Lightweight @ ZF Friedrichshafen AG

Derek Zhu, Head of Engineering, Chassis Systems

ZF Friedrichshafen AG
1. ZF Friedrichshafen AG
2. The Need for Lightweight Design
3. Hybrid Brake Pedal
4. Composite Leaf Spring Axle
5. Innovation as a Whole System
6. ZF Lightweight Design Capabilities
7. Retrospective
ZF Group
Key Figures 2014

The ZF Group – An Overview

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2014 / 2013*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>€ 18.4 billion</td>
<td>+ 9 %</td>
</tr>
<tr>
<td>Employees (end of year) **</td>
<td>71,402</td>
<td>+ 5 %</td>
</tr>
<tr>
<td>Capital expenditure</td>
<td>€ 1 billion</td>
<td>+ 5 %</td>
</tr>
<tr>
<td>R&amp;D expenditure</td>
<td>€ 891 million</td>
<td>+ 7 %</td>
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</tbody>
</table>

113 production companies in 26 countries

7 main development locations in 4 countries

33 service companies and more than 650 service partners

*excluding ZF Lenksysteme.
**Without employees of the Rubber & Plastics business unit and without AIBC employees.
Organization
Status: January 2015

<table>
<thead>
<tr>
<th>CEO</th>
<th>Car Powertrain Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate Market</td>
<td>Automatic Transmissions</td>
</tr>
<tr>
<td>Corporate R&amp;D</td>
<td>Manual Transmissions / Dual Clutch Transmissions</td>
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<tr>
<td>Corporate Finance, IT, M&amp;A</td>
<td>Axle Drives</td>
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<tr>
<td>Corporate Human Resources</td>
<td>Powertrain Modules</td>
</tr>
<tr>
<td>Corporate Governance</td>
<td>Electric Drive Technology</td>
</tr>
<tr>
<td>Corporate Production</td>
<td>Die Casting Technology</td>
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<tr>
<td>Corporate Materials Management</td>
<td></td>
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<tr>
<td>Corporate Quality</td>
<td></td>
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<tr>
<td>Electronic Systems</td>
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<tr>
<td>ZF Services</td>
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<table>
<thead>
<tr>
<th>Car Chassis Technology</th>
<th>Commercial Vehicle Technology</th>
</tr>
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<tbody>
<tr>
<td>Chassis Systems</td>
<td>Truck &amp; Van Driveline Technology</td>
</tr>
<tr>
<td>Chassis Components</td>
<td>Axle &amp; Transmission Systems for Buses &amp; Coaches</td>
</tr>
<tr>
<td>Suspension Technology</td>
<td>CV Chassis Modules</td>
</tr>
<tr>
<td></td>
<td>CV Damper Technology</td>
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<tr>
<td></td>
<td>CV Powertrain Modules</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Industrial Technology</th>
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<tbody>
<tr>
<td>Off-Highway Systems</td>
</tr>
<tr>
<td>Test Systems</td>
</tr>
<tr>
<td>Special Driveline Technology</td>
</tr>
<tr>
<td>Marine Propulsion Systems</td>
</tr>
<tr>
<td>Aviation Technology</td>
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<tr>
<td>Wind Power Technology</td>
</tr>
</tbody>
</table>
Car Chassis Technology Division

Corporate Functions Division

- Finance / Controlling / IT
- Human Resource
- Production
- Development
- Quality
- Materials Management
- Market

Chassis Components
- Suspension joints
- Cross-axis joints
- Tie rods
- Stabilizer links
- Control arms
- Wheel carriers and hubs

Chassis Systems
- Front axles
- Rear axles
- Corner modules
- Active Kinematics Control (AKC®)

Suspension Technology
- Active Systems
- Conventional Dampers
# Agenda

1. ZF Friedrichshafen AG
2. The Need for Lightweight Design
3. Hybrid Brake Pedal
4. Composite Leaf Spring Axle
5. Innovation as a Whole System
6. ZF Lightweight Design Capabilities
7. Retrospective
Trends for the Future
4 Main Topics

- Lightweight
- Electrification
- Connected
- Efficient
Emission Laws vs. Passenger Car Weight

Increasing weight spiral
Due to additional equipment

Change of vehicle weight 1970-2006

More stringent requirements
CO₂ reduction

Reduced CO₂ emissions legislation (EU)

Weight spiral reversal
Targeted, innovative material use

Reduced weight
Thanks to new materials

e.g.: VW Golf Weight 1975-2013

Lightweight design strategy:
Weight spiral reversal

Package adjustment of tank volume
Driving performance
Adjust engine type

Body stiffness
Comfort
Driving performance
Safety
Universality

平均重量份额在车辆中

- Equipment
- Electric
- Body
- Chassis

- Drive

- Average weight shares in the vehicle today

- Car with approx. 1,200kg up to 2017

- Car with approx. 850kg up to 2025

- Car with approx. 500kg up to 2025

- Car with approx. 350kg up to 2025

- Car with approx. 180kg up to 2025

- Car with approx. 100kg up to 2025

- Car with approx. 25kg up to 2025
Fiber-Reinforced Plastic - FRP

Savings potential thanks to **weight reduction** of 100 kg
- Consumption: 0.3l/100km
- CO₂ emissions: 7.5g/km CO₂

- Weight reductions thanks to functional integration
- Material use according to weight through endless fibers

Source: Bond Laminates
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## Hybrid Brake Pedal

### Continuous Fiber Reinforced Composite

<table>
<thead>
<tr>
<th>Pedal Type</th>
<th>Weight</th>
<th>Steel Insert</th>
<th>Plastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel pedal</td>
<td>100 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal hybrid pedal</td>
<td>66 %</td>
<td>60 %</td>
<td>40 %</td>
</tr>
<tr>
<td>FRP hybrid pedal</td>
<td>~ 50 %</td>
<td>23 %</td>
<td>77 %</td>
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</tbody>
</table>

**Images:**
- Organo sheet
- Tool
- Insert
- Injection molding
- Brake pedal
Hybrid Brake Pedal Processing Techniques – One Shot Process

Process technology at ZF

One-shot process
Thermoforming & injection molding

Organo sheet tailoring, plasticizing
Thermoforming & injection molding
Granulate drying and loading

Component handling - fully automated
Plastic Pedal Box

- Extended freedom of design with maximum functionality
- Lower weight saves fuel
- Reduced manufacturing costs
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Composite Leaf Spring Axle

Product Description

- FRP leaf spring axle with wheel control, suspension spring and anti-roll bar function
- Integration functionality associated with reduction of parts

Benefits

- 15 % weight reduction vs. 4-link suspension
- Optimal space as a result of reduction of parts
- Optimized driver performance vs. twist beam
Composite Leaf Spring Axle Functional Integration

<table>
<thead>
<tr>
<th>Integration step 1</th>
<th>Spring</th>
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<tbody>
<tr>
<td>Integration step 2</td>
<td>Spring</td>
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<tr>
<td>Integration step 3</td>
<td>Spring</td>
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<tr>
<td>Integration step 4</td>
<td>Spring</td>
</tr>
<tr>
<td>Anti-roll bar</td>
<td></td>
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<tr>
<td>Anti-roll bar</td>
<td></td>
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<tr>
<td>Wheel guidance</td>
<td></td>
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<tr>
<td>Wheel guidance</td>
<td></td>
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<tr>
<td>Damper strut</td>
<td></td>
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</table>

Strut
Control arm
Central bearing
Trailing link
Composite Leaf Spring Axle
FEM Simulation

Load Case Simulation

mount at knuckle

central bearing

stress exposure of fiber
Composite Leaf Spring Axle Testing Base Materials

Several test devices on lab and part level within ZF quality tests

- fiber volume percentage
- CT scanner
- ultrasonic sound
- etc.

Geometry tests

- dimensional
- tolerances
- distortion
- etc.
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ZF Innovation Car

- E-mobility in combination with optimized suspension light weight
- Innovative e-drive
- Increased traveling range
- CO$_2$ reduction
- Optimized driving performance
ZF Innovation Car
Combination of Electric Drive and Lightweight Chassis

**Lightweight suspension strut and knuckle module**
- Innovative FRP design with closed surface
- Integration of damper strut and knuckle
- Usage of fiber-reinforced plastics
- Advantages for driving dynamics thanks to reduction of unsprung masses
- Up to 40% weight reduction

**Lightweight damper**
- Aluminum cylinder tube instead of steel tube
- Integration of bottom plate, ring eye and rubber joint into one plastic joint assembly
- Up to 25% weight reduction
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Process Technology
Dielingen Plant + Schweinfurt Plant

Dielingen Plant
Thermoplastics

- Injection molding
- Insert technology
- Thermoforming
- One shot
- Handling
- Prototyping
- Small series

Schweinfurt Plant
Duroplastics

- RTM
- HP-RTM
- C-RTM
- Prepreg hot pressing
- Handling
- Preforming
- Cutter
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Retrospective

- Innovative combination of materials
- Integration of functions
- Usage of alternative materials (CRP and GRP)
- Integration of manufacturing steps
- Advantages for driving dynamics thanks to reduction of unsprung masses
Thank you for your attention