Cost-efficient structural composite parts combining unidirectional tape reinforcements and injection molding processes

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Agenda

- **Introduction Institute for Materials Technology and Plastics Processing (IWK)**
- **Process Injection molded components with UD-tape reinforcement**
  - **Challenge Part**
    High-Performance ring shaped Element

  - **Challenge 50% lighter**
    Fiber reinforcement why - and why not)
  - **Challenge 50% costs**
    Efficiency and Performance by combining two processes

Mechanics/
Kinematics
(2005)

Composites/
Light weight
design (2015)

Injection
Moulding/
Polyurethane
(2005)

Light weight
design

Simulation

Hybrid technology

Integration of
functions and
processes

Fields of Innovation

Additive Manufacturing

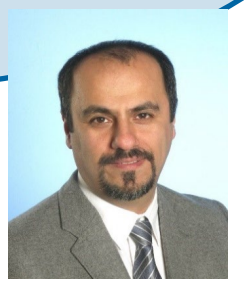
Polymer engineering

Interfaces and surfaces

Biobased plastics

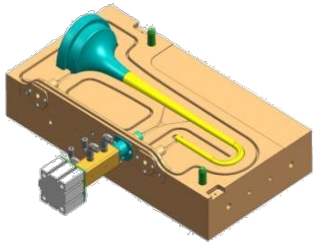
Joining
technologies
(2015)

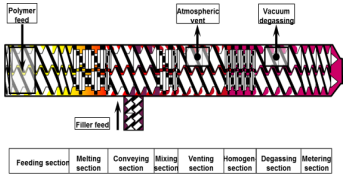
Compounding/
Extrusion (2010)

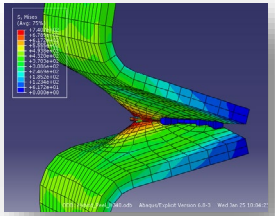


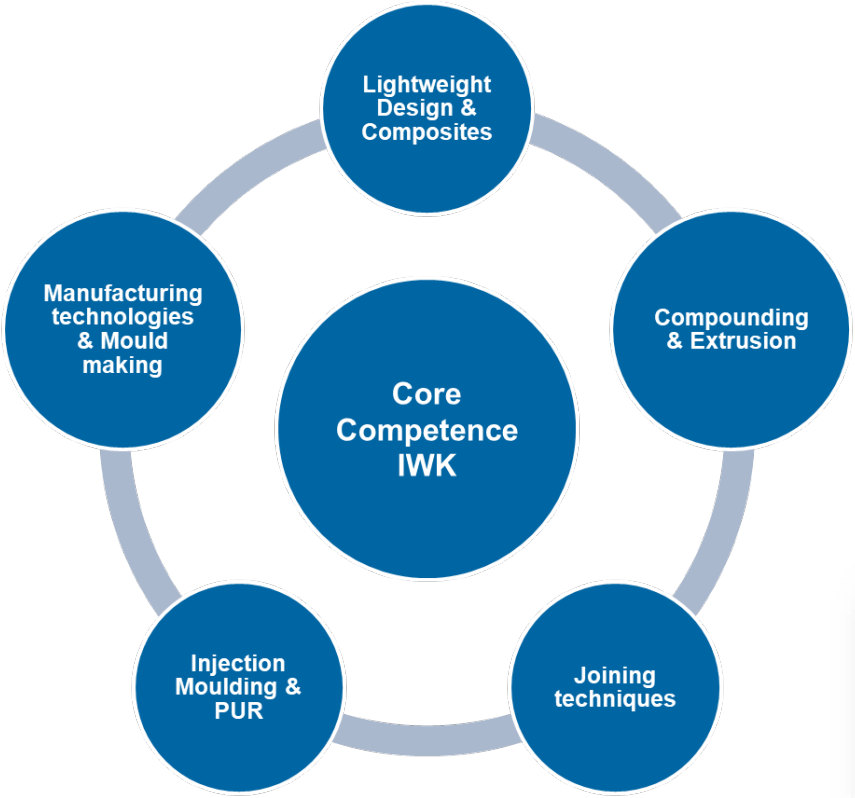
Metal Processing
(2016)

IWK Institute for Materials Technology and Plastics Processing



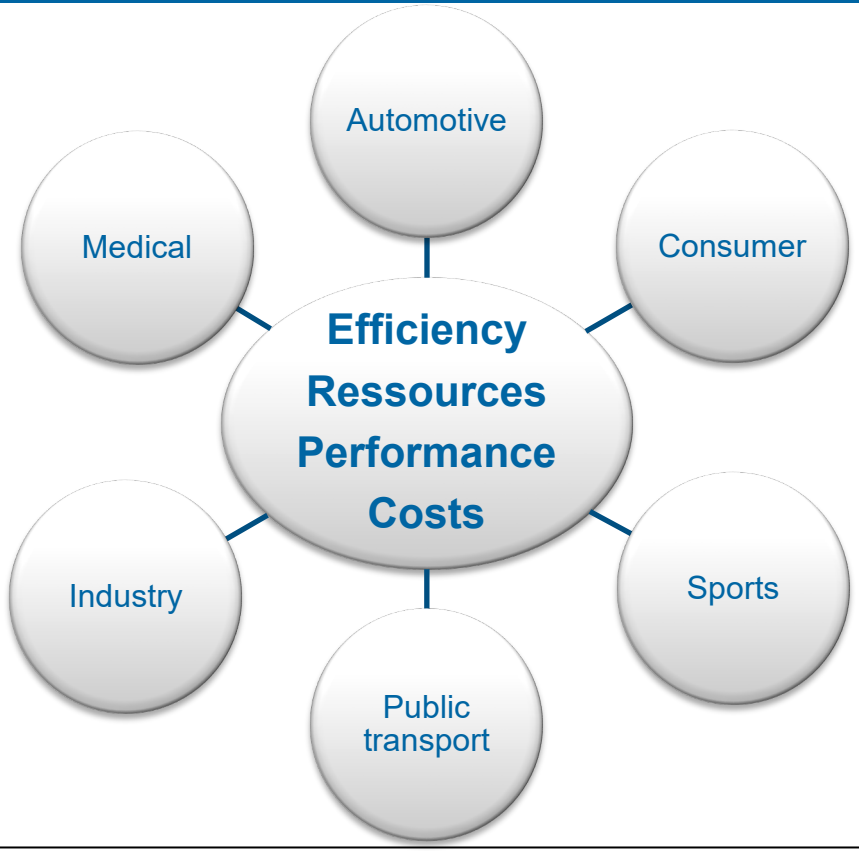






Challenge

Challenge – High Performance parts



Complexity of the parts

Performance

Weight

Costs

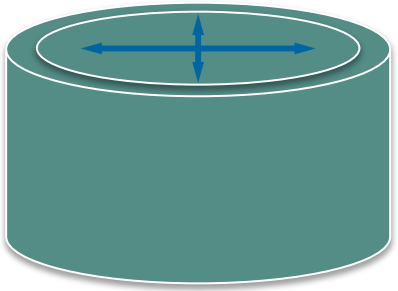
Lightweight structural parts

Challenge – High Performance parts

- **Challenges of a thin-walled part for automotive application**
  - Static pressure-loaded
  - Very high reliability
  - Long lifecycle
  - 100 % tightness against fluids is essential
  - Hot/wet conditions in service
  - Efficiency and function – big lot size, easy to mount
  - Integration of functions
  - Corrosion resistance

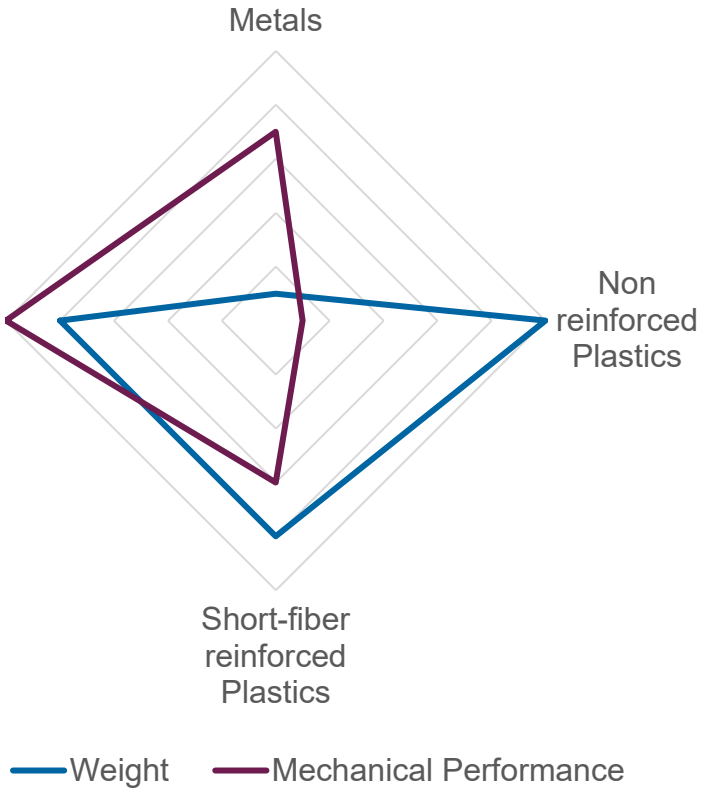
Challenge 50 % Lighter

Challenge 50% LIGHTER

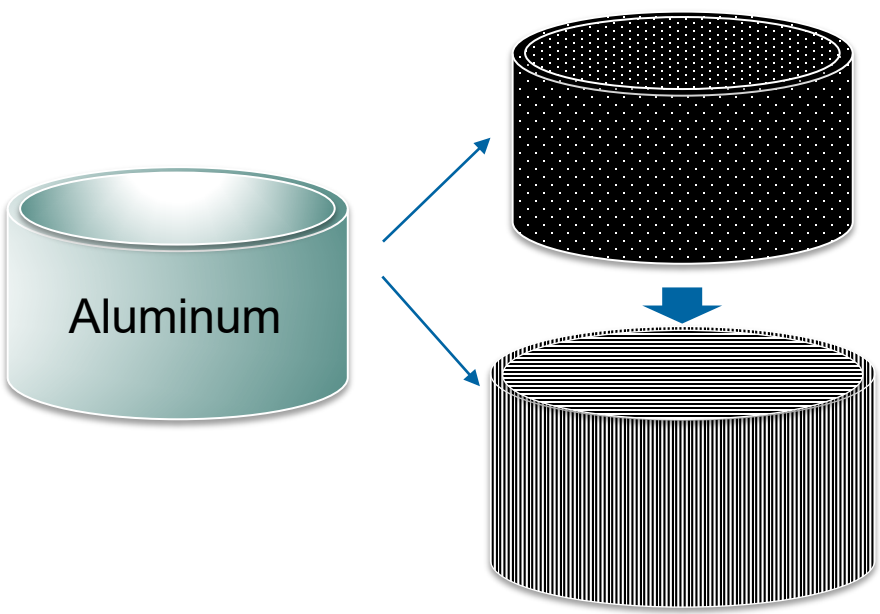


Aluminum	2.7 g/cm^3
Fiber reinforced plastics (50 % FVC)	1.4 g/cm^3

50 % LIGHTER



Challenge 50% LIGHTER



Shaping Plastics

- geometric requirements
- Integration of functions

Long fiber reinforcement

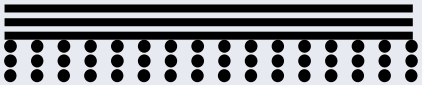
- mechanical requirements

Challenge 50% LIGHTER

- **High strength of glass or carbon fibers: 1.7-7 Gpa (high-alloyed steel max. 2.0 GPa)**
- **High stiffness of carbon fibers: 230-700 GPa (steel 210 GPa)**
- **Low density of composites materials: 1.5-2.0 gr./cm^3 (steel 7.5 gr./cm^3)**
- **High potential with regard to integration of functions/geometry in a broad variety of production processes**
- **Very good fatigue behavior**
- **Corrosion resistance of composite materials**
- **Specific strength:** $\frac{\sigma_B}{\rho} = \frac{[MPa]}{[g/cm^3]}$
- **Specific stiffness:** $\frac{E}{\rho} = \frac{[GPa]}{[g/cm^3]}$

Challenge 50% LIGHTER

Exemplary calculation for different layer sequences

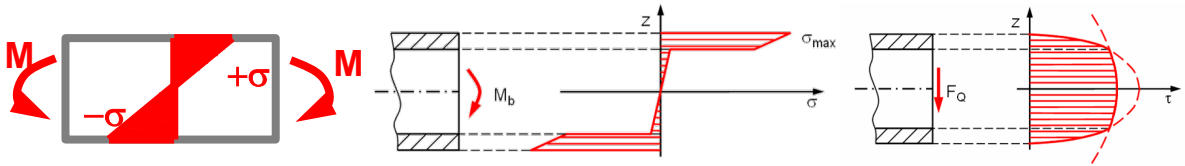
Layer sequence	Young's Modulus in 0° [GPa]		Density [g/cm³]	Spec. Young's Modulus [GPa/g cm⁻³]		Cross section view
CFK-UD (0°)	142	**100%**	1.5			
CFK-biax. (0/90°)						
CFK-quasi-iso. (0/				36	**38%**	
Aluminium	72	**51%**	2.7	26	**28%**	Composite: 10% weight savings

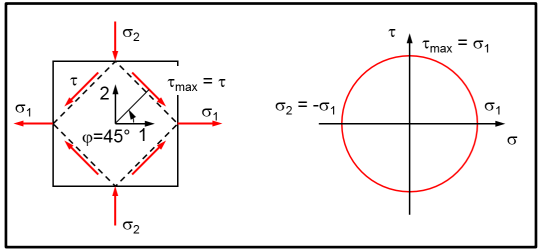
- Only uniaxial stress state???
- Appropriate load cases???

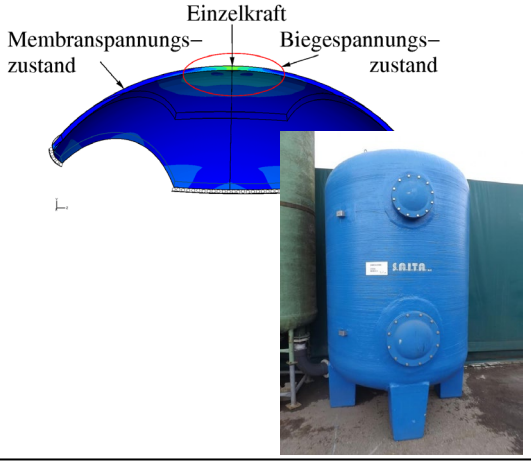
(Assumptions: Young's Modulus fiber: 230GPa; approx. 60% fiber volume content)

Challenge 50% LIGHTER

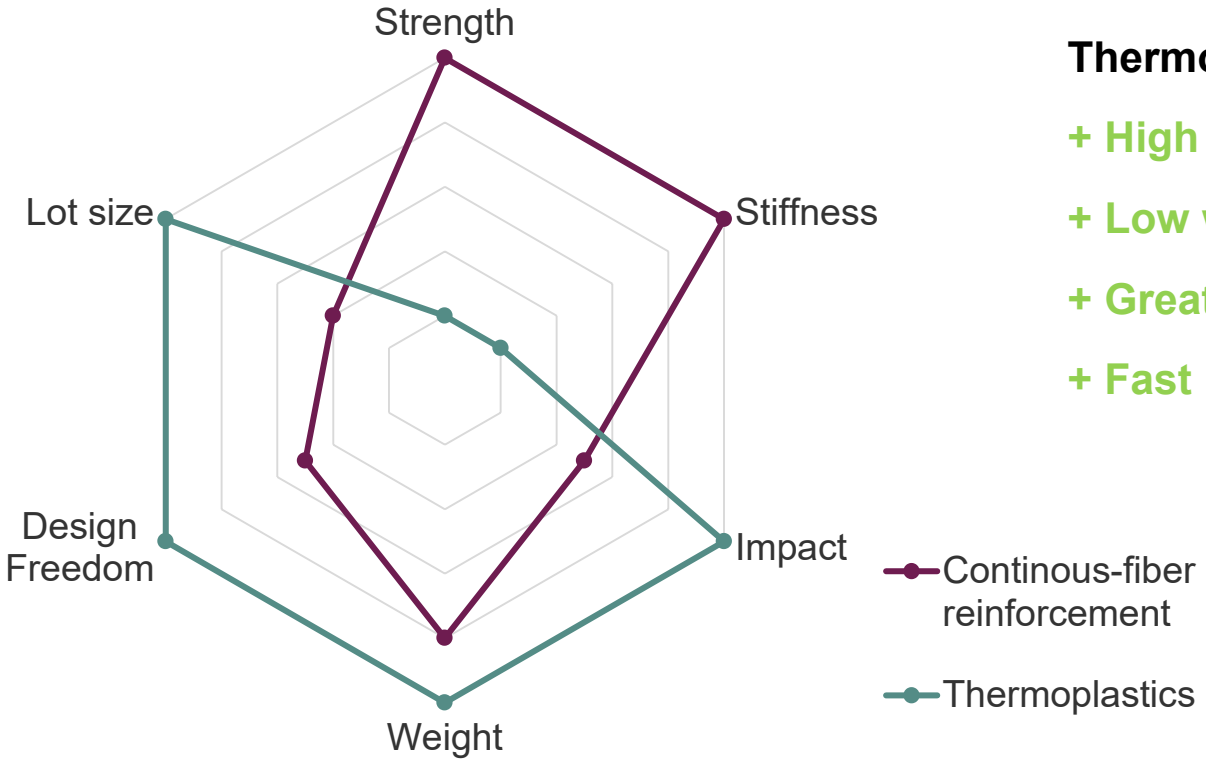
- **The appropriate uniaxial (or even biaxial) stresses seem very limiting.**
- **In fact, a lot of suitable applications exists.**
- **The fibers have to be oriented in a way taking into account the flow of forces.**
- **However, 3-axial, fast changing stress states are not suited in general.**







Challenge 50% LIGHTER



Thermoplastic Materials

+ High mechanical performance

+ Low weight

+ Great design freedom

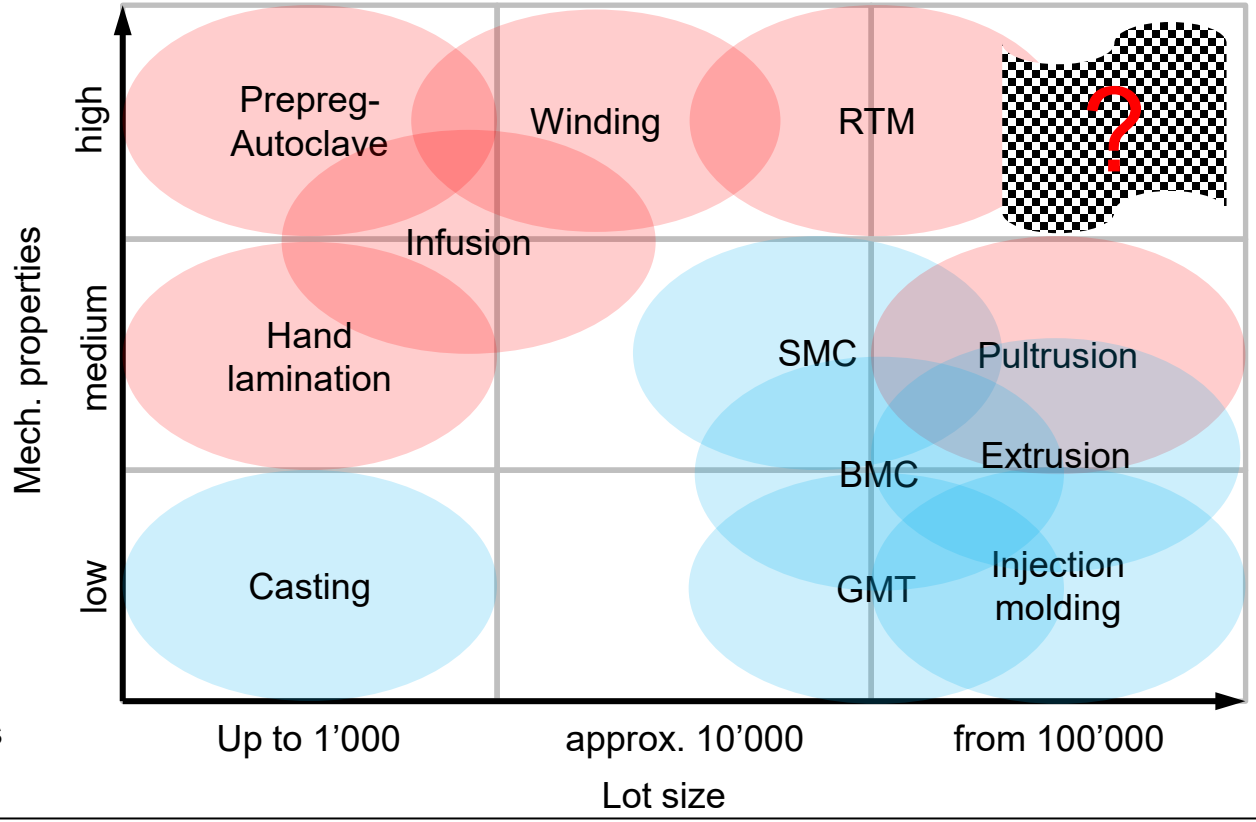
+ Fast processing times

Challenge 50% LIGHTER

	Short fibre reinforced	Long fibre reinforced	Continuous fibre reinforced
Fibre length	0.3-2mm, random	5-50mm, random	>50mm, oriented
Typical stiffness	<20GPa	<30GPa	<380GPa
Typical strength	<220MPa	<350MPa	<2200MPa
Geometry	Complex parts	Shell like parts	Depending on process
Process	• Injection molding • Low material costs • High lot sizes • Automated	• Press processes • Low material costs • Medium lot sizes • Automated	• Various processes • High material costs • Small lot sized • Labour-intensive

Challenge 50% LIGHTER

- **The combination of excellent mechanical properties and high lot sizes is still challenging with composites**
- **In general, cycle times remain relatively high towards the top end of the mechanical properties**



Structural components

Challenge 50 % costs

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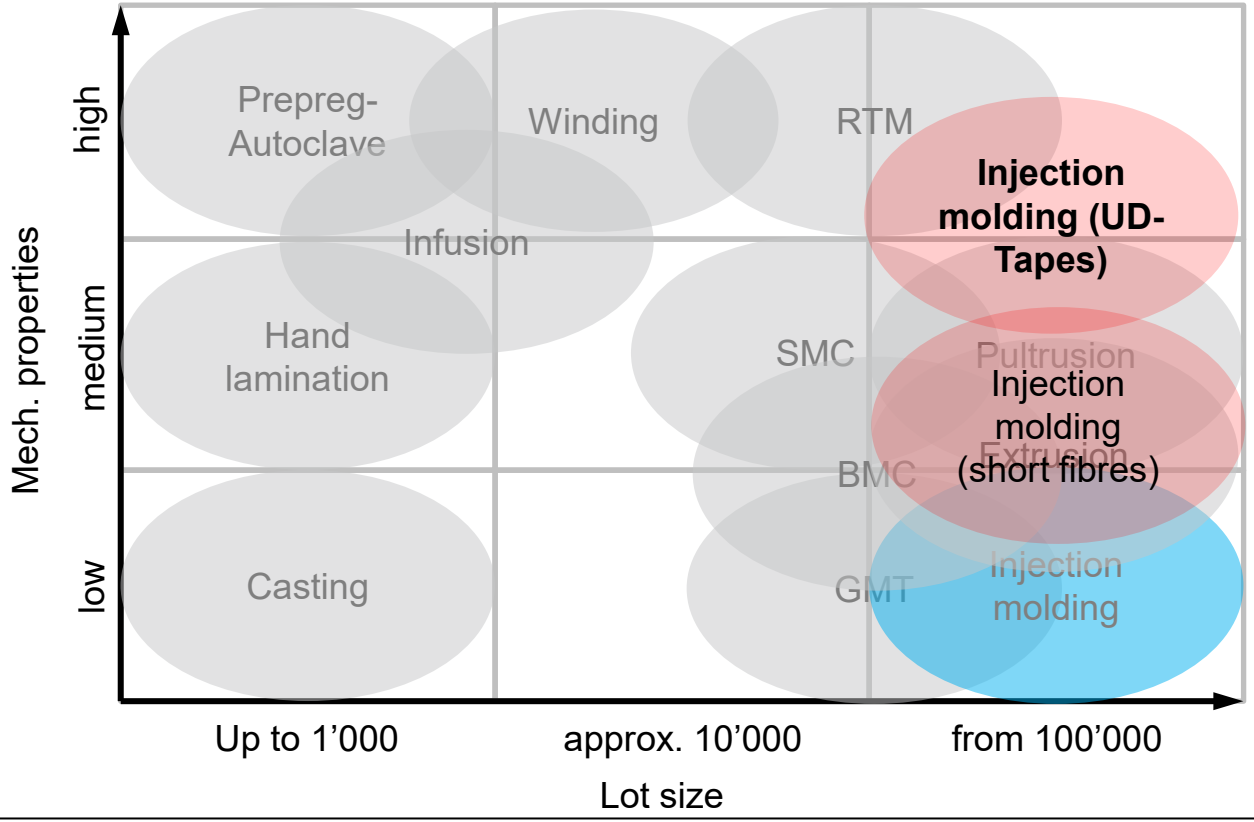
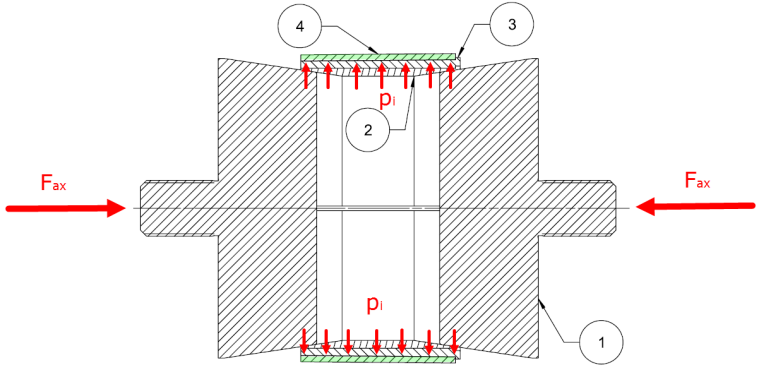


Structural components

Challenge 50% Costs

- **Mechanical Testing with specialized tools**
  - Application of inner pressure by conical punching tool



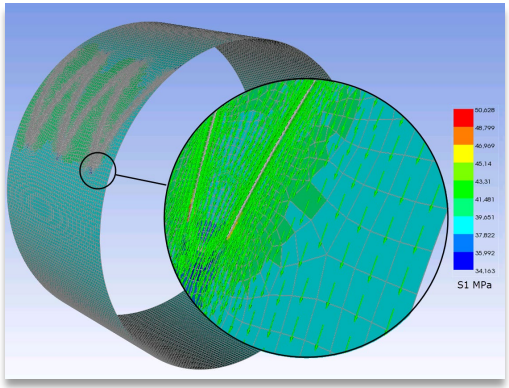
→ Compression strength of the part

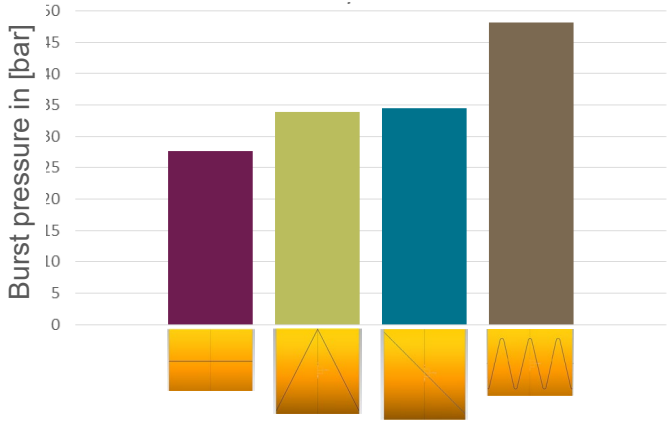
→ Strength at the joining of the circular tape

→ Comparison with results from simulation and optimization

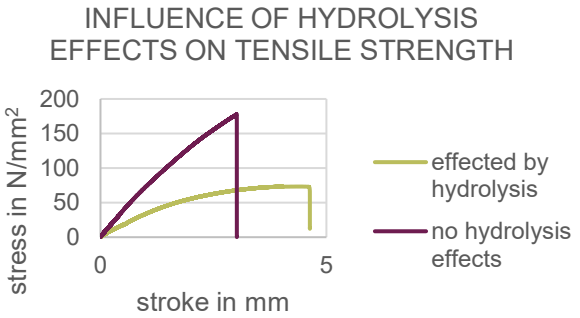
Challenge 50% Costs

- **Optimization of tape joint is done by FEA**
- **The manufactured samples are tested in a quasi-static setup (punching tool)**
- **Dependent on the joint design, the failure mode changes from delamination to fiber fracture**
- **Hydrolysis effects have to be taken into account**



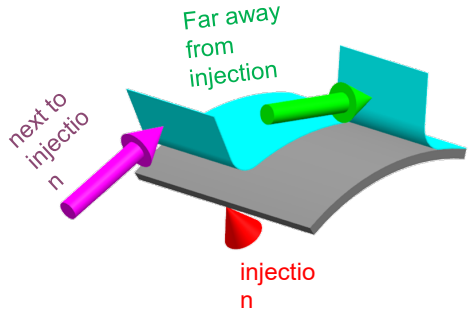


Delamination vs. fiber fracture



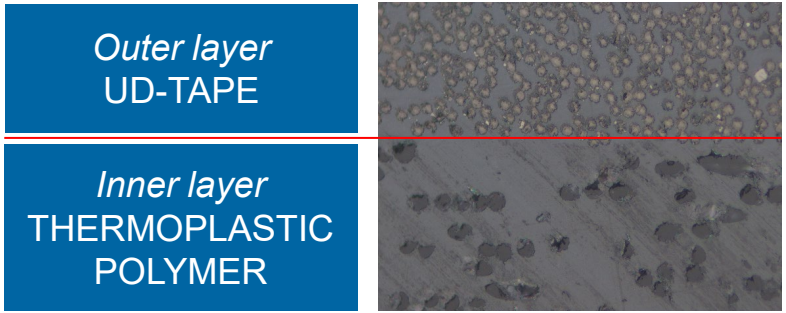
Challenge 50% Costs

- **The adhesion between tape and thermoplast depends on several process parameters:**
  - Combination of materials
  - Tool and material temperature
  - Flow path and mold design
- **A perfect bond has to be achieved for optimal mechanical properties**

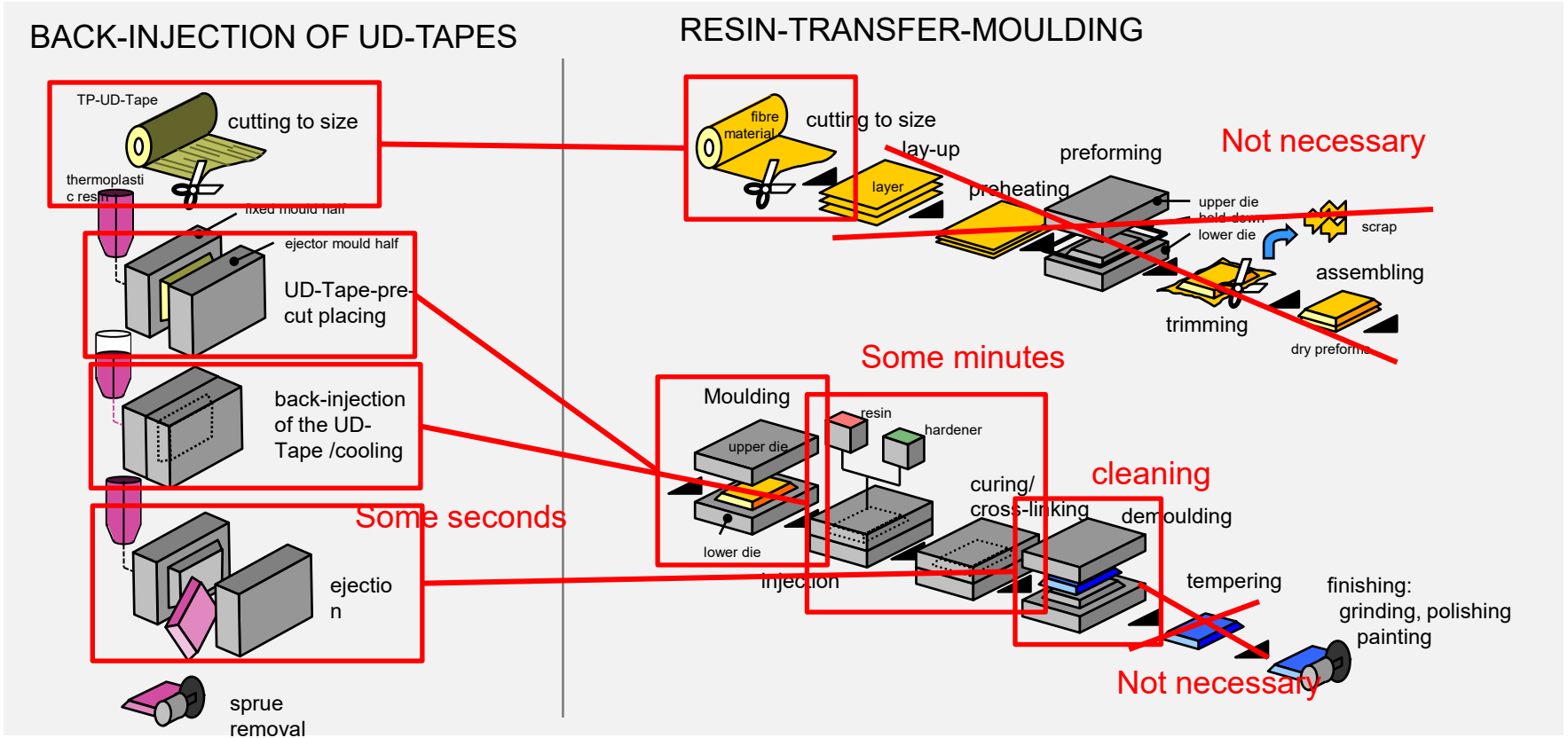


Surface next to injection point
cohesive fracture in thermoplast

Surface far away from injection point
adhesive fracture between tape and thermoplast

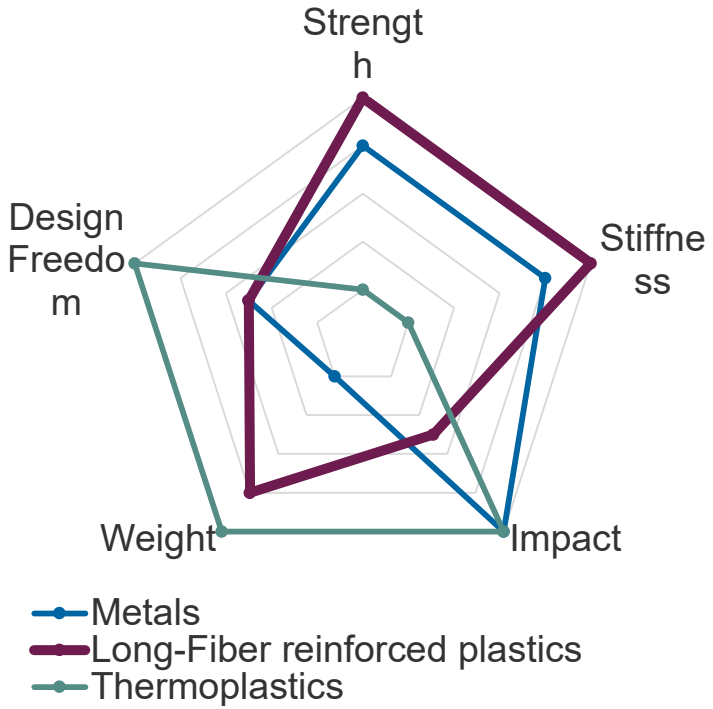


Challenge 50% Costs



Challenge 50% Costs

- **Back-injection of UD-Tapes combines the excellent mechanical properties of the tape with the short cycles times of injection molding**
  - Structural components become feasible (overcome limitation of injection molding material)
  - High lot sizes and reasonable costs become feasible (overcome limitation of typical composites)
  - Complex parts are feasible
- **The unidirectional properties have to be considered when designing a component**
- **There is a wide variety of materials and applications**
- **Fatigue life and ageing is limiting some applications**
- **Due to the automation potential, a production of such components is possible in Switzerland**



Challenge 50% Costs

50% Lighter

- Replacement of Metals by continous fiber reinforcement

50% Costs

Replacement of RTM process by injection moulding + Long fiber reinforcement

Thank you for your attention !

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