Component Manufacturing via LCM: customized components for the application of frp

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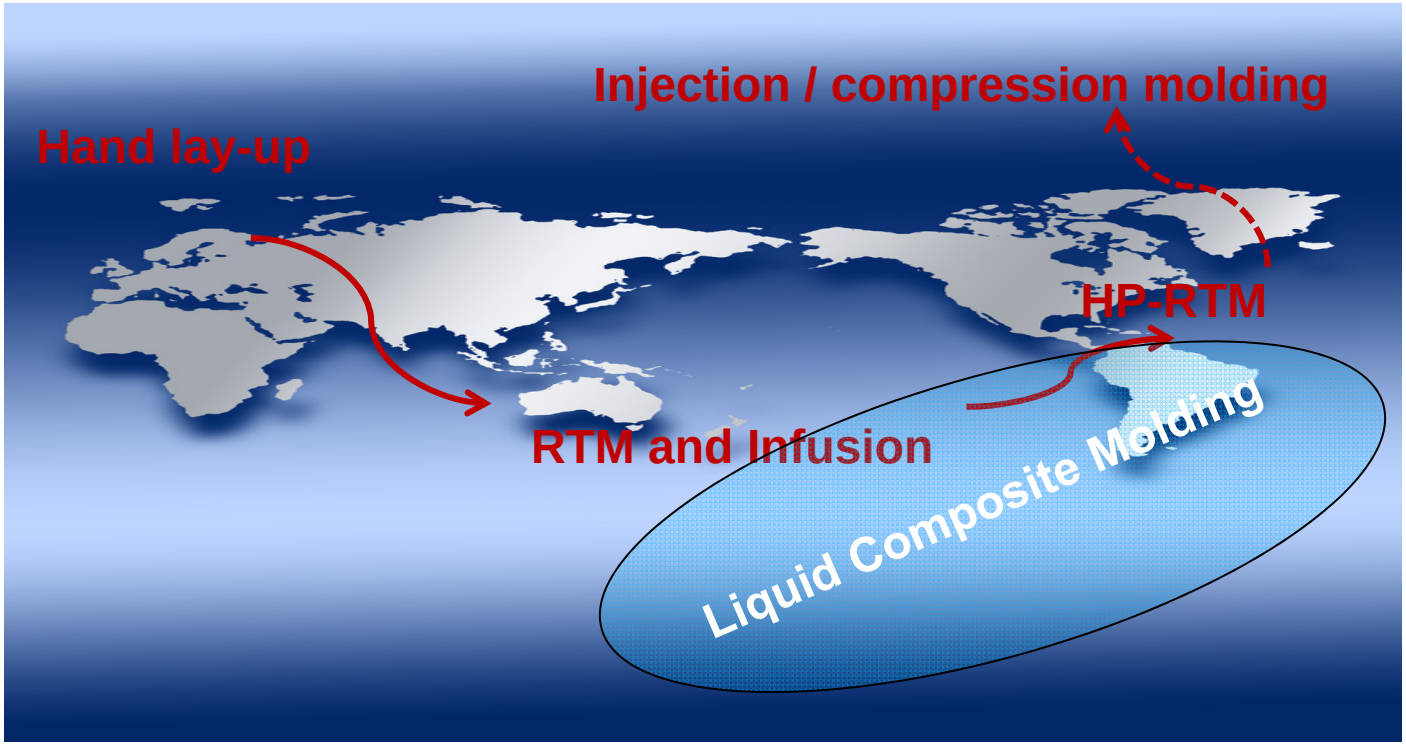
Dr.-Ing. Eva Bittmann
Plastics Expert Bureau werkstoff & struktur
www.werkstoff-und-struktur.de

Outline

- Status of development of plastics for liquid impregnation of fiber reinforcement material
- Consideration of frp components from renewable resources

Frp from continuous fiber: Progress



Innovation in reactive processing

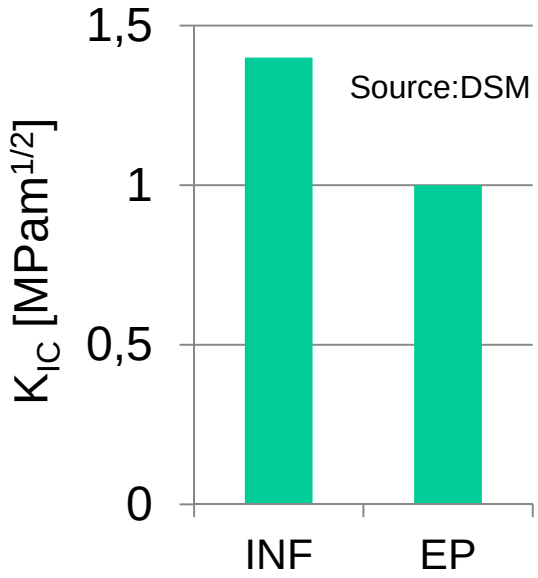
- **Motivation**: Lightweight design in automotive high volume production
- **Advantage** of LCM compared to thermoplastic high performance frp:
  - Complex preforms und sandwich material
  - optimized structures
- **High pressure RTM** facilitates cycle times of minutes
- **Demands** on material:
  - Low viscosity
  - „non-reactive“ when injected
  - Highly reactive during consolidation
- **Development** of material inures the benefit of traditional LCM
  - Completey new systems resulting in thermoplast
  - Modified traditional reaction resins

Reactive liquid systems

	Status	LCM processing		
		traditional		High pressure
		Vacuum	Pressure	
Unsaturated Polyester / VE	Economic and popular	+	+	-
Epoxy	Current for high performance frp	+	+	+
Polyurethane	First types available	(+)	+	+
In-situ-Polyamide	*Advanced stadium of development*	+	+	+
In-situ-Methacrylate	Thermoplastic „alternative“ for UP	+	+	-

Unsaturated polyester resin

- UP and VE resins are universal basis especially for big structural parts
- Some new aspects:
  - cobalt-free accelerator systems or Co-Octoate substitutes
  - styrene free resins
  - partial replacement of petrochemical by bio-based raw material, evaluation of sources
- Tough and sustainable infusion resin (INF) based on new chemistry



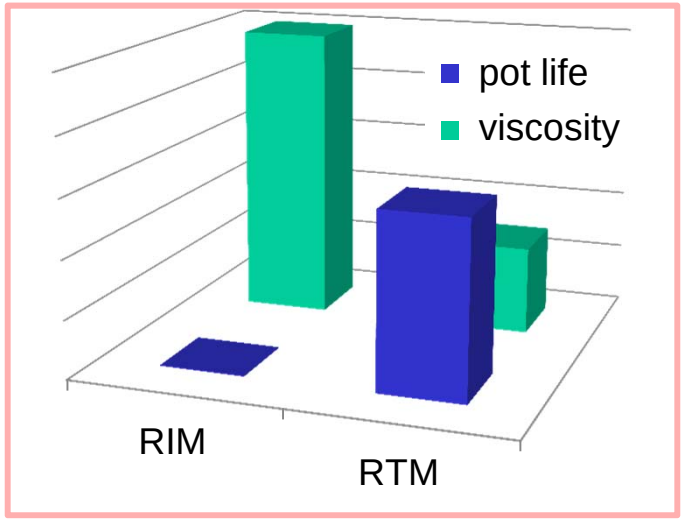
Polyester resin from soy bean oil, available for 10 years now

Epoxy

- Thermoset with outstanding properties: Temperature durability / stiffness / fatigue profile
- Epoxy resin have been modified for Liquid Composite Molding in large scale since 2000 – wind rotors als driving force
- Milestone for the series: BMW M3 roof
- Basis for efficient impregnation of fibers and short cycle times are latent systems – long pot life, quick crosslinking in the heat.
  Status: 2 minutes curing time
- Today, LCM compatible resin systems for large structural parts, high temperature application (Tg > 200 ° C) and high pressure RTM are available.

Polyurethane

- Challenge: longer pot life
- PUR-Systems for high and low pressure processing available
- Speed of reaction can be regulated by dosage of catalysator
- Relatively low exotherm compared to EP
- Parts show high toughness / damage tolerance
- Temperature limit lower than with traditional epoxies



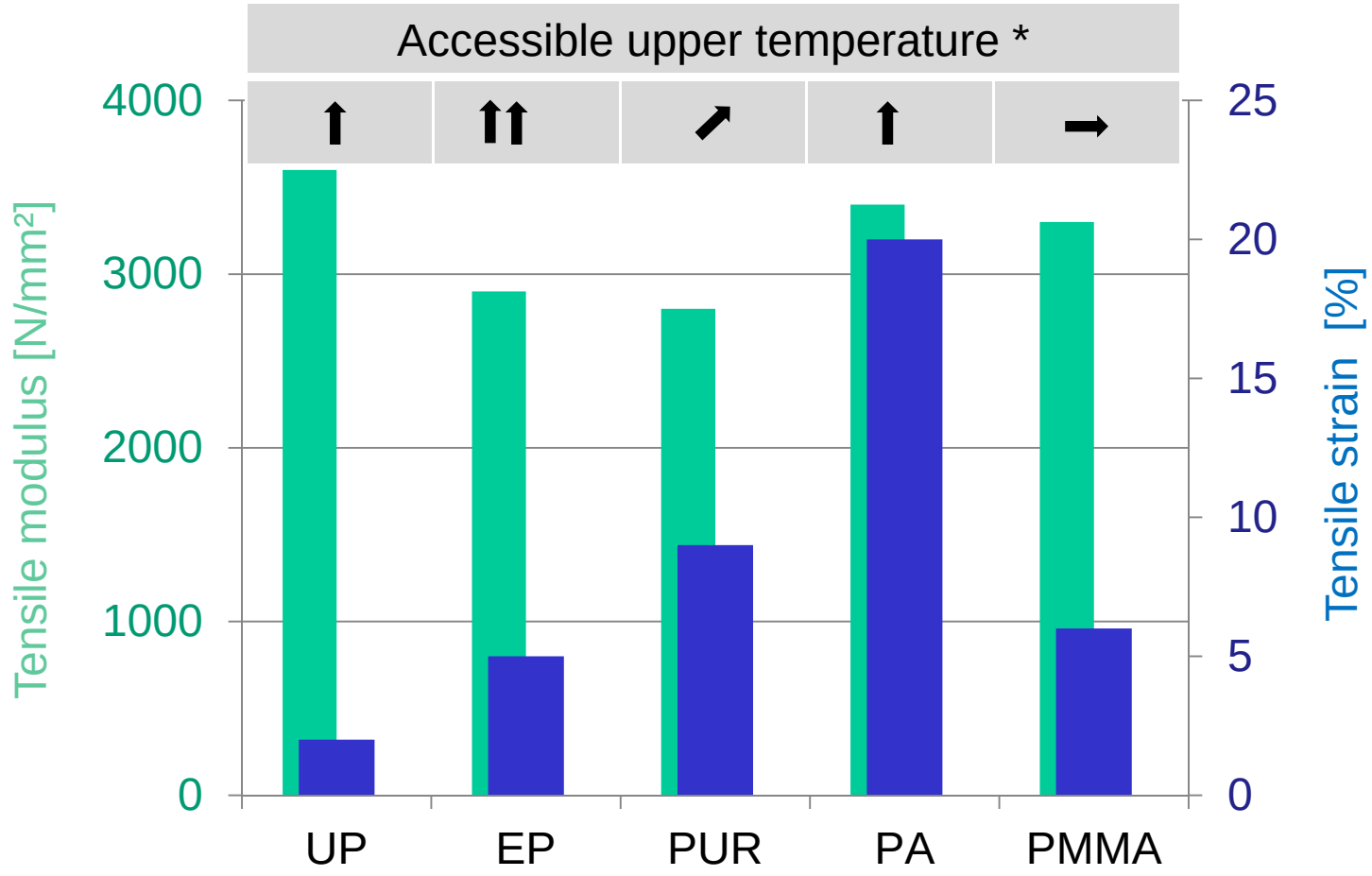
Leaf spring from PUR with glass fiber reinforcement: RTM capable of series production, Benteler-SGL

In-Situ-Polymethylmethacrylate

- Processable at room temperature, viscosity about 300 mPas
- Radical, peroxide-catalyzed reaction, crystal clear parts
- Curing time < 15 min @ 80 ° C
- Glass fiber reinforced acrylate reaches short-time mechanical data of EP-GF
- Heat distortion temperature 109 ° C
- Thermoforming and joining with acrylate adhesive are possible

Prototype of a Bus side panel: PMMA with carbon fiber

Comparison: LCM-Systems



Source: DSM, Henkel, BASF, Arkema

*for selected LCM types

Sustainable economics with frp

- **Approved:**
  nonwovens from natural fibers, resinated with PP or EP, especially for automotive interior

- **Desired:**
  Higher stiffness and strength – continuous reinforcement

- **Future:**
  Biobased matrix systems

Bio material

	matrix	reinforcement
What is being replaced?	fossile by plant-based vegetable-based raw material	mineral (GF) or fossile (CF, AF) by vegetable-based raw material
Height of Substitution	10 up to 50%	(up to) 100%
Ecological profit	sustainability	energy saving
Properties compared to standard	more or less comparable (UP, VE, EP)	weight-stiffness–ratio comparable to GF. Potential in many aspects (processing, consistency of properties, long-term behaviour)
Economical profit	less concise	improving price performance ratio

Bio reinforcements

Raw material	Price [€/kg] woven / UD fabric*	Description	Status
Glass	5-20	most current fiber	high density (2,6 g/cm³)
Carbon	20- >100	high-performance	„commodity“-types (non-aerospace) on the rise
Jute	See glass	for semi-structural and decorative applications	wovens available
Flax	12-30	for structural applications, best-tried natural fiber	wovens and UD available
Cellulose	n.b.	aspect similar to glass	advanced stadium of development

*from catalogue

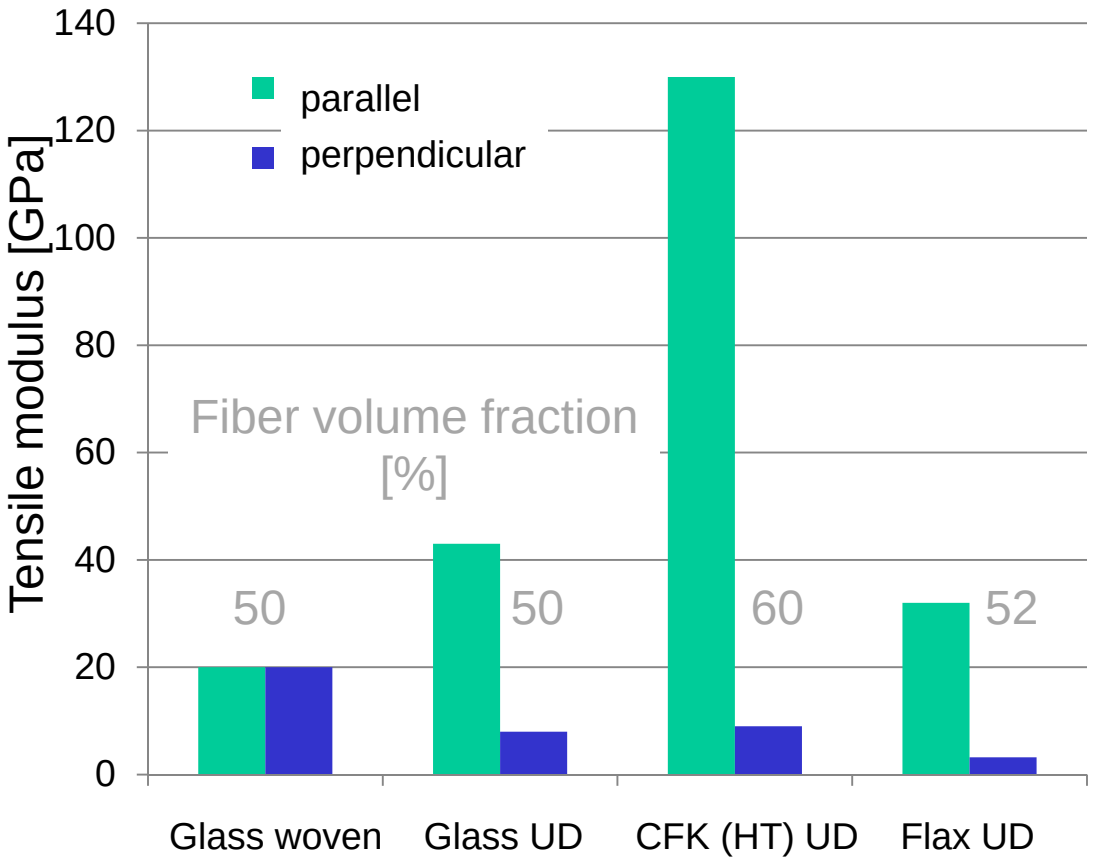
Flax fiber

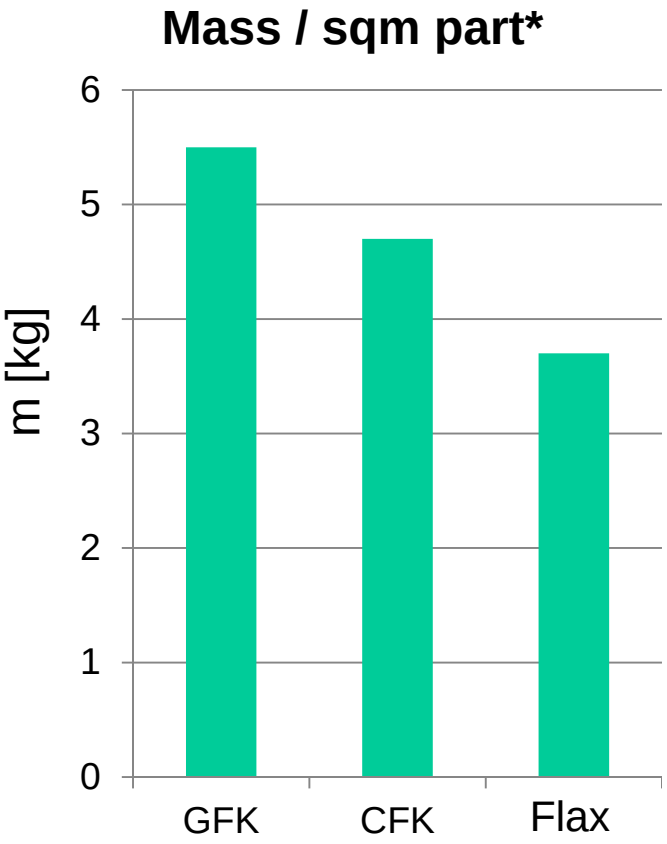
- Established supply chain for material with constant property level
- Density of fiber: 1,35 g/cm³
- High mechanical and acoustic dampening
- In focus: Surface treatment for good wetting with current resins and for long-time duration of the composite
- Fiber volume fraction limited to 50 weight-% for vacuum processing
- First large-scale automotive project

Source: bcomp

Woven and biax-reinforcement from flax fibers

Comparison of epoxy laminates





Source: bcomp, hexcel

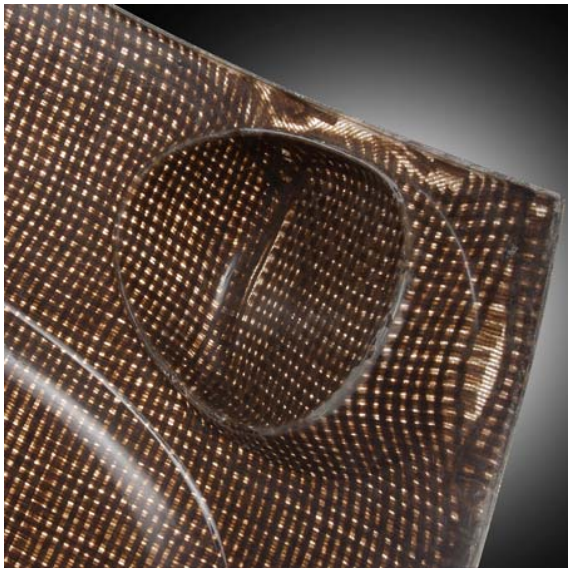
*3 mm thick

Applications of flax frp

Source: lineo

Racing Boat „Araldite“:

Epoxy-coated flax fibers in combination with CF (50/50), vacuum infusion with epoxy resin



Source: Arkema

Engine hood - prototype

In-Situ-PMMA with flax fibers

Cellulose-based fiber

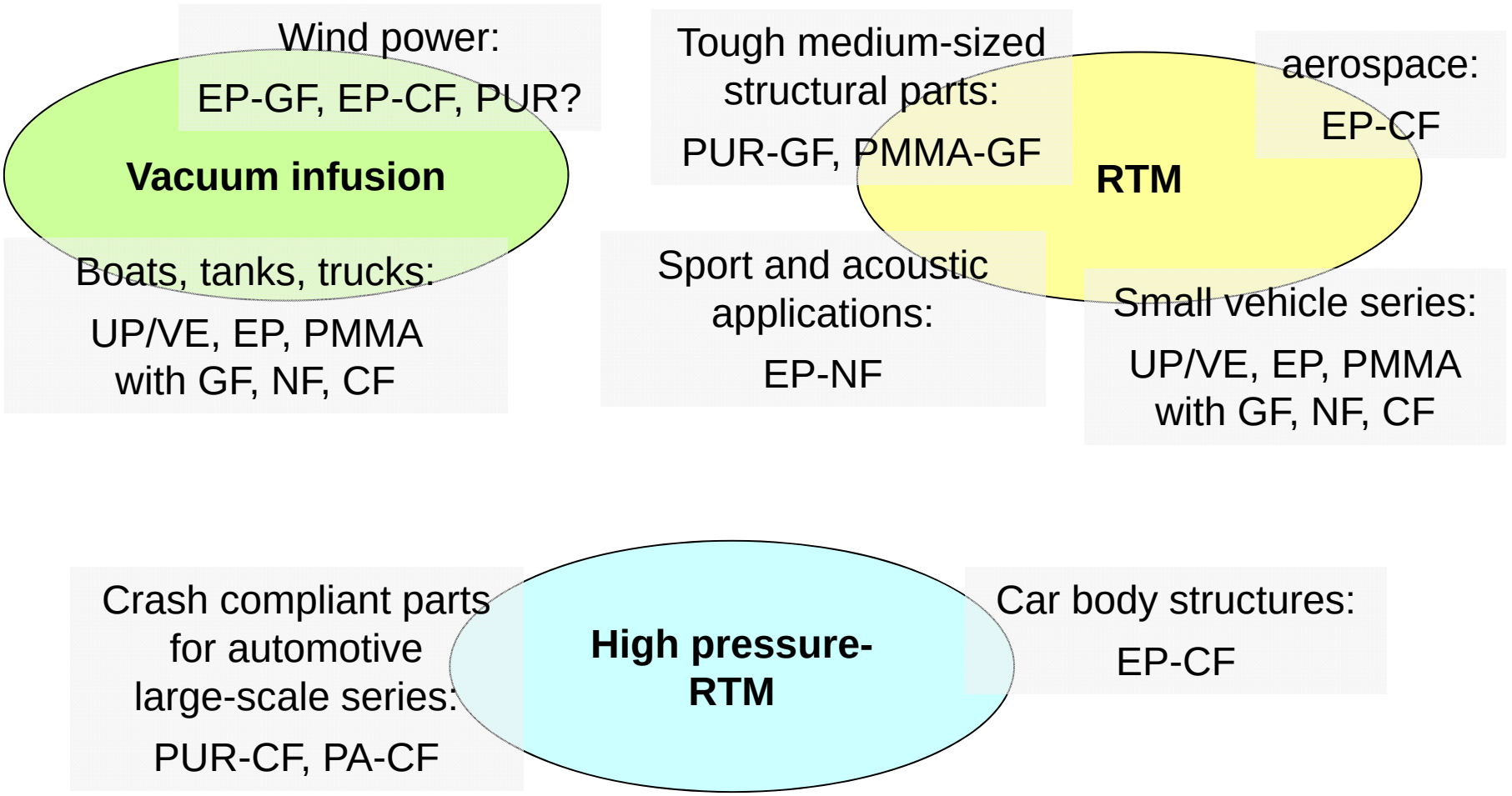
Tensile strength [N/mm²]	144
Bending strength [N/mm²]	237
Bending modulus [kN/mm²]	9,6
density [g/cm³]	1,23

Source: Gordon Shank

Data of VE-laminate with 50 Gew.-% woven cellulose fiber

- Starting Product wood; Preparation by spinning from solution
- Continuous fiber; constant properties along fiber length
- diameter 11 μm; easy impregnation
- Density about 1,5 g/cm³
- cristallinity 95%
- Aspect similar to glass fiber: no darkening of the laminate

Conclusion: What for what purpose?



Thank you

…for your attention!

… and thanks to

Ashland Inc.	Bayer MaterialScience	Henkel AG & Co. KGaA
Arkema Inc.	Bcomp Ltd	Momentive
BASF SE	DSM Composite Resins	Saertex / Gordon Shank