„Lightweight by bionic design approach”

Georg Fischer Automotive

Stefan Hess, 09.10.2014
Overview

- Competences R&D Schaffhausen
- Definition of Bionics
- Motivation for lightweight design
- Bionic design process
- Examples of use
- Summary
Research & Development

material
design
process
testing
Research & Development

Product Development process

- FEA, linear
- FEA, non-linear
- temperature simulation
- life time prediction
- casting simulation
- NVH simulation
- structure optimization
- casting simulation
the material parameters determined by GF Automotive provide the basis for virtual development and carry the design philosophy of lightweight construction
Research & Development

Competences

material
design
process
component testing
# Research & Development

## SiboDur

**High Strength Cast Iron**

<table>
<thead>
<tr>
<th>SiboDur 450-17 HD</th>
<th>SiboDur 450-17 HS</th>
<th>SiboDur 550-12</th>
<th>SiboDur 700-10</th>
<th>SiboDur 800-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>High strength</td>
<td>High strength</td>
<td>High strength</td>
<td>Very high strength</td>
<td>Maximum strength</td>
</tr>
<tr>
<td>Very high</td>
<td>High deformability</td>
<td>High deformability</td>
<td>High deformability</td>
<td>High deformability</td>
</tr>
<tr>
<td>deformability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>Good machinability</td>
<td>Good machinability</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>machinability</td>
<td></td>
<td></td>
<td>machinability</td>
<td>machinability</td>
</tr>
<tr>
<td>Crash relevant</td>
<td>Chassis</td>
<td>Hubs for trucks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>parts</td>
<td>components</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Research & Development

SiboDur
High Strength Cast Iron

damper strut
SiboDur 700-10

control arm
SiboDur 450-17

rear knuckle with integrated pin
SiboDur 700-10

rear knuckle with pressed in steel pin
SiboDur 450-17
Research & Development

component testing

design

material

process

testing
Research & Development

component testing

- accredited testing laboratory
- test facilities for sample and components testing
  - static component test
  - hydro-pulsators for vibration and durability tests
- rotating bending tests
- vertical impact machine
- multi-channel test bench (up to 3 K) for testing with real-time signals (also under corrosion influence)
- verification of numerical simulation and real-time test
- climatic test chamber
What is bionics?
Research & Development

Bionics
The expression

- The English term bionics was coined 1958 by the American Jack E. Steele.
- It was first used at a congress in Ohio with the topic: optimisation of radar by imitating the biological sonar of bats.
- Bionics meant „Learning from nature to discover and develop technical solutions“.
Bionics

The lotus effect

Selfcleaning surface - the lotus-effect:

- The lotus flower is a symbol for purity in asian religions: spotlessly clean it unfolds its leaves from the muddy water

- Natural feature to protect itself against pollutants as well as micro organisms.

- By transferring these features on technical surfaces, almost all materials used outdoors can be cleaned by the rain.
Air retaining surfaces

- Air retaining surfaces can be found amongst various plants and animals, that live partially or permanently in or on the water.

- They have surfaces that don’t wet when immersed in water and therefore stay dry. Responsible for the air retaining characteristics are mostly fine hair structures, that can be formed in various ways.
Bionics
The bionic tire

- While «braking» the paws of cats widen itself by spreading. Due to the enlarged surface «braking» is more effective.

- The paw of a cat is adaptiv

- Knowledge was transferred from the fundamental biological research to the structure of a tire.

- Moderate fuel consumption / Braking distance reduced by 10%.
Research & Development

Bionics

Mercedes Benz Bionic car

- The boxfish as basis for the shape of the body.

- Reduction of $C_d$ coefficient to 0.19 by shape designing.

- Reduction of fuel consumption by 20% due to lightweight concept and optimised aerodynamics.
Bionics
Bones and foams

- Bones are foam structures that are realized with minimal use of material. Along load pathes more dense foam structures occur, while they are thinning out drastically in less stressed areas. This is still a vision for technical materials.

- Metal foams have a low density due to pores and cavities, but feature a high specific stiffness and strength.
Why do cars have to become lighter?
Research & Development

Bionics
Motivation for lightweight design

Environmental facts

- Problem of CO$_2$-emission
- Growing number of cars
- CO$_2$ –penalty tax
- Finite resources

CO$_2$-Emissionen in Prozent

- Pkw
- übriger Straßenverkehr
- übriger Verkehr
- Privathaushalte
- Kraft-/Fernheizwerke
- Industrie, Gewerbe, Handel

(Quelle: ADAC)
Bionics
Motivation for lightweight design

Weight spiral

Entwicklung der Fahrzeuggewichte

Dr. Goede, Volkswagen AG

Quelle: EBK/ Poznanski-Eisenschmidt
Research & Development

Light weight solutions
Strategies

Lightweight by material

- watch „Cradle-to-grave“ eco balance
- usualy cost intensive
- limited use for „Low-Budget-vehicles“

Lightweight by design

- affordable light weight
- suitable for big lot sizes
- preserves Ressources
Research & Development

Bionic Design Development Process

- start model
- structural optimization
- FE-Analyses
Research & Development

Bionic Design
Development Process

Learning from nature:

• adjust cross sections
• avoid notches
• Harmonize stresses
Research & Development

Bionic Design
Development Process

Bauteile optimieren mit Zugdreiecken

Quelle: Prof. Dr. Claus Mattheck
Example of use
Passenger car front knuckle

Target: - Finding the lightest possible geometry within the given design space

Tool: - Topology optimisation
Example of use
Passenger car front knuckle

Start design

Desing space model

- Loads linear / nonlinear
- Lifetime expectations
- available design space
- Neighboring parts
- …
Research & Development

Example of use
Passenger car front knuckle

not or less loaded elements will be eliminated
Research & Development

Example of use
Passenger car front knuckle

Topology after smoothing
Example of use
Passenger car front knuckle

**Front knuckle serial production**
- Material: GJS 400-15
- Weight: 4.39 kg
- Weight potential:

**Bionic front knuckle**
- Material: SiboDur 700-10
- Weight: 2.98 kg
- Weight potential: -1.41 kg (-32%)

**Weight reduction:**
- 2.82 kg per vehicle

**CO₂ reduction:**
- 11,600 Tons per year at 2.4 Mio. vehicles
Example of use
Passenger car crank shaft

<table>
<thead>
<tr>
<th>Goal:</th>
<th>Tool:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress reduction</td>
<td>Shape optimisation</td>
</tr>
</tbody>
</table>
Research & Development

Example of use
Passenger car crank shaft

Shape optimization
Research & Development

Example of use
Passenger car crank shaft

Shape optimization

- Start design: 410 MPa
  - $\Delta \sigma_{V_{\text{max}}} = -21\%$
- Intermediate result: 331 MPa
  - $\Delta \sigma_{V_{\text{max}}} = -21\%$
- Optimum: 295 MPa
  - $\Delta \sigma_{V_{\text{max}}} = -29\%$
Research & Development

Bionic design

Conclusion

- Bionic design needs
  - Designspace
  - Requirements and loads
  - Experience

- Bionic design offers
  - Weight savings
  - Innovative shapes
Bionic design

Conclusion

Lightweight design has to be …

- used more intensly for future vehicles
- looked at comprehensivly
- affordable
Bionic design can...

- help to find efficient concepts in product development
- identify new light weight solutions
- reduce development time
- minimize development costs
Passion ...  
... for your Lighter Future