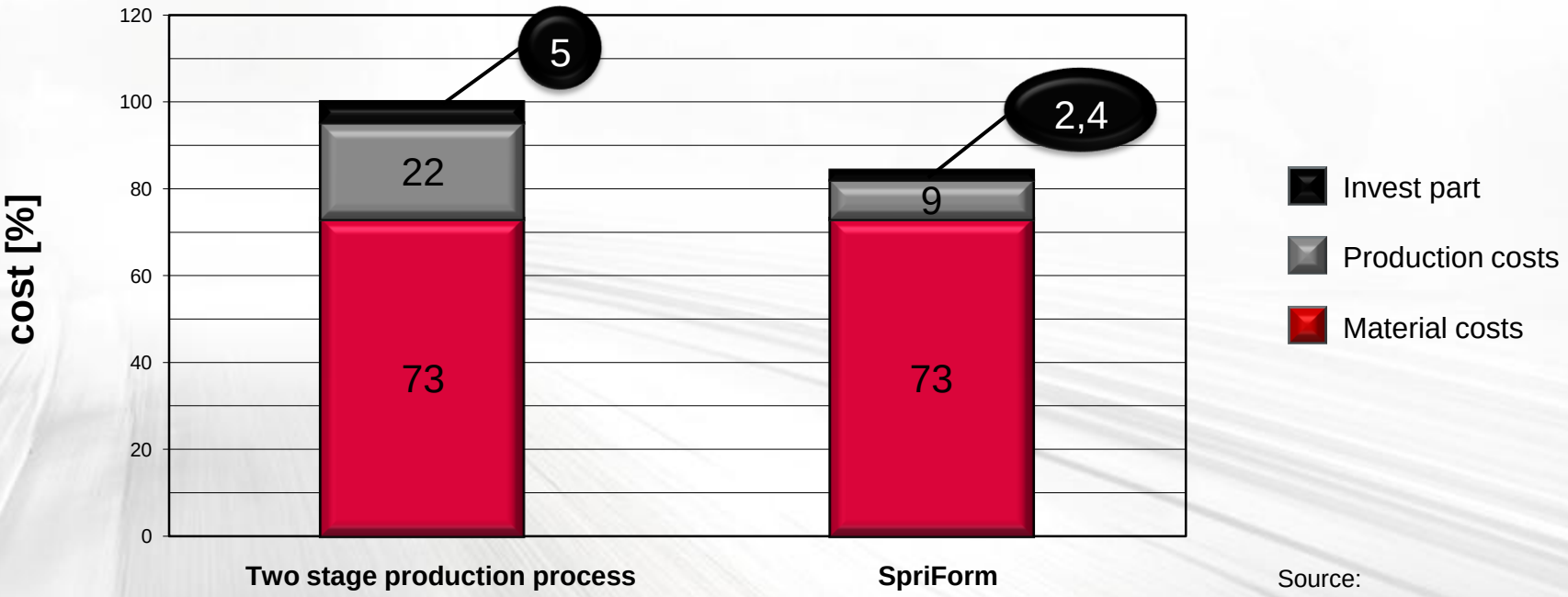


Source:
A. Jäschke (I/PG-631)

Results
Costs reduction by SpriForm

- Economic efficiency analysis at door inner panels Audi A4 predecessor

Comparison Spriform – two stage production process



Source:
A. Jäschke (I/PG-631)

Projectpartner: KraussMaffei, BOND LAMINATES, LANXESS, Institut für Verbundwerkstoffe, PTKA Projektträger Karlsruhe, Bundesministerium für Bildung und Forschung, JACOB PLASTICS GROUP, Audi Vorsprung durch Technik

- Trend to Multi-Material-Design with CFRP applications
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- **Weight and cost reduction using anisotropic material properties**
- Optimized material properties using 3-d reinforced CFRP
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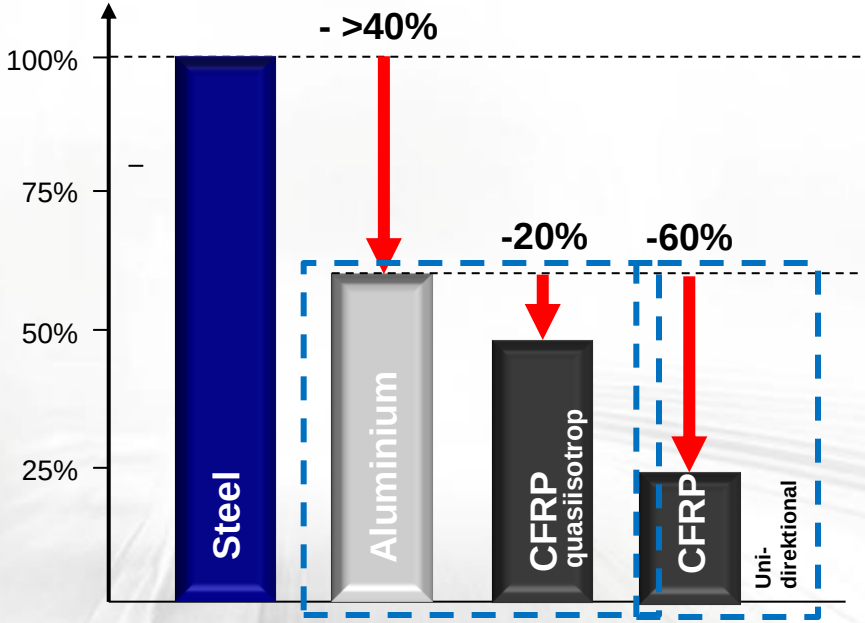
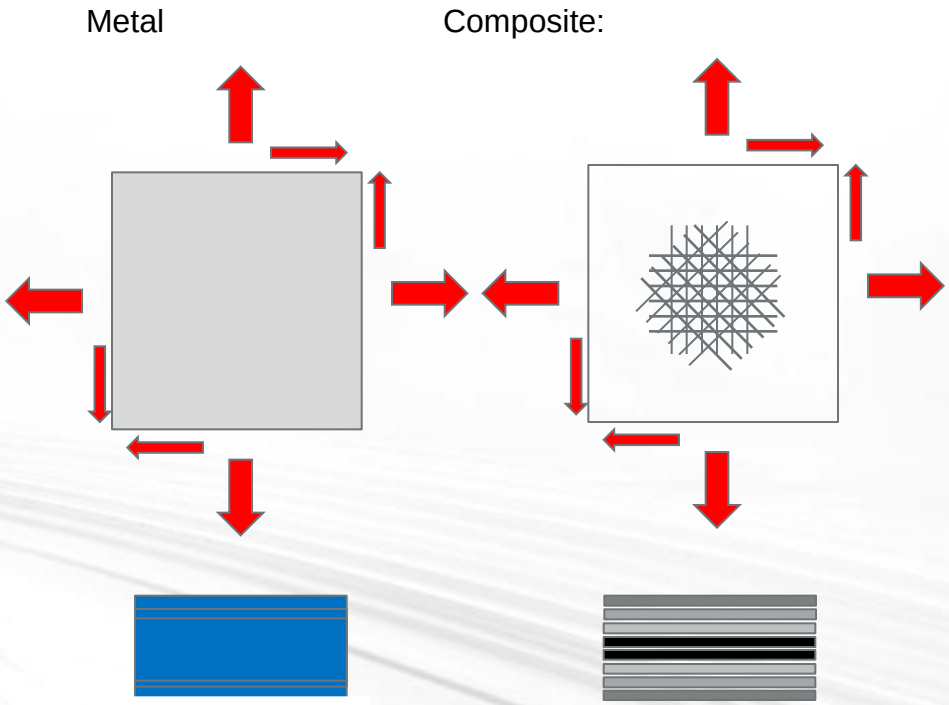
Weight and cost reduction using anisotropic material properties

Potential analysis CFRP parts

- Lightweight potential of metals and CFRP





- The layup and mechanical properties of a CFRP can be designed depending on the load direction
- The lightweight potential is dependent on the degree of anisotropy

New method to evaluate the lightweight potential of CFRP

Basic design concept:

- The designable degree of anisotropy is depending on the relevant load path and orientation
- The analysis and evaluation of the stress distribution of every element within the structure is the key factor to quantify the theoretical leightweight potential
- All relevant load cases (crash) are taken into account for the analysis

Quasi-isotropic
load distribution

Bidirectional
load distribution

High anisotropic
load distribution

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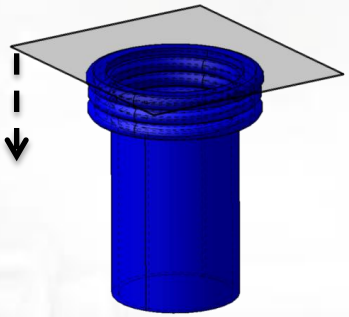
Optimized material properties using 3-d reinforced CFRP

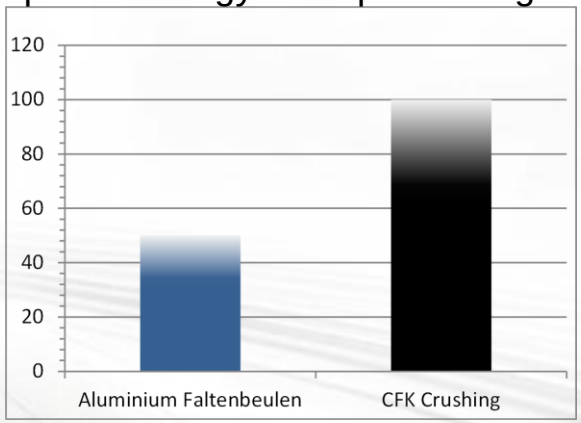
CFRP Energy absorbing structures

METAL

Fold buckling

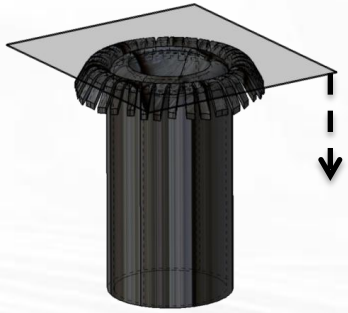


Specific energy absorption kJ/kg

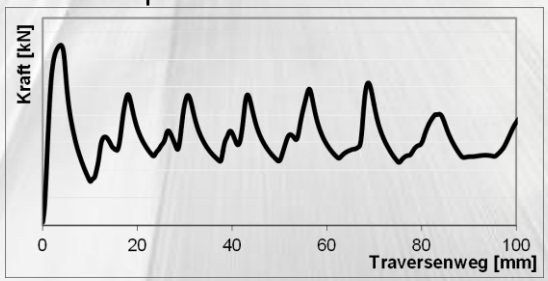


COMPOSITE

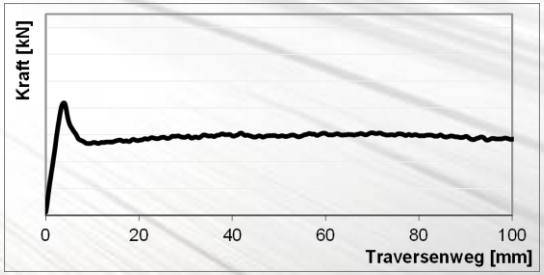
Crushing



Force displacement

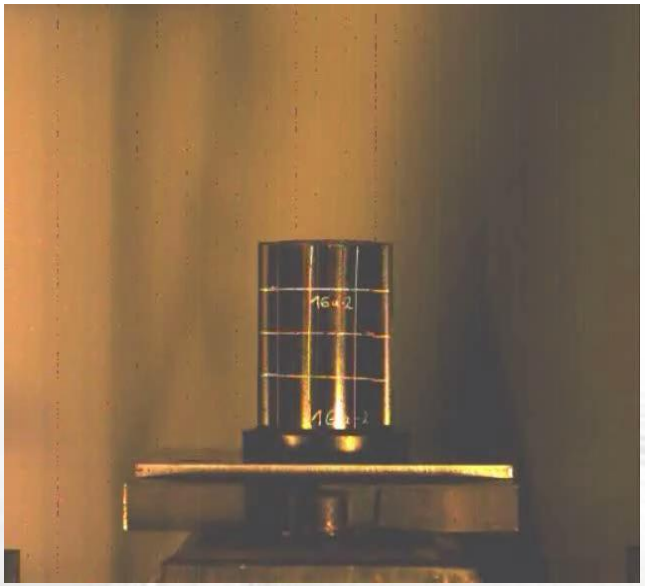


Force displacement

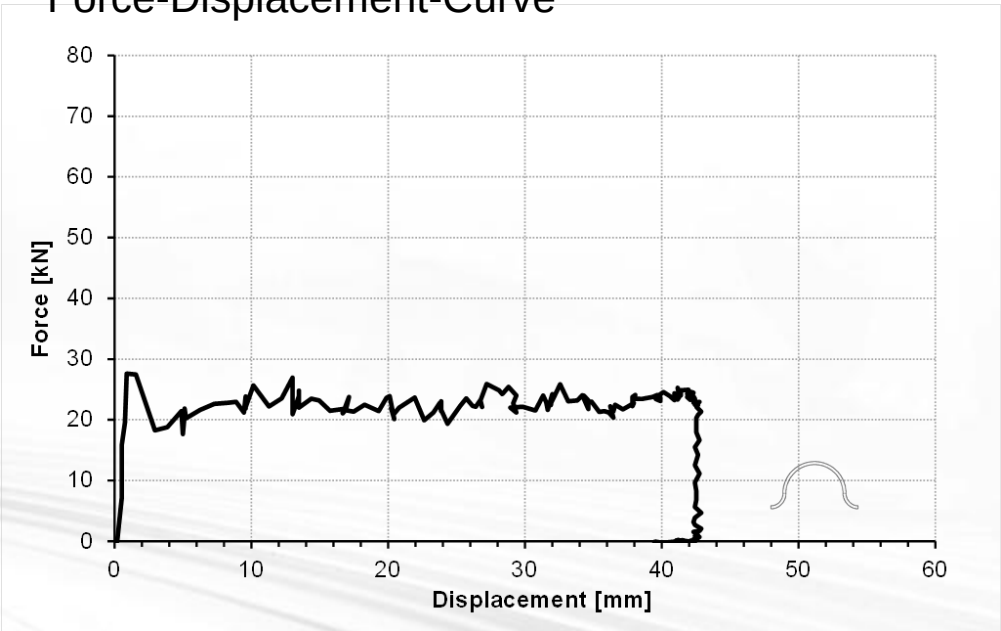


CFRP Energy absorbing structures

Drop Tower (Experiment)



Force-Displacement-Curve



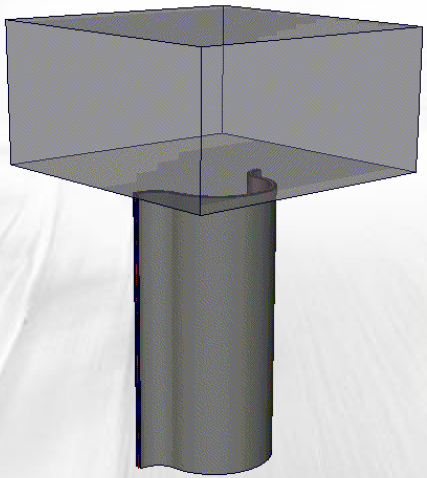
Experiment

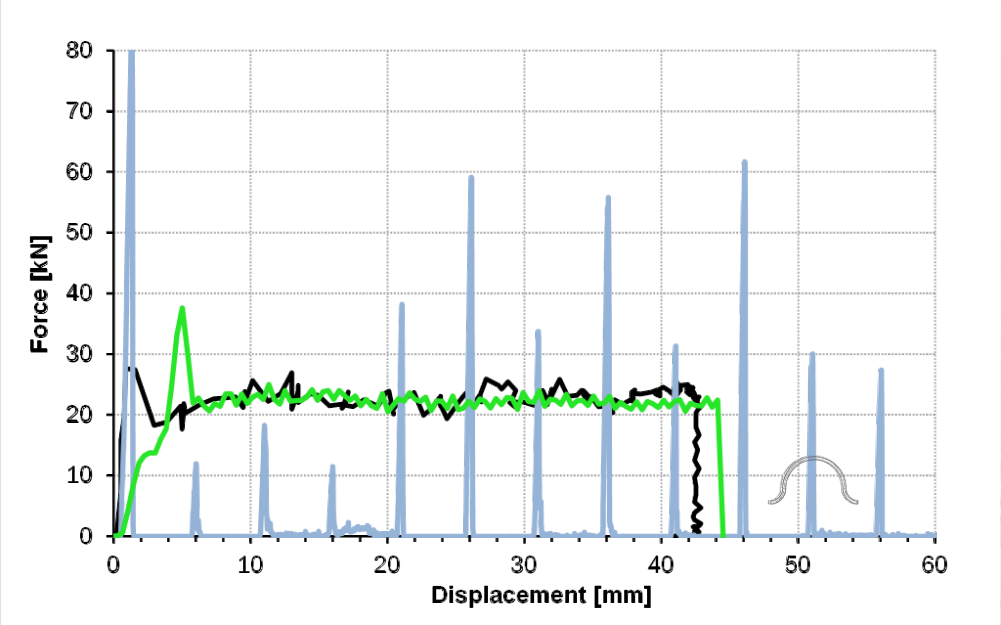
Composite energy absorpting elements:

- High weight specific energy absorption (>200% to aluminum)
- High lightweight potential
- Low force oscillation
- Use of open structures (e.g. wavelike profiles) possible

Simulation CFRP Energy absorbing structure

- Explicit Analysis
  - PAM-CRASH 2G
  - shell element ($l_{element}$=0,5-0,8mm) / delamination model
  - modified damage material model (MAT131 / ITYP 1)





Experiment

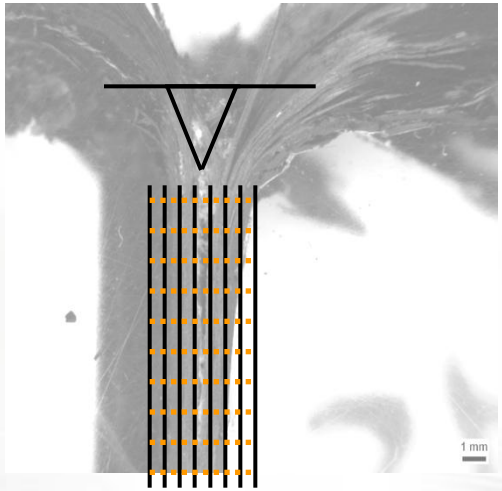
Simulation shell

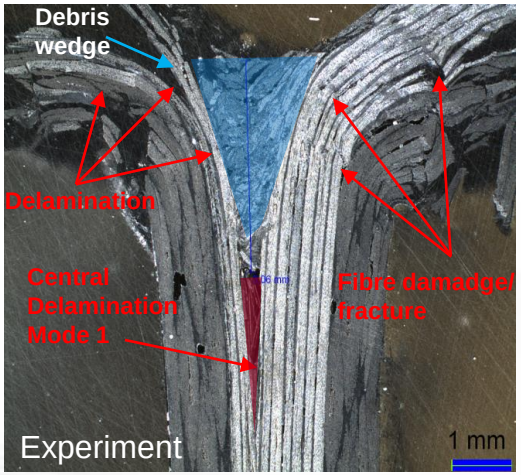
Simulation detailed model

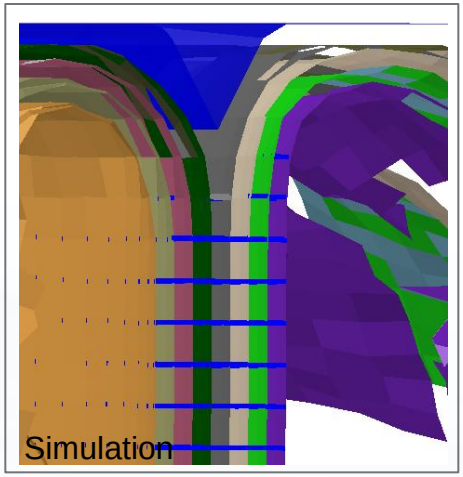
Simulation CFRP Energy absorbing structure

Model Setup

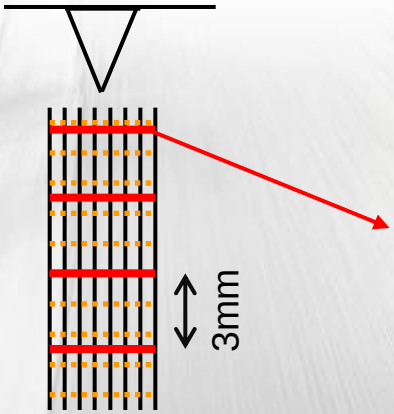
Reference



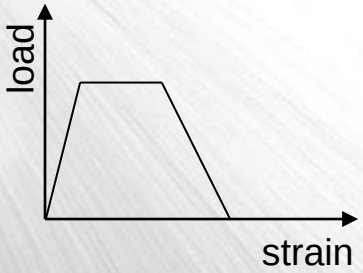


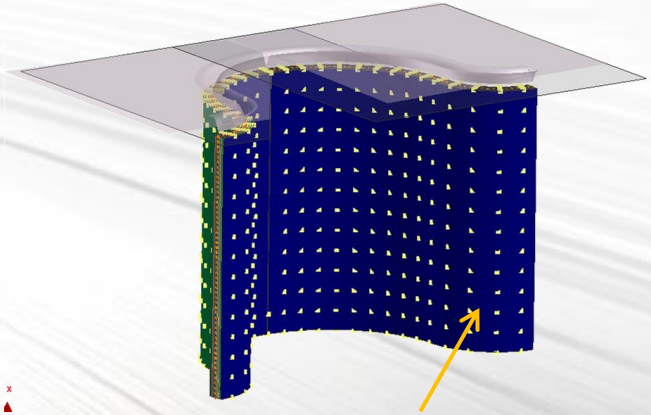


Through thickness toughening



Toughening model

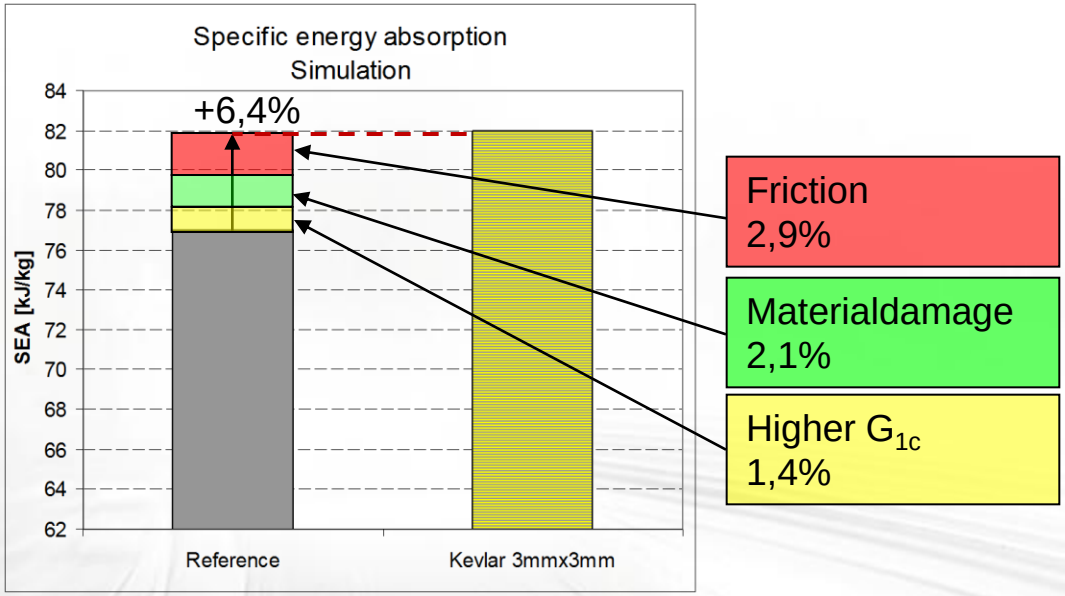


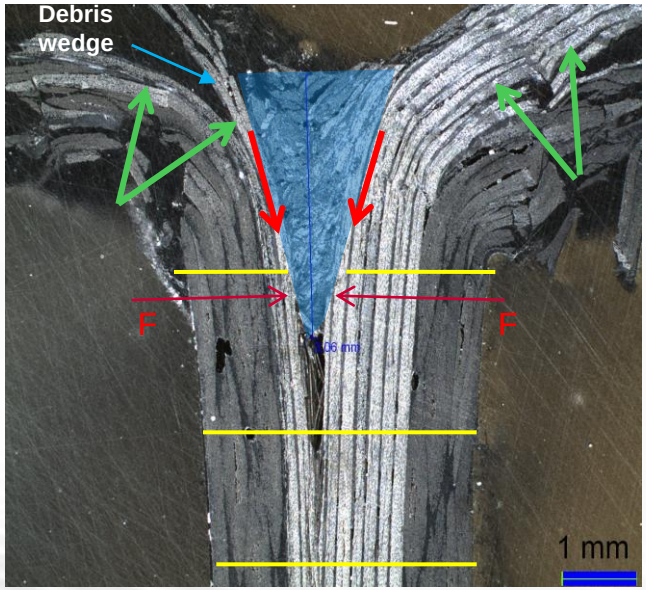


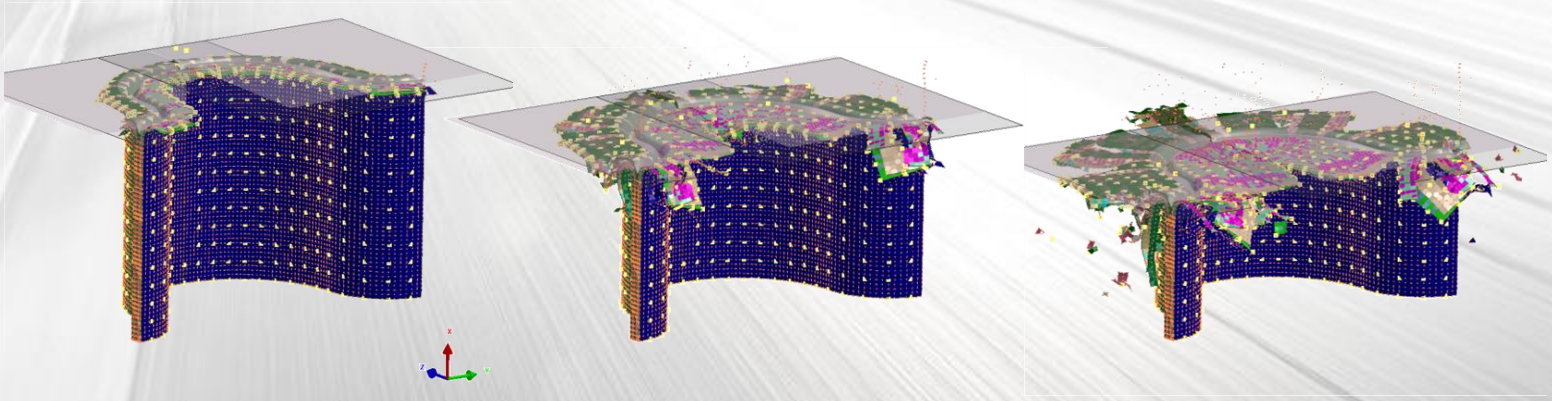
Additional toughening

Simulation CFRP Energy absorbing structure

Simulation results - SEA

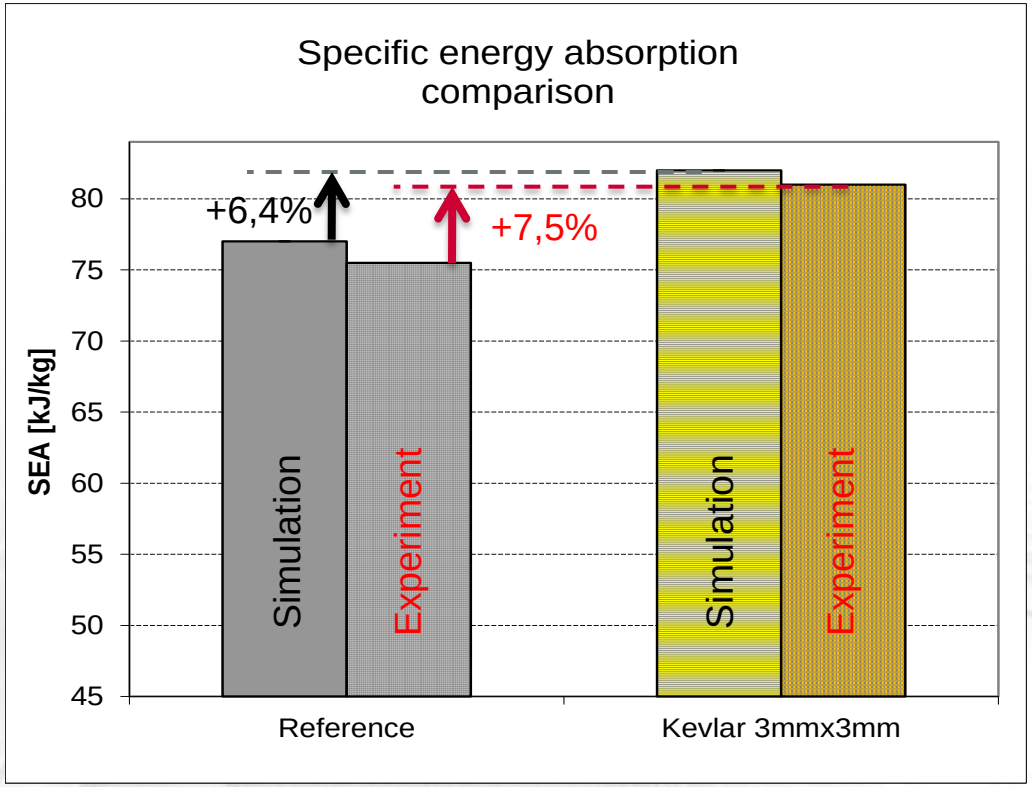


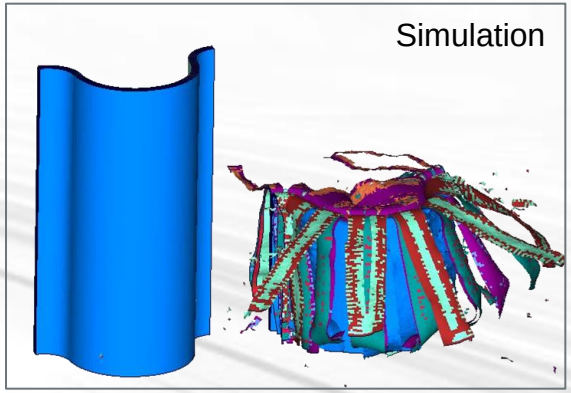




Comparison tufted vs. untufted

Specific energy absorption





- Tufting can increase the specific energy absorption
- The developed numerical model shows a good correlation
- Higher SEA results mainly from higher friction and material damage

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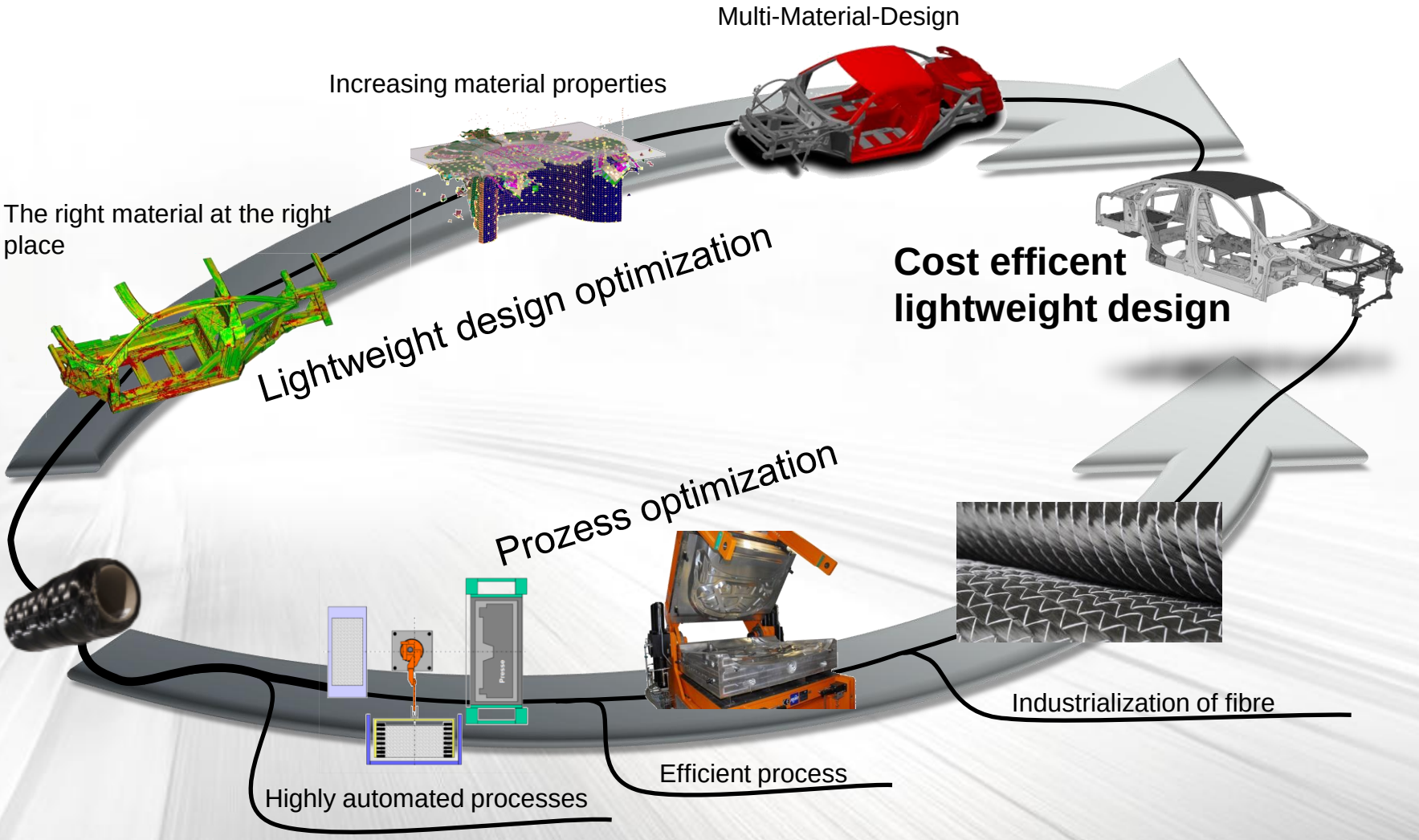
Conclusion

The way to cost efficient lightweight design



Thank you for your attention.