The project: Sustainability Racing -
The vision: mobility of the future

Christoph Habermann, Hans-Josef Endres,
IfBB - Institute for Bioplastic and Biocomposites
University of Applied Sciences Hanover
www.ifbb-hannover.de

Einsatz von biobasierten Werkstoffen im Automobilbereich

Berlin, 14.11.2013
Agenda

• Why should we use biobased plastics?
• Development of bioplastics and biocomposites
• Materials for the Bioconcept Car
• Specific comparison of materials
• Conclusions
Plastics are amazing materials (in cars)

Golf 1

Weight

Costs

Golf 6

Source: VW, Peter Helmke
Future of petro-based plastics?

Consumption of crude oil 5,000,000 x higher than its rate of regeneration
→ future problem only to convert energy, but to meet the increased quantity requirements for plastics will become a feedstock problem!

Growth of population
(Expectation: plastic consumption per head in India and China as high as in Europe)
→ Worldwide production of plastics has to be doubled!

Issue for environment:
critical exploitation of oil with increasing ecological impacts and littering of plastics (globally considered)
Current Stage of Development and Production Scale of Thermoplastic Bioplastics (2012)

CA: Cellulose acetate
PA: Polyamide
PBS: Polybutylene succinate
PBSA: Polybutylene succinate adipate
PBT: Polybutylene terephthalate
PCL: Polycaprolactone
PE: Polyethylene
PET: Polyethylene terephthalate

PHA: Polyhydroxyalkanoate
PLA: Polylactides
POM: Polyoxyymethylene
PP: Polypropylene
PTT: Polytrimethylene terephthalate
PUR: Polyurethane
PVAL: Polyvinyl alcohol
PVC: Polyvinyl chloride

Durables
- Bio-PVC
- PBT
- Bio-PP
- Bio-POM

Degradables
- Degradable polyesters
- Cellulose regenerates
- Starch blends
- PLA
- PVAL

R & D Pilot Scale Commercial Large Scale Industrial
biobased partly biobased
petrobased

Source: H.-J. Endres, A. Siebert-Raths; Engineering Biopolymers, Carl Hanser-Verlag, 2011, modifiziert
Chemically novel polymer types

Chemically known polymer types

Petro

PBAT
PBS
...

Bio

PLA
PLA blends
Starch blends
...

PP
PET
PA
...(conventional)

Bio PE
Bio PET
Bio PA
...
= Drop-Ins
(Novel) possibilities to produce biobased fibers

**Fiber grades**
- Ceramic fibers
- Carbon fibers
- Glass fibers
- Synthetic fibers
- Boron fibers
- Natural fibers

**Possible renewable resources**
- Rayon, Lignin
- C-Fibers based on cellulose or lignin
- PLA fibers
- Polylactide based on corn starch
- Bio-PE
- Bio-Ethanol based on sugar cane
- Bio-PA
- Based on castor-oil
- Bio-PET, PTT
- Based on bio-alcohols
- Regenerates
- Chemical solution and precipitation of cellulose
- animal
- Silk, Wool
- plant
- Wood, Cotton, Hemp, Flax, Sisal, Jute
What are Biocomposites?

**Biobased Matrix**
- Bio-PA + GF
- Bio-PP + GF
- Bio-Resin + GF
- Bio-Resin + CF
- ...

**Petrobased Matrix**
- PLA + NF
- Natural rubber + CRF
- Bio-PA + CRF
- ...

**Conventional Fibers**
- PA + GF
- PP + GF
- PP + CF
- ...

**Biobased Fibers**
- PE + NF
- PP + Wood flour
- PA + CRF
- PP + CRF
- ...

**Biobased Composites**
- Bio-PA + GF
- Bio-PP + GF
- Bio-Resin + GF
- Bio-Resin + CF
- ...

**Conventional Composites**
- PA + GF
- PP + GF
- PP + CF
- ...

**Biobased Fiber**
- PLA + NF
- Natural rubber + CRF
- Bio-PA + CRF
- ...

**Petrobased Fiber**
- PE + NF
- PP + Wood flour
- PA + CRF
- PP + CRF
- ...

Director of the institute: Prof. Dr.-Ing. Hans-Josef Endres
Different material concepts for the BCC

<table>
<thead>
<tr>
<th>short fibers (&lt; 4mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>glass fiber (GF)</td>
</tr>
<tr>
<td>wood fiber (NF)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>long fibers (fabric)</th>
</tr>
</thead>
<tbody>
<tr>
<td>glass fibers (GF)</td>
</tr>
<tr>
<td>carbon fibers (CF)</td>
</tr>
<tr>
<td>natural fibers (NF)</td>
</tr>
<tr>
<td>regenerated fibers (NF)</td>
</tr>
</tbody>
</table>
Bioconcept-Car

**Now**

1. Bio-based thermoset* with flax fiber
2. Bio-based thermoset* with flax fiber
3. Bio-based thermoset* with flax fiber
4. Bio-based thermoplastic

**Before**

Steel plates
Petro-based thermoset with carbon fiber
Petro-based thermoplastic
Petro-based thermoplastic

*Epoxy resin, vacuum bagging prozess; **PA = Polyamide; ***PTT = Polytrimethylterephthalate

Director of the institute: Prof. Dr.-Ing. Hans-Josef Endres
Example: reinforced thermoplastics

Bio-PA
Polyamid with talcum

- high stiffness
- utilization of existing mould
- industrial process ability
- bio-based material
- superior technical characteristics
Example: reinforced thermoplastic bioplastic

PP+NF
Polypropylen + Natural Fiber

- dimensional stability
- stiffness
- good glossy finished surface
- processable on original series mould
Characterization of fiber morphology

Histogram of fiber length

Percentile  
0.0 [\%]  
10.3393 [\mu m]  
5.0 [\%]  
11.9261 [\mu m]  
10.0 [\%]  
13.5129 [\mu m]  
50.0 [\%]  
33.8269 [\mu m]  
90.0 [\%]  
119.0076 [\mu m]  
95.0 [\%]  
159.1029 [\mu m]  
100.0 [\%]  
1617.7164 [\mu m]

Histogram of fiber width

Percentile  
0.0 [\%]  
5.0170 [\mu m]  
5.0 [\%]  
5.6438 [\mu m]  
10.0 [\%]  
6.2706 [\mu m]  
50.0 [\%]  
10.9951 [\mu m]  
90.0 [\%]  
21.5709 [\mu m]  
95.0 [\%]  
28.1520 [\mu m]  
100.0 [\%]  
348.4149 [\mu m]
Compoundierung

Natural fiber
Additives
Plastics
Example: Thermoset plastic composites

NFK
Natural fiber reinforced thermoset

- large flat surface elements
- low component weight
- bio-based fiber
- high weight-specific flexural strength
- low price

62% weight save
Overview on fiber fabrics

Glass fibers

- Twill weave K 3/3, 238g

Carbon fibers

- Panama P3/3, 227g

Natural fibers

- Twill weave K3/3, 228g
- Canvas L2/1, 220g
Materials and methods

- Different natural and non-natural fabrics with variable weight and variable weave
- Test samples by a vacuum bag process with epoxy resin
- Mechanical parameters are determined after DIN EN ISO 527_4
Composite Density vs. Young's Modulus

- **Glassfiber-Fabric** (280g/m²)
- Carbonfiber-Fabric (285g/m²)
- Viscosefiber-Fabric (190g/m²)
- Flaxfiber-Fabric (238g/m²)
- Aluminium

**Legend**:
- Purple square: Glassfiber-Fabric
- Black square: Carbonfiber-Fabric
- Green triangle: Viscosefiber-Fabric
- Red cross: Flaxfiber-Fabric
- Blue circle: Aluminium

**Graph Details**:
- **Y-axis**: Young's Modulus (length/lateral) [MPa]
- **X-axis**: Density [g/m³]
- **Label**: 3-layer, n=8
Composite Density vs. Tensile Strength

Tensile Strength (length/lateral) [MPa]

Density [g/m³]

Glassfiber-Fabric (280g/m²)
Carbonfiber-Fabric (285g/m²)
Viscosefiber-Fabric (190g/m²)
Flaxfiber-Fabric (238g/m²)
Aluminium

3-layer, n=8
Density and energy specific Young's modulus materials

Density and energy specific Tensile Strength materials

*Cradle-to-Gate, Without biogenic carbon, n=8
Framework conditions

**Sponsorship:** BMELV, (Projektträger FNR)

**Team:** Four Motors

**Also biobased fuel** (Neste Oil, Ufop, etc.)

**Driver:**
- Smudo (Fantastische Vier)
- Tim Schrick
- Tom von Löwis of Menar (Teamchef)
Thanks for the attention!

Contact
IfBB – Institut für Biokunststoffe und Bioverbundwerkstoffe
Hochschule Hannover
Heisterbergallee 12
30453 Hannover

Tel. 05 11 / 92 96 – 22 68
Fax 05 11 / 9296 – 99 22 68

E-Mail: info@ifbb-hannover.de

www.ifbb-hannover.de