Fibre Reinforced Plastic Concepts for Structural Chassis Components

Gundolf Kopp,
Oliver Deisser,
Prof. Dr. Horst E. Friedrich
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- Why lightweight design?
- Chassis suspensions in general
- Fibre reinforced plastics (FRP) and chassis suspensions
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- Conclusion and forecast
Locations and employees


Research Areas:
- Aeronautics
- Space Research and Technology
- **Transport**
- Energy
- Space Administration
- Project Management Agency
Mass reduction for decreasing the running resistance

Equotation of motion:

\[ \Sigma F_w = m_g \cdot g \cdot f_R \cdot \cos \alpha + r_L \cdot A \cdot c_w \cdot v^2/2 + b \cdot (m_g + \Sigma m_{rot}) + m_g \cdot g \cdot \sin \alpha \]

\[ \Sigma F_w = F_R + F_L + F_B + F_{St} \]

\[ \approx 35\% \quad \approx 25\% \quad \approx 40\% \]

\[ \approx 75\% = F(m) \]

⇒ Reducing the need for energy by reducing mass:

- Within the system boundary chassis suspension:
  - Mass of wheelmount, control arm,…
  - Mass of springs, dampers,…
- With inclusion of other subsidiary systems (eg. drivetrain):
  - Wheel integrated or wheel close engine
Increase of range by mass reduction

- **Small vehicle with recuperation**
  - Urban
  - Road
  - Motorway
  - NEFZ

- **Small vehicle without recuperation**
  - Urban
  - Road
  - Motorway
  - NEFZ

- ~21%
- ~23%
Mass distribution in the vehicle

**Baseline**
- Body: 23%
- Powertrain: 22%
- Interior: 15%
- Brakes, wheels & tires: 13%
- Closures/fenders: 9%
- Chassis: 8%
- Glazing: 3%
- Electric: 1%
- Lighting: 1%
- Misc: 2%

**Low development 2017**
- Body: 24%
- Powertrain: 24%
- Interior: 14%
- Brakes, wheels & tires: 12%
- Closures/fenders: 8%
- Chassis: 8%
- Glazing: 4%
- Electric: 1%
- Lighting: 1%
- Misc: 2%

**High development 2020**
- Body: 20%
- Powertrain: 29%
- Interior: 14%
- Brakes, wheels & tires: 11%
- Closures/fenders: 8%
- Chassis: 9%
- Glazing: 4%
- Electric: 1%
- Lighting: 1%
- Misc: 2%

Δm = -21,5%
Δm = -38,4%

Reference: Toyota Venza

Δm\_{\text{suspension}} = -27%
Δm\_{\text{suspension}} = -43%

No verification of the results
(neither by simulation nor by testings)

Lightweight design strategies

Step 1

Requirements, Conditions and Standards

- Law
- Customer and Market
- CO2-Strategy

Step 2

Concept

- Package
- Integration
- Modularisation
- Technologies

Materials

- Materials
- Surfaces
- Processes

Design

- Shape
- Geometry

Source: Haldenwanger (1997)

DLR (2007)
The six requirements of the chassis suspension

<table>
<thead>
<tr>
<th>Vertical flexibility</th>
<th>Longitudinal stiffness</th>
<th>Transverse stiffness</th>
<th>Precise toe-in</th>
<th>Camber stiffness</th>
<th>Support of braking force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsion spring, coil spring</td>
<td>Trailing link</td>
<td>Transverse arm</td>
<td>2 horizontal arms</td>
<td>2 vertical transverse arms</td>
<td>Long-short arm (sword)</td>
</tr>
<tr>
<td>Traverse, longitudinal leaf spring</td>
<td>(unequal length) A-frame arm, stiff triangle structure</td>
<td>Trailing link</td>
<td>(unequal length) A-frame arm, stiff triangle structure</td>
<td>(unequal length) A-frame arm, stiff triangle structure</td>
<td>Torsion bar</td>
</tr>
<tr>
<td>C-shaped spring</td>
<td></td>
<td>Semi-trailing arm, stiff triangle structure</td>
<td></td>
<td></td>
<td>Vertical guidance</td>
</tr>
</tbody>
</table>

Source: ZF Friedrichshafen AG
Overview in conventional chassis suspensions
FRP lightweight design in chassis suspensions
Concept design of a long-short arm (sword)

Development chain of a long-short arm concept design in FRP:
- Definition of the design space and boundary conditions
- Design of the topology model and definition of the loads
- Simulation and interpretation of the results
- Concept design of different variants
- Draft simulation of the variants with different material data
- Rating of the variants
FRP lightweight design in chassis suspensions
Concept design of a MacPherson front suspension

Aim:
concept design of a MacPherson front suspension with a traverse leaf spring

Approach:
- Detection of design space and the reference parts
- Analytical dimensioning of the traverse leaf spring
- Concept design of the traverse leaf spring
- Concept design of the subframe
- Draft simulation of the parts for evaluation of the concept

Result:
- Mass reduction by 26%
FRP lightweight design in chassis suspensions
chances and risks

Reasons for not applying known concepts in series production:
- Up until now elaborative manufacturing processes
- Lacking confidence in FRP
- Complex simulation methods because of anisotropic behaviour
- No existing databases for FRP materials

Potential for coming developments:
- Optimization of large-volume production of FRP
- Optimization of simulation tools
- Build up of material databases

By verification of generic parts
Verification of generic parts in FRP systematic approach at BMBF-ALF

Definition of load cases

Material properties

Simulation

Verification of the simulation with testing results

Plot and analysis of test results

testing

Design of testing rig
Verification of generic parts in FRP at an example workpackages form BMBF-ALF done at DLR

- Design and dimensioning of testing rig
- Nondestructive analysis by CT
- Testing of generic parts
- Plot and analysis of test results
Possibilities in activating functions in chassis suspension

- Use of active systems to change the spring rate
- Simplest way: block the rotational degree of freedom
  - Traverse spring leaf behaves like two independent short spring leaves
- Increase in spring rate

Example for Change of spring rate

<table>
<thead>
<tr>
<th></th>
<th>Without active system</th>
<th>Blocking of rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equilateral load</td>
<td>19.8 N/mm</td>
<td>98.9 N/mm</td>
</tr>
<tr>
<td>Alternating load</td>
<td>42.4 N/mm</td>
<td>98.9 N/mm</td>
</tr>
</tbody>
</table>
Development of drive-train/vehicle concepts for the individual mobility for tomorrow’s needs

Probable concepts for tomorrow:
- Universal Vehicle:
  range <600km, CI engine (start of fuel cell),
  ability for zero emission >~50km (with hybrids, Generally with FC)
- Long-Distance Vehicle:
  Range <1000km, CIE-Hybrid (pos. FC), no zero emission (with Otto-Hybrid)
- City Vehicle:
  Range <200km zero emission modus, electric traction, batteries, Range Extender

Subsequent concepts:
- New Generation Car:
  Range <1000km, CIE-Hybrid and Fuel Cell,
  ability for zero emission <100km
- City Vehicle:
  Range <300km zero emission modus, electric traction, batteries
- New concepts of Use, Ownership and business model
Conclusion for the chassis suspensions of the future:

- **Application Universal / Long-Distance Vehicle**
  - Demand for vehicle dynamics, comfort and safety will be preserved respectively will increase
  - Efficiency will be gained by low specific mass and where applicable recuperation of energy

- **Application City Vehicle**
  - Demand for vehicle dynamics and where applicable comfort will be adapted; safety standards must be preserved
  - Efficiency will be gained by low specific mass and where applicable recuperation of energy

Automobile mobility persists to be a success model.