Stahl | Steel Institute VDEh

DEUTSCHE MASSIVUMFORMUNG

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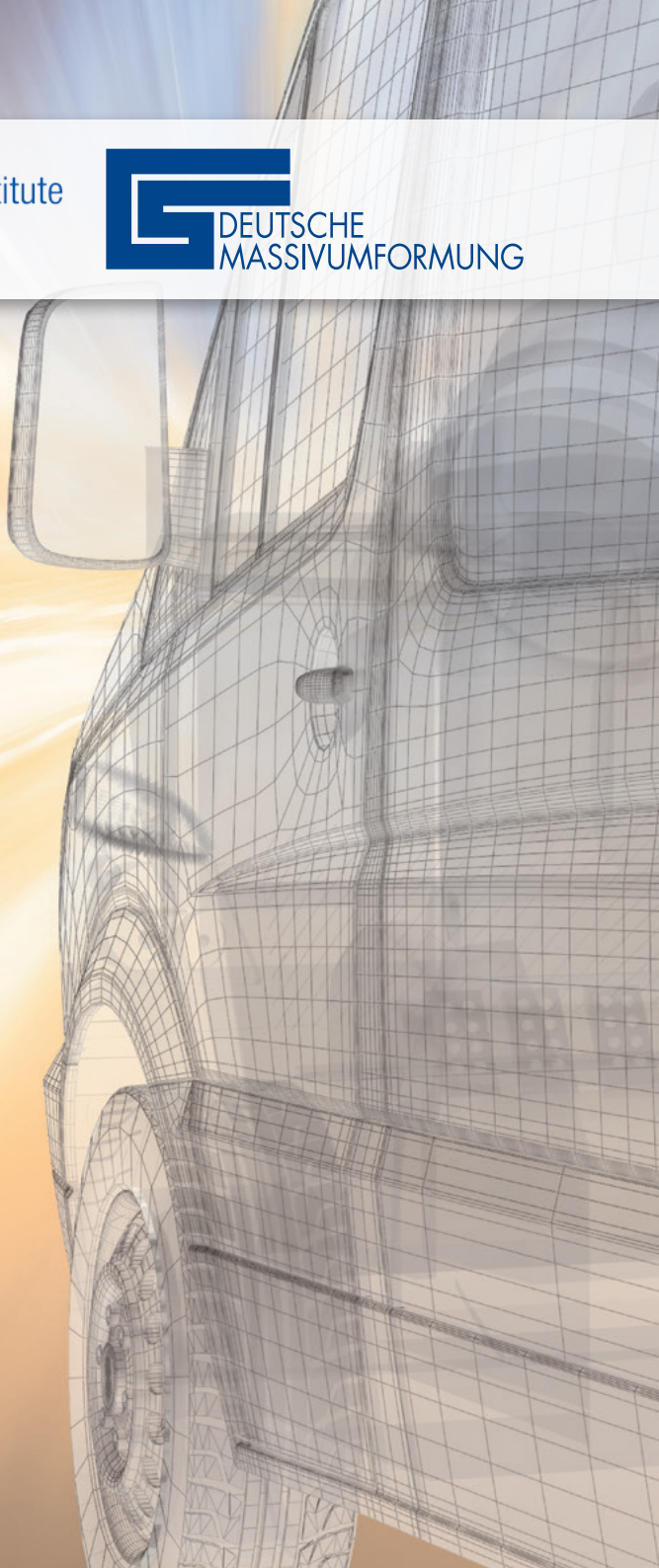
(Lightweight Forging)

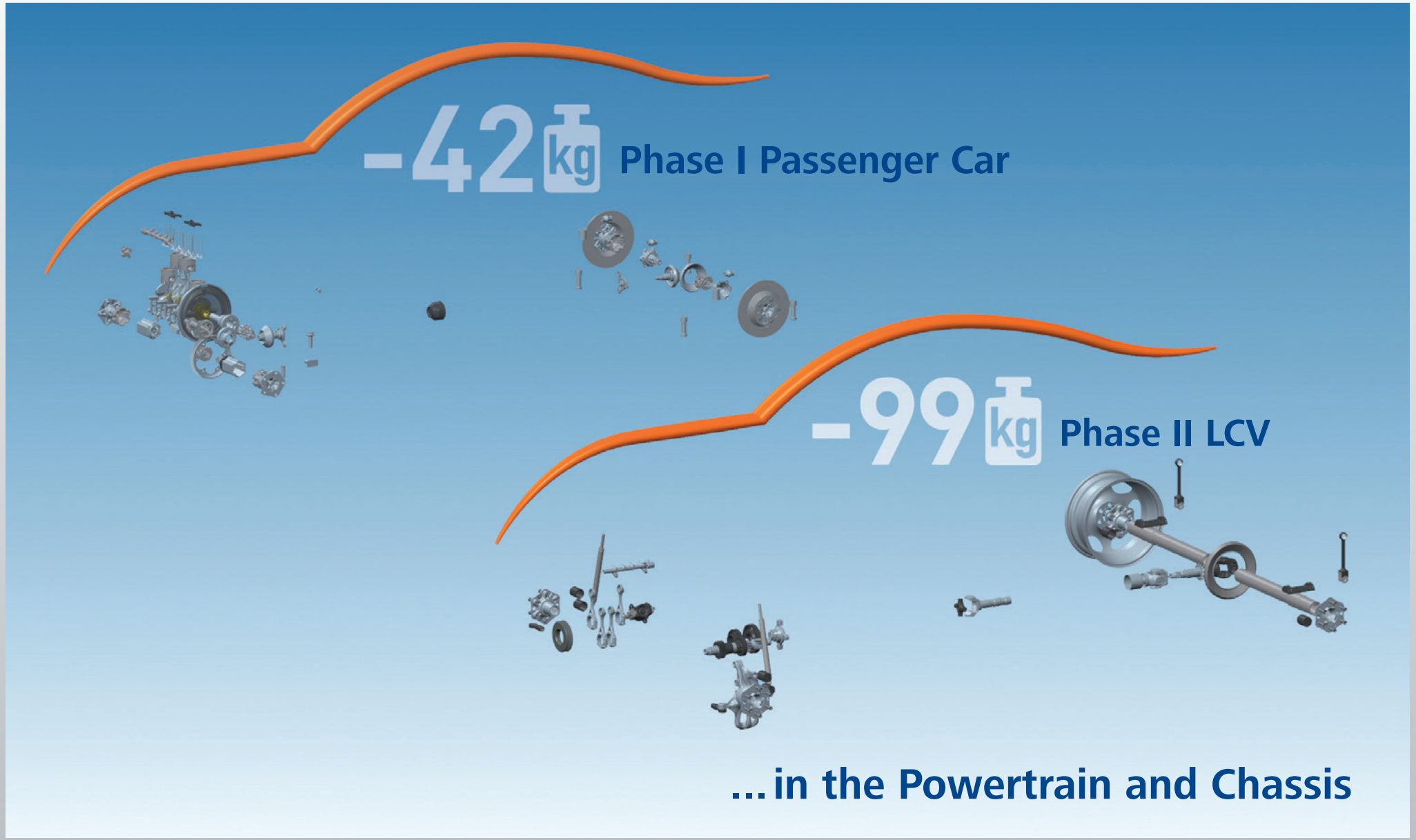
www.lightweightforging.com

Phase II Light Commercial Vehicle (LCV)

2015 – 2016



Lightweight Forging …



Project Overview

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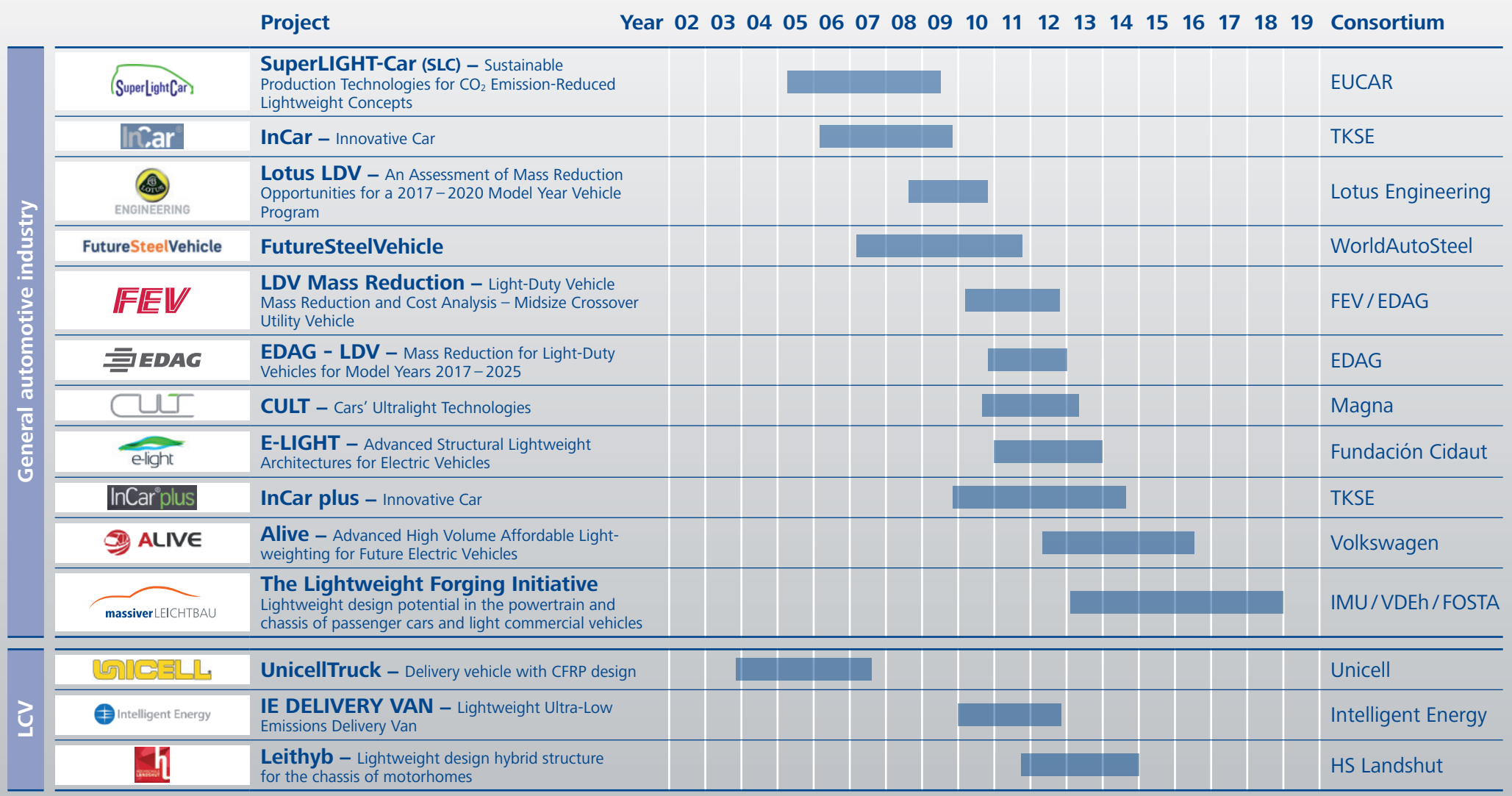
Selected Automotive Lightweight Design Projects …



▶ **Only very few public projects for component lightweight design in light commercial vehicles (LCV)**

Automotive Lightweight Design with Forging

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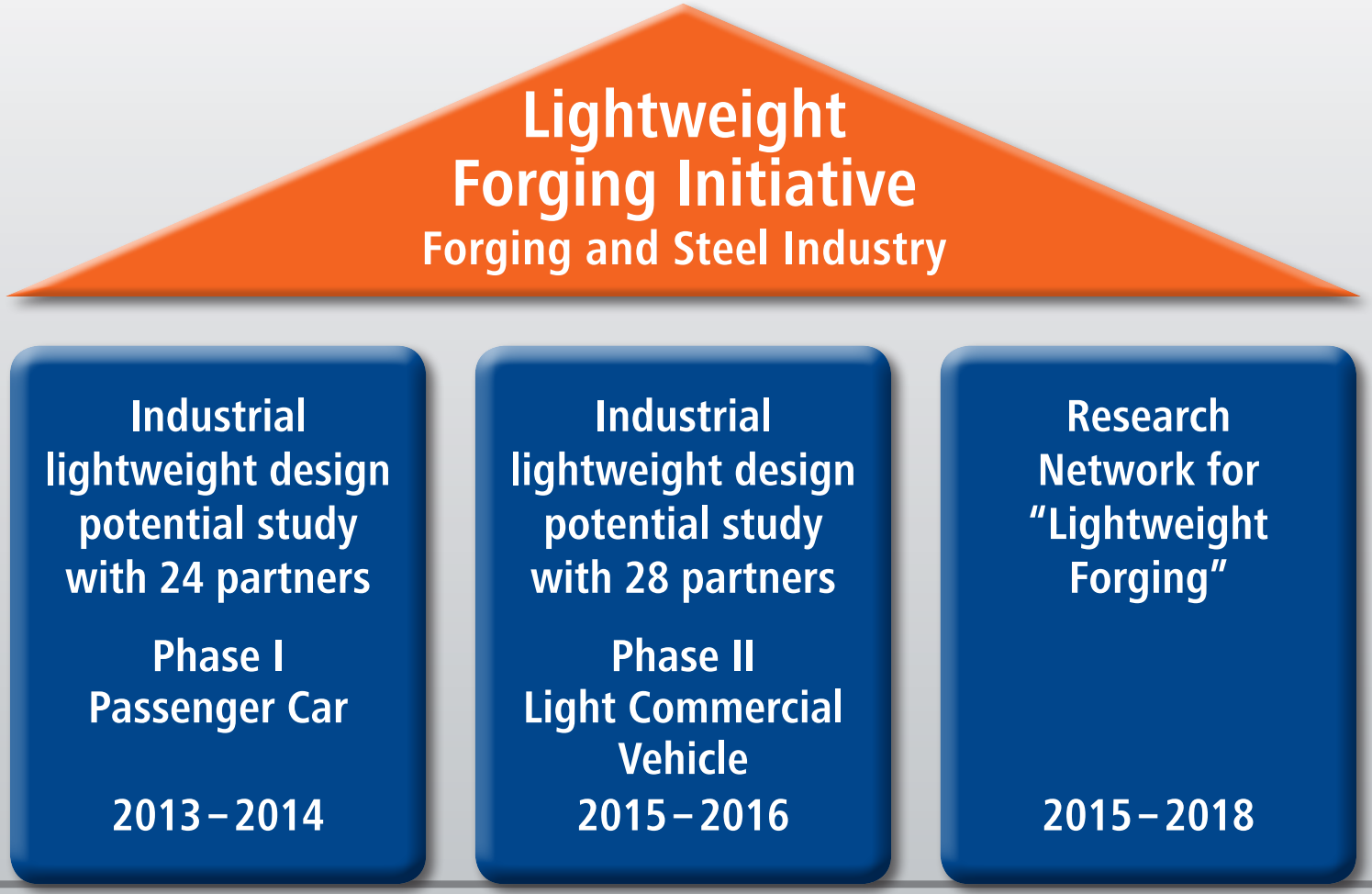

Automotive Lightweight Design with Forging

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- **Phase I (2013 – 2014) – Medium-Sized Passenger Car**
  - 15 forging companies
  - 9 steel manufacturers
  - 42 kg of lightweight design potential through the use and optimization of forged components
- **Phase II (2015 – 2016) – Light Commercial Vehicle (LCV, up to 3.5 t)**
  - 17 forging companies
  - 10 steel manufacturers
  - 1 engineering service provider
  - Focus on part optimization and greater emphasis on new materials in the powertrain and chassis
- **The "Lightweight Forging" Research Network (duration: 3 years from May 2015)**
  - 64 companies from the entire process chain, 4 research associations, 10 research institutes and 2 universities
  - Goal: to render vehicles lighter using modern steel materials as well as through part design and production methods

▶ **Significant reduction in energy consumption and CO_2 emissions through NEW lightweight solutions based on design and material concepts for forged components**

The Consortium of The Lightweight Forging Initiative

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ArcelorMittal

BGH

Buderus Edelstahl

DEUTSCHE EDELSTAHLWERKE
Providing special steel solutions

EZM EDELSTAHLZIEHEREI MARK

FELSS SHORTCUT TECHNOLOGIES

FUCHS

Georgsmarienhütte
GmbH · seit 1856 · Edelstahl

Hammerwerk Fridingen

HAY GROUP

HEWI

Hirschvogel Automotive Group

KAMAX

LSW Lech-Stahlwerke

LEIBER GROUP

metaldyne

NEUMAYER

FUCHS

RG Ruhrtaler Gesenkschmiede
F. W. Wengeler GmbH & Co. KG

saarstahl

sachs engineering
... innovations included!

SCHMIEDETECHNIK PLETTENBERG

SCHONDELMAIER PRESSWERK

LINAMAR SEISSENSCHMIDT FORGING

sona
Driving Tomorrow

SAH Stahlwerk Annahütte

SWISS STEEL
Providing special steel solutions

voestalpine
EINEN SCHRITT VORAUS.

In collaboration with:

fka

IPEK
Institut für Produktentwicklung
am KIT • o. Prof. Dr.-Ing. Dr. h.c. A. Albers

Project Motivation

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Drivers for Innovations in the Powertrain and Chassis of Light Commercial Vehicles

Regulating emissions

- Fleet targets for LCVs for 2017: 175 g CO_2/km
- Target from 2020: 147 g CO_2/km

Entry Restrictions

- Expansions of environmental zones
- Tightening of entry restrictions in cities

Customer Requirements

- Increasing payload
- Loading volume
- Reliability

Cost Reduction

- Economic purchasing decisions of the customers
- Focus on Total Cost of Ownership (TCO)

Main drivers

Secondary drivers

Project Procedure – 1

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Method:

Context Analysis

- Trends and drivers of the LCV industry
- Analysis of the developments in the powertrain
- Overview of public research

Benchmarking

- Systematic disassembly and documentation of a reference vehicle
- Generation of an online documentation tool for documentation and evaluation

Workshops

- Holding facilitated workshops on the powertrain and chassis with experts from the consortium

and in addition …

1. Determining the total vehicle weight

Reference Vehicle:
120 kW / 163 hp
2.1 l Turbo DI diesel engine
Manual transmission, standard drive (rear-wheel drive)
Total mass: 2,394 kg

2. Disassembling the entire vehicle

Combustion engine

Transmission

Differential

3. Listing and naming all individual parts

4. Analysis of individual parts

Bauteilcode	Bezeichnung	Gewicht [kg]	x [m]	y [m]	z [mm]	Bauteilwerkstoff
22202010112	Ölablassschraube (Typ 1) Gehäuse Differential	0,0278	16	16	40	Stahl
22202010113	Differentialträger	5,62	143	252	143	Stahl
22202010114	Kegelrollenlager 1 Differentialträger	0,1968	70	19	70	Stahl
22202010115	Lagerschale Kegelrollenlager 1 Differentialträger	0,0941	75	14	75	Stahl
22202010116	Distanzscheibe Lagerschale Kegelrollenlager 1	0,0143	75	2	75	Stahl
22202010117	Radialwellendichtring (Typ 1) Kegelrollenlager 1	0,0292	83	8	83	Stahl/Kunststoff
22202010118	Kegelrollenlager 2 Differentialträger	0,2865	84	20	84	Stahl
22202010119	Lagerschale Kegelrollenlager 2	0,1328	89	14	89	Stahl
22202010120	Distanzscheibe Lagerschale Kegelrollenlager 2	0,0213	89	2	89	Stahl
22202010121	Radialwellendichtring (Typ 1) Kegelrollenlager 2	0,0297	83	8	83	Stahl/Kunststoff

Project Procedure – 2

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… Transmission modelling

- Transmission model
- Assessment of the influencing variables with the Institute of Product Development (IPEK), Karlsruhe
- Working on permissible steel alternatives
- Assessment of hard and soft influencing factors on transmission design

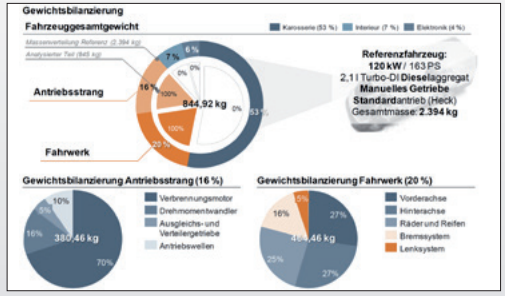
Deriving lightweight design potential

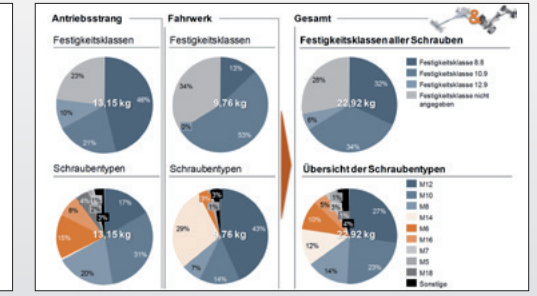
- Identifying the lightweight design potential of forged components
- Implementation in the form of concrete lightweight design proposals

Documentation

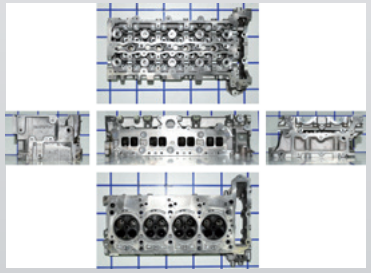
- Accompanying PowerPoint presentation
- Implementation of an online database

5. Weight of assemblies





6. Photo documentation



- ISO views
- Detailed views
- Installation position, where necessary
- Digital removal of manufacturer logo

7. Database implementation with proposals for lightweight design potential

Breakdown of an LCV according to Weight

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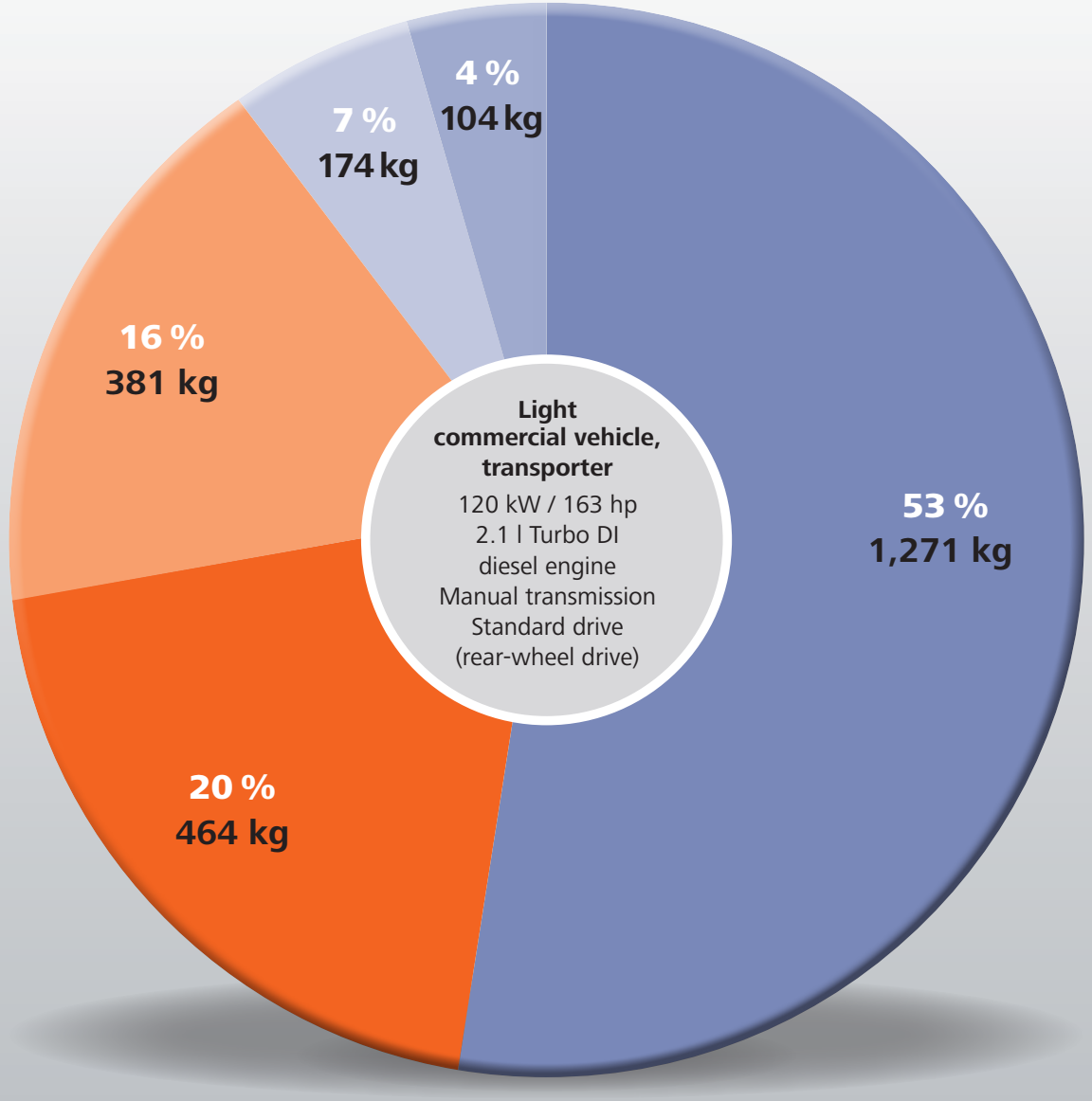

- Car body
- Interior
- Electronics
- **Chassis**
- **Powertrain**

Focus of analysis: 845 kg
Total weight: 2,394 kg

Workshop Overview

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Workshops with several **experts** from **over 30 companies** and **research institutions**

Analysis of **parts** from the **powertrain**, **chassis and transmission** as well as other selected components

Formulation of **535 lightweight design ideas**, which may be subdivided into different lightweight design categories

Main documentation in the **benchmarking database**

▶ In total, a feasible lightweight design potential of 99 kg has been identified for the areas under consideration

Evaluation of the 535 Lightweight Design Ideas

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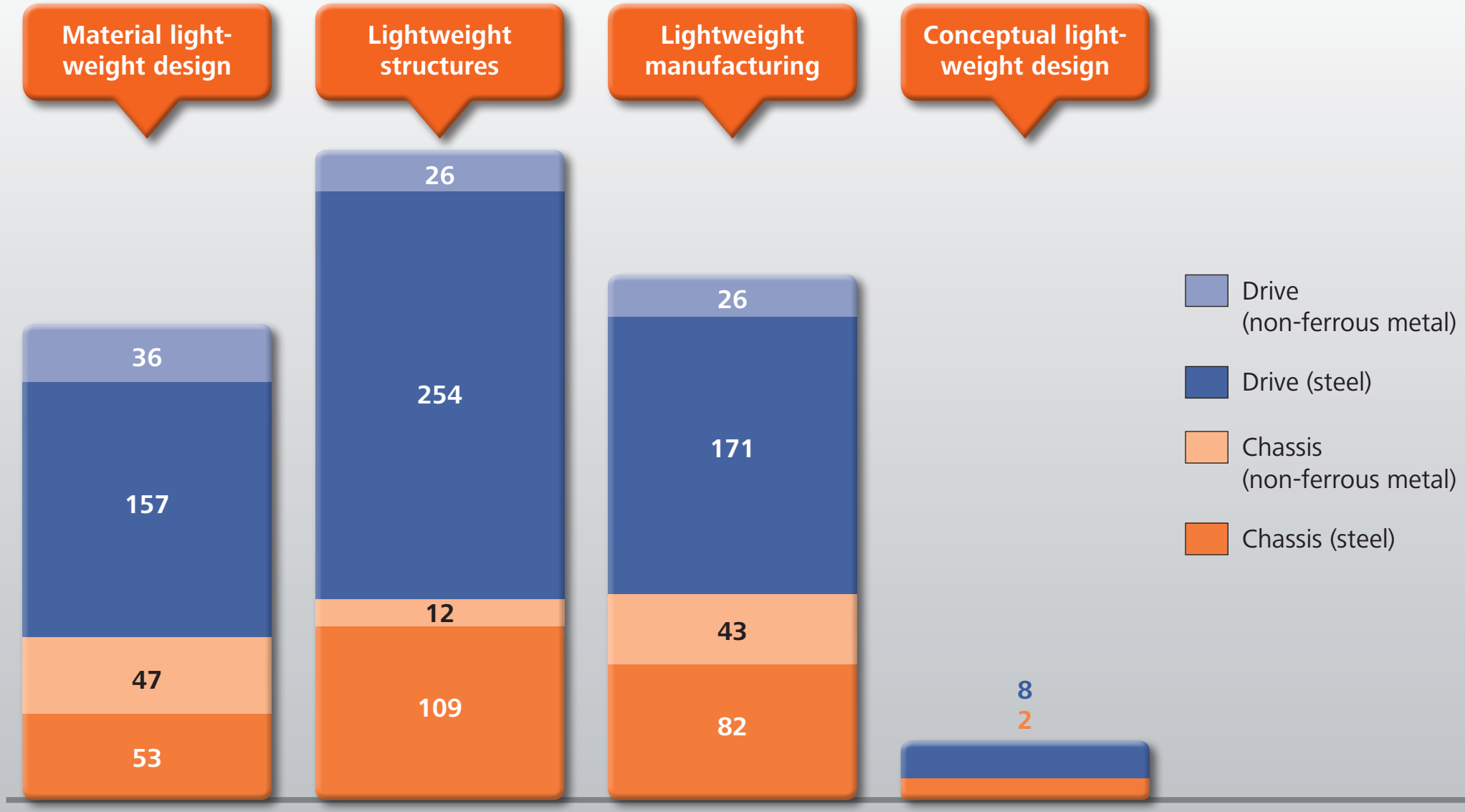

Lightweight ideas may be **assigned to various types of lightweight design at the same time.**
The use of a new material may lead to an adapted manufacturing process, for example.

Portfolio Chart of the Lightweight Design Ideas

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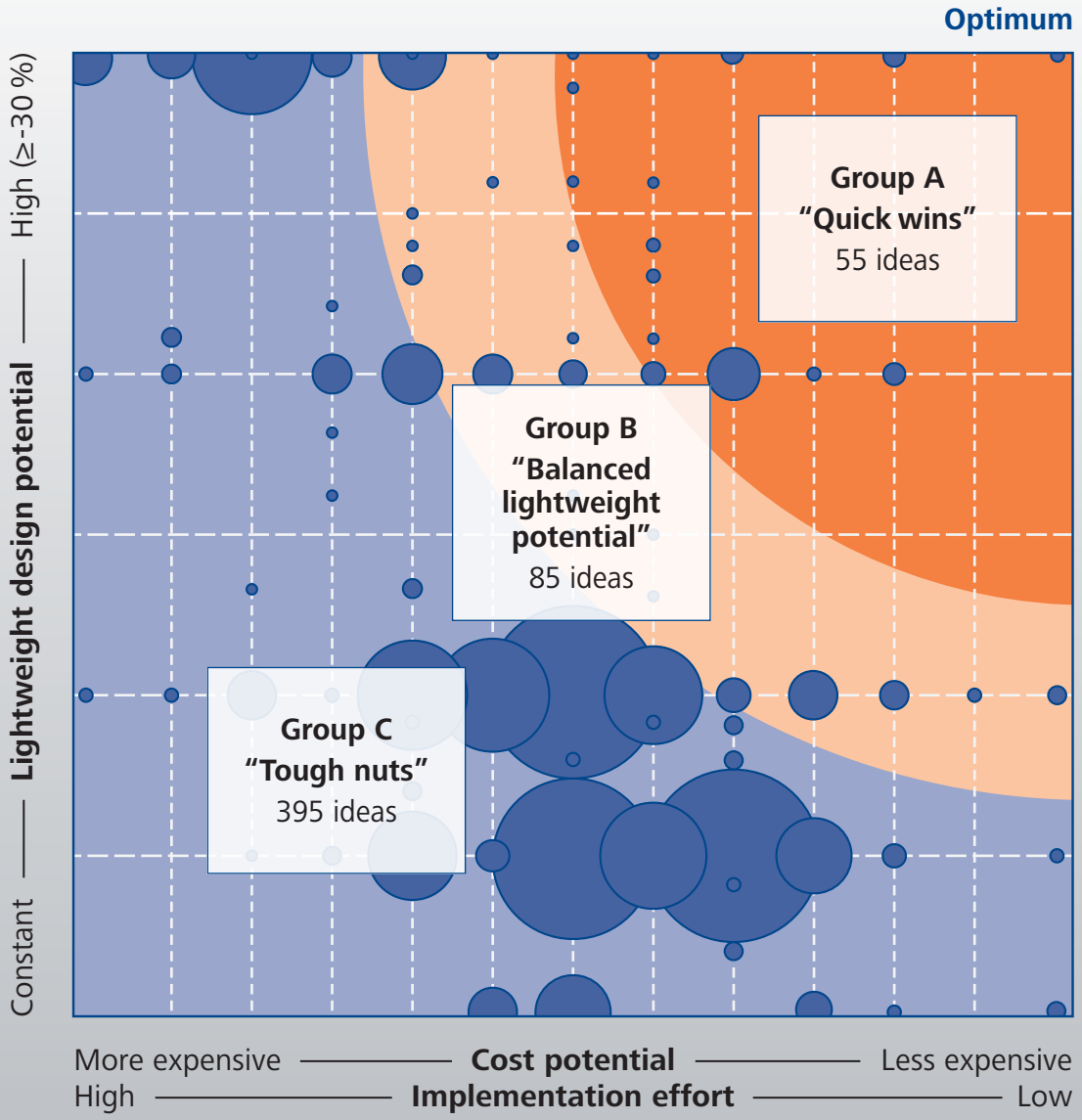
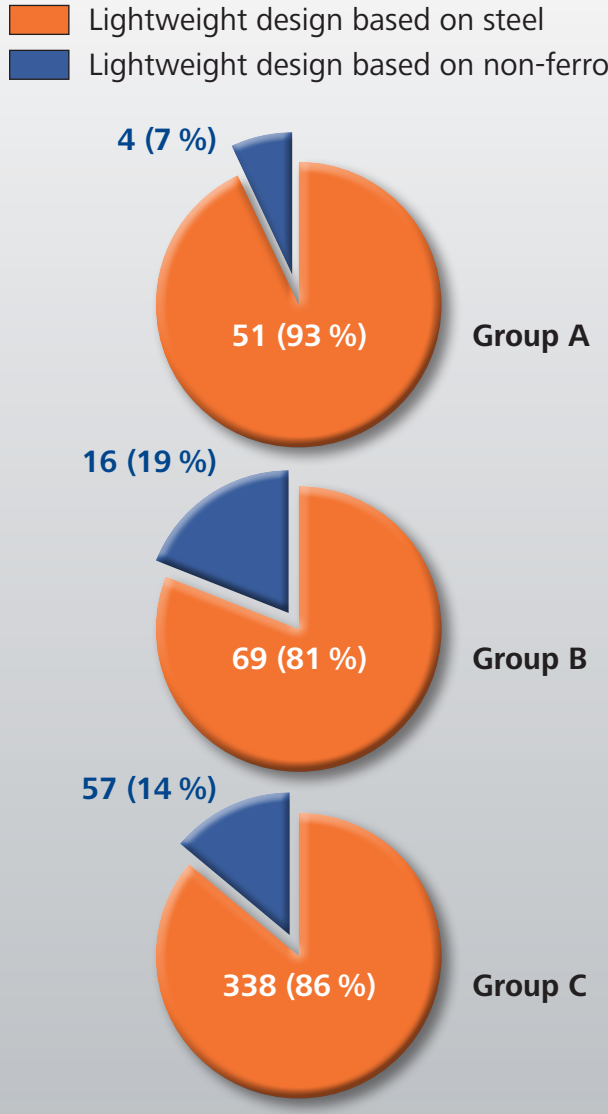


The blue circles show the number of ideas in this point.

Breakdown of the ideas based on material



Source: fka for Phase II of The Lightweight Forging Initiative

Portfolio Chart Evaluation …

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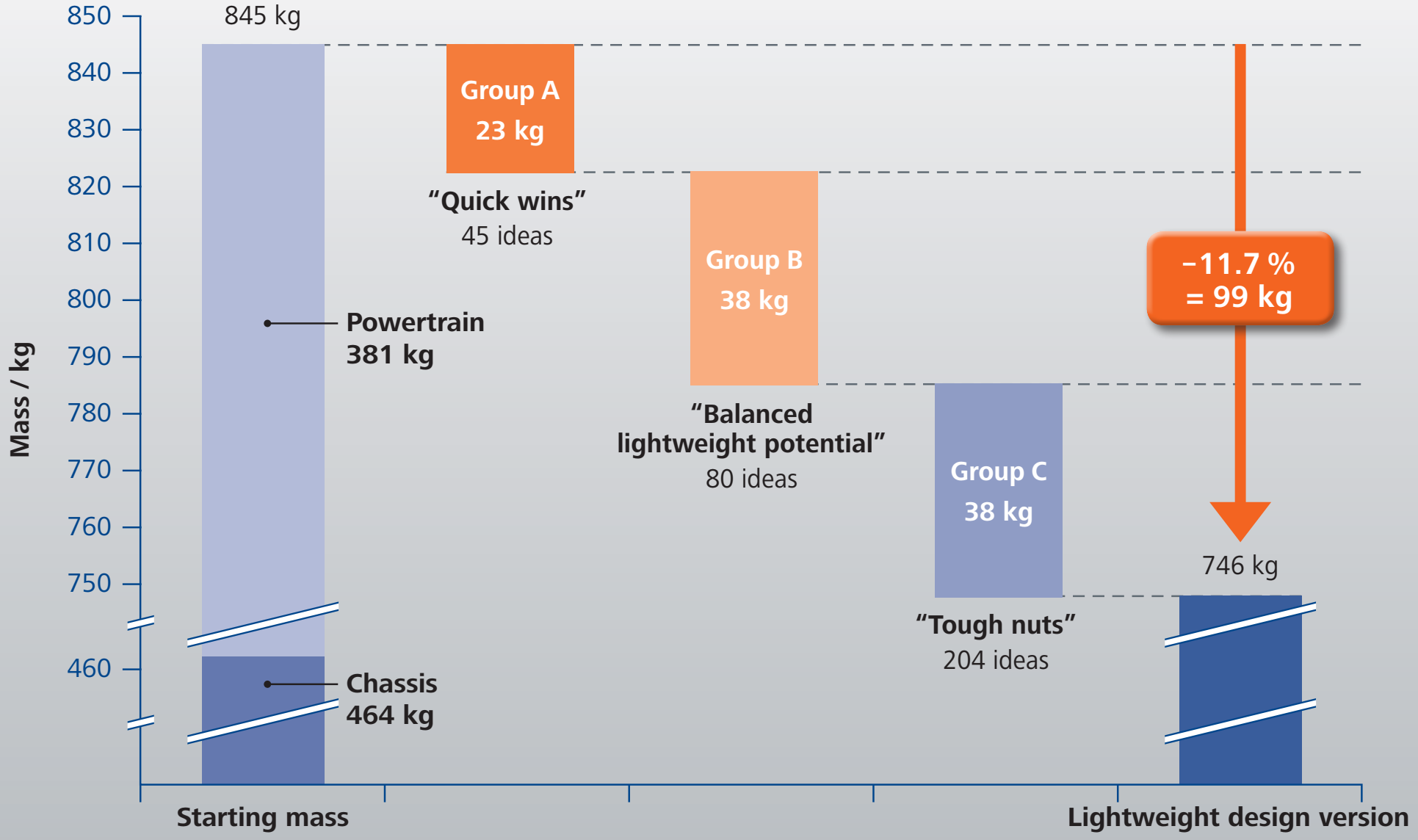
… according to lightweight design potential, costs and implementation effort



Source: fka for Phase II of The Lightweight Forging Initiative

Selected Lightweight Design Potential

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Lightweight Design in the Engine

The percentages in the examples state how much heavier (in %) the current part is compared to the lightweight design proposal.

Connecting Rod

Series

C70S6mod

$R_{p0.2}$ = 650 MPa

R_m = 1,000 – 1,150 MPa

Potential

46MnVS6

$R_{p0.2}$ = 750 MPa

R_m = 1,000 – 1,150 MPa

Δm = 63 g (10 %)

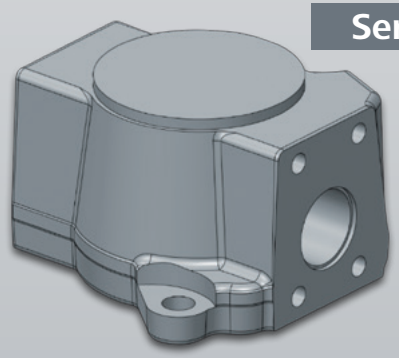
Crankshaft

- Bainitic steel (e. g. 32MnCrMo6-4-3)
- Drill holes through connecting rod bearing
- Load-adapted design (bending torque variable across the length)

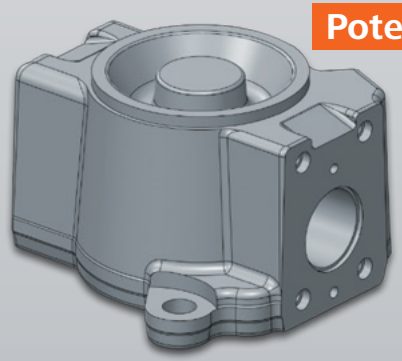
Δm = 10 – 20 % (of 16.54 kg)

Diesel Pump Housing

Series



Potential

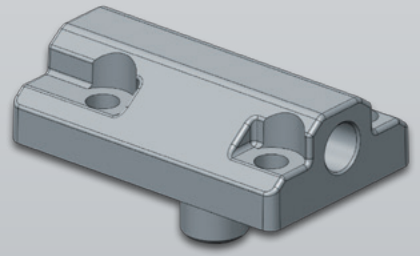


Δm = 281 g (18 %)

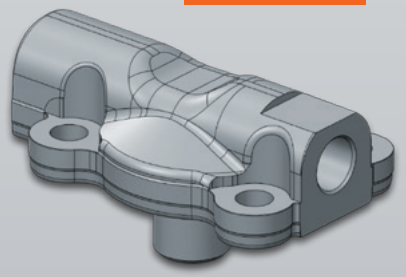
- Remove unnecessary material
- More filigree, lighter forged part

Diesel Pump Cover

Series



Potential



Δm = 77 g (36 %)

Sources (from top left in clockwise direction): Schmiedetechnik Plettenberg, GMH, Saarstahl, sachs engineering, Hirschvogel Automotive Group

Selected Lightweight Design Potential

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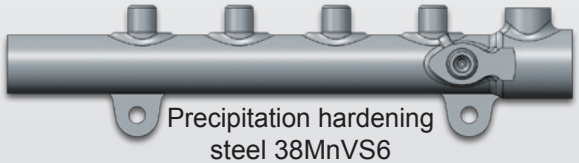
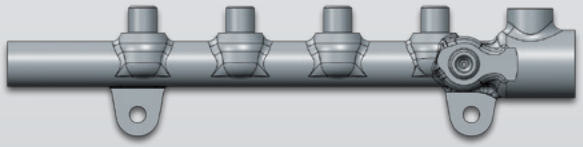
Lightweight Design in the Engine and Transmission

Common Rail

Series



Potential

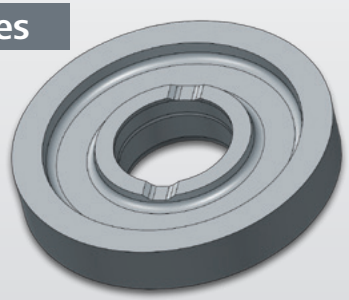


- Reduce external contour in a load-adapted way
- Use higher strength bainitic steel (16MnCrV7-7)
- Other bainitic steels which can be used for series parts: 32MnCrMo6-4-3, 20MnCrMo7

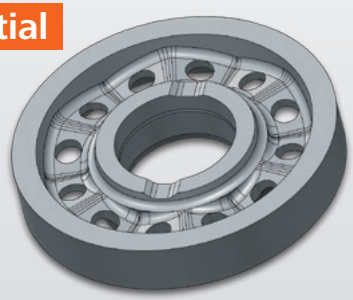
Δm = 293 g (28 %)

Gearwheel of the Output Shaft

Series



Potential

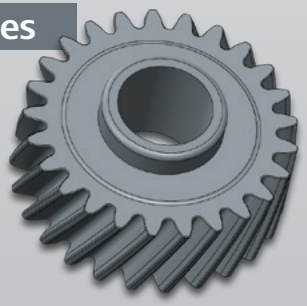


- Produce holes on pitch circle
- Fixed member with wave profile, thinner fixed member

Δm = 294 g (21 %)

Gear: Countershaft

Series



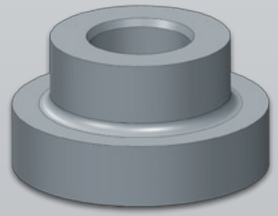
Potential

- Weight savings through front-side forged concave shape

Δm = 134 g (8 %)

Gearwheel of the Countershaft

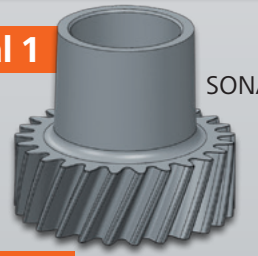
Series



- Reduce wall thickness on the cone

Δm = 355 g (37 %)

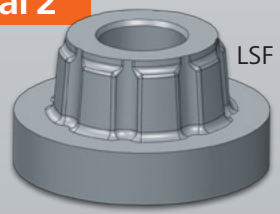
Potential 1



- Recesses, e. g. grooves with a depth of 10 x 2 mm
- Steel rim, internal ring as composite metal material

Δm = 116 g (10 %)

Potential 2



Sources: Hirschvogel Automotive Group, GMH, Saarstahl, EZM, Linamar Seissenschmidt (LSF), SONA BLW Group

Selected Lightweight Design Potential

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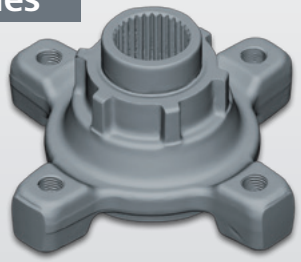
Lightweight Design in the Transmission

Output flange

Series



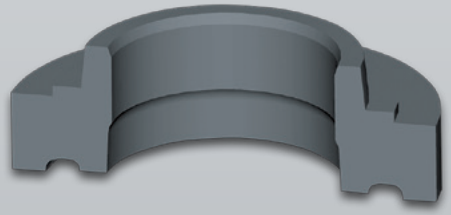
Potential

- Lower wall thicknesses, modern fastenings, slanted splines

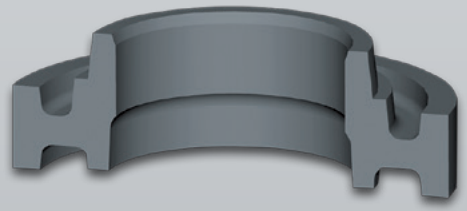
Δm = 129 g (9 %)

Gearwheel

Series



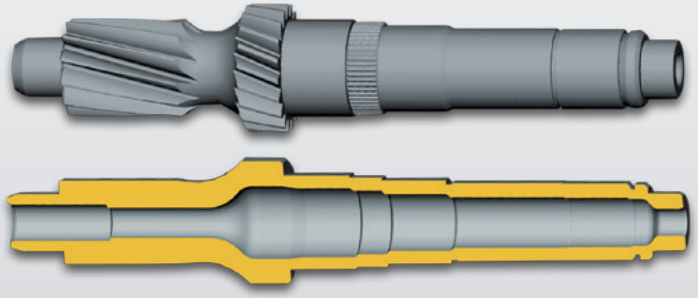
Potential



- Lower wall thicknesses and deeper grooves

Δm = 322 g (29 %)

Countershaft Type 1



Series

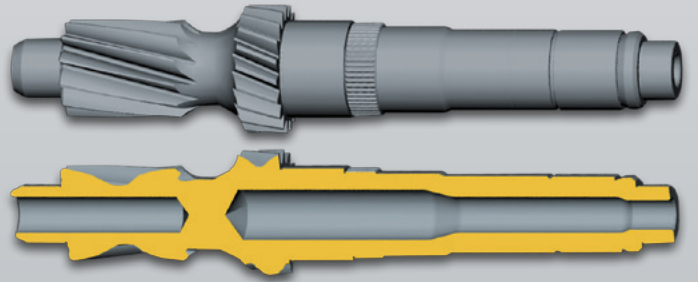
Solid shaft
25MoCrS4

Potential

- Shaft swaged from extruded billet
- Use of higher-strength steel 14NiCrMo13-4 possible

Δm = 1,533 g (57 %)

Countershaft Type 2



Series

25MoCrS4

Potential

- Hollow shaft with internal undercut produced through a combination of forming – drilling – forging
- Higher load-bearing capacity possible with sulphur-free type 25MoCr4

Δm = 882 g (26 %)

Sources: Hammerwerk Fridingen, Felss Group, Stahlwerk Annahütte, Hirschvogel Automotive Group, GMH, Linamar Seissenschmidt

Selected Lightweight Design Potential

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Lightweight Design in Other Areas of the Powertrain (Differential)

Differential

Series

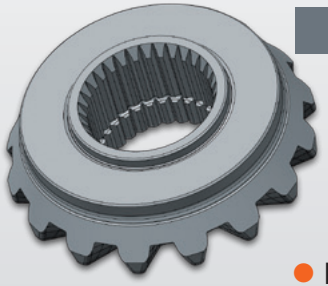
Potential

- 4-bolt instead of 2-bolt design → 6 instead of 4 bevel gears

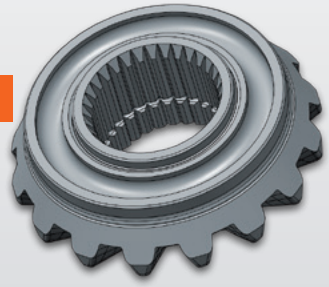
Δm Diff wheels = 194 g (14 %)
Δm Diff housing = 642 g (11 %)

Balancer Shall Differential

Series



Potential



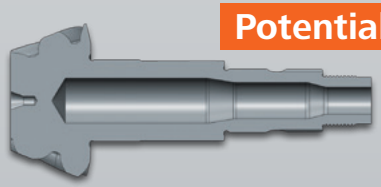
- Remove flash
- Generate ring
- Provide holes in splines

Δm = 41 g (8 %)

Drive Pinion Differential Transmission

Series

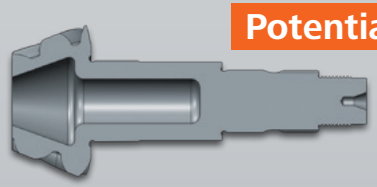
Potential 1



- Cold forging, drilling, hollow extrusion

Δm = 506 g (25 %)

Potential 2



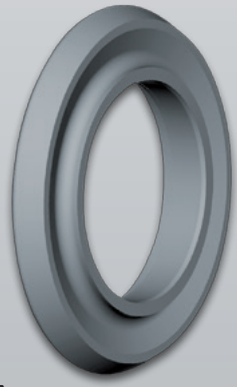
- Cold forging, drilling, hollow upsetting of the head

Δm = 610 g (31 %)

Differential Ring Gear

Series

Potential



- Groove on the rear side of the gear

Δm = 317 g (8 %)

Sources: Metaldyne, Linamar Seissenschmidt, HAY|Group, Hirschvogel Automotive Group

Selected Lightweight Design Potential

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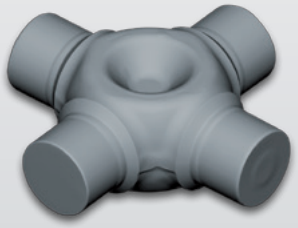
Lightweight Design in Other Areas of the Powertrain (Drive Shaft)

Yoke

Series



Potential 1

- Radial drilled bolt holes
- Centred hole

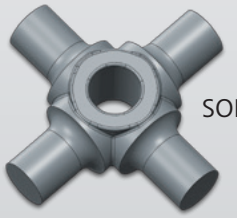
Δm = 88 g (15 %)

HF

Potential 2

- Centred hole

Δm = 55 g (9 %)



SONA

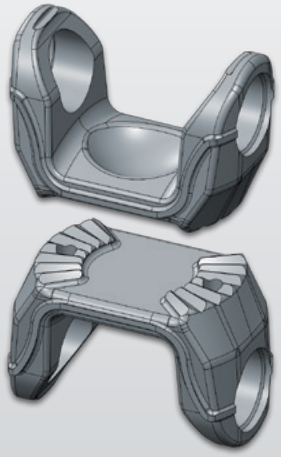
Yoke Part 1 Drive Shaft

Series

Potential

- Eliminate flange corners
- Connection via Hirth gears

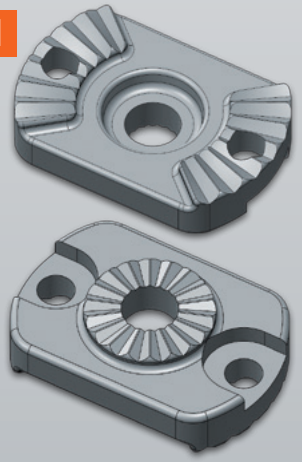
Δm = 244 g (29 %)



Companion Flange Drive Shaft

Series

Potential



- Eliminate hub area and flange corners
- Connection via Hirth gears or alternatively via splines

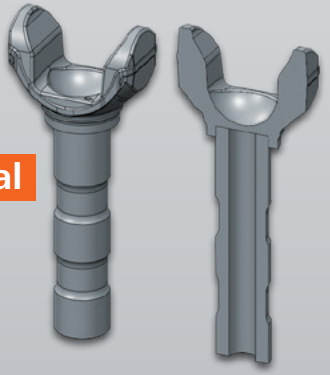
Δm = 388 g (111 %)

Yoke Part 2 Drive Shaft

Series

51CrV4

Potential



- Non-continuous splines
- Weld part 1 and part 2
- Use of higher-strength heat-treatable steel 30CrNiMo8 possible

Δm = 564 g (36 %)

Sources: Hammerwerk Fridingen (HF), SONA BLW Group, Linamar Seissenschmidt, Stahlwerk Annahütte

Selected Lightweight Design Potential

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Lightweight Design in the Chassis

Piston Rod Front Damper

Series

Potential

- Swaged hollow part replaces solid part

Δm = 867 g (124 %)

Nuts (General)

Series

20MnB4
quenched and
tempered

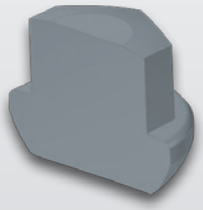
Potential

- New patented geometry
- Use of bainitic steel which achieves high strength without quenching and tempering

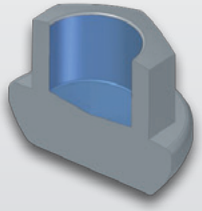
Δm = 6 g/nut (30 %)

Fasteners (general)

Series



Potential



Δm = 12 g/fastener
→ 24 fasteners/vehicle
= 288 g/vehicle

- In addition, steels with a higher strength class may be used (14.9 instead of 8.8)

Δm = 0.52 g – 10.2 g (size of head 10 – 27 mm)
→ Δm = 700 g for entire vehicle

Series

Potential

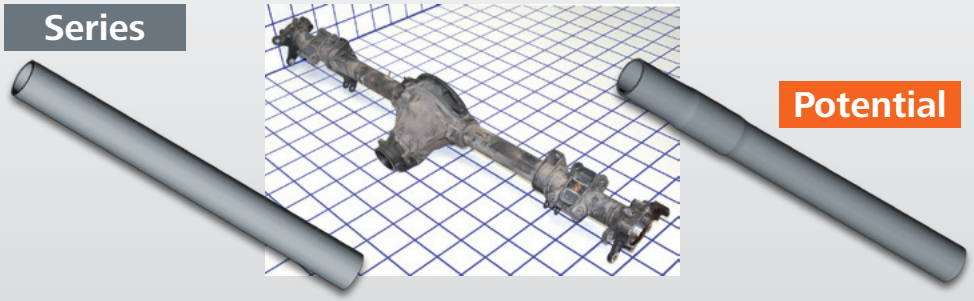
Sources: Felss Group, Kamax Automotive, Fuchs Schraubenwerk, DEW, HEWI

Selected Lightweight Design Potential

Lightweight Design in the Chassis

Rear Axle

Series



Potential

- Replace tube of constant wall thickness with higher-strength steel of uneven wall thickness

Δm = 2,520 g (44 %) (times two for the entire axle)

Brake Piston

Series S235JR

- Reduced wall thickness of the brake piston (from 4.8 to 3.5 mm) and use of higher-strength steel, e.g. precipitation hardening steel 27MnVS6

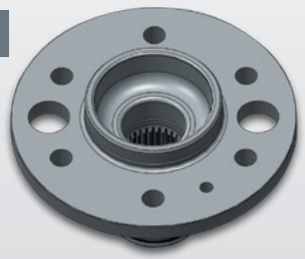
Potential

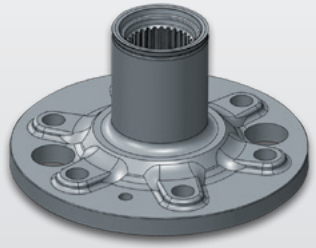
Δm = 102 g (35 %) (four times in the car)

Wheel Hub

Series

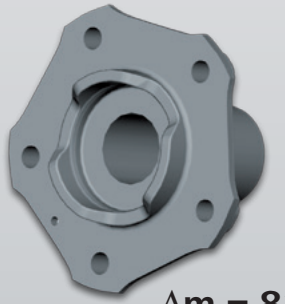
C56E2



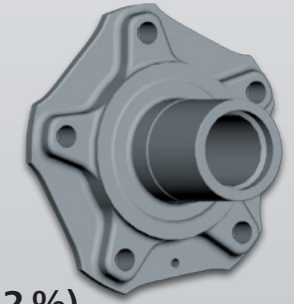


- Various geometry optimizations
- In addition, higher-strength dispersion-hardening steel or 100Cr6 may be used

Potential 1

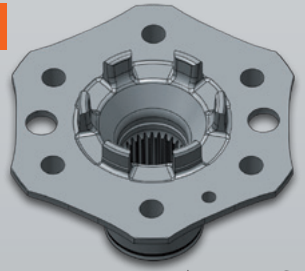


LSF

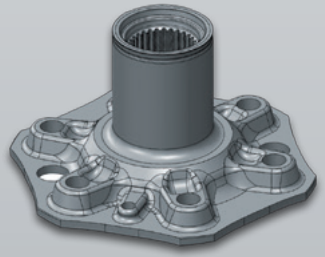


Δm = 817 g (32 %)

Potential 2



HiVo



Δm = 874 g (35 %)

Sources: voestalpine Metal Engineering, Saarstahl, Linamar Seissenschmidt (LSF), Hirschvogel Automotive Group (HiVo), Schondelmaier Presswerk, DEW

Selected Lightweight Design Potential

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Lightweight Design in the Chassis – Al

Support Beam Subframe

Series

Potential

- Replace sheet-metal part with forged extruded profile made of Al

Δm = 790 g (42 %)

Wheels

Series

Potential

- Replace sheet metal with forged aluminium

Δm = 2,620 g (29 %)

Leaf Spring Locking

Series

Potential

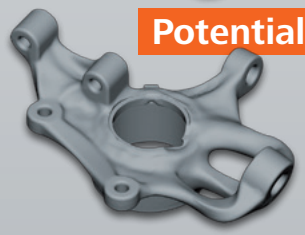
- Replace cast part with Al forged part

Δm = 770 g (181 %)

Steering Knuckle

Series

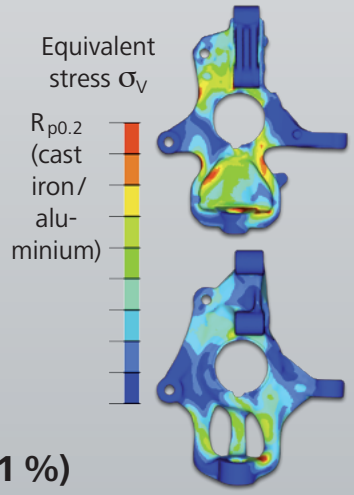
Potential



- Replace cast iron steering knuckle with bionically optimized Al forged component

Equivalent stress σ_V

$R_{p0.2}$ (cast iron / alu-minium)



Δm = 4,438 g (161 %)

Sources: Otto Fuchs, Leiber Group

High-Strength Steels

Wide Spectrum of Steels –
Steels with high Strength and high Toughness

- Steel variety offers use-oriented lightweight design
- Combination of high strength and high toughness leads to material lightweight design
- Steel family trees allow for a product based material selection

Properties of Rod Steel

Microstructure dependent strength and toughness of rod steel

Family Tree "High Strength Special and Alloyed Steels"*

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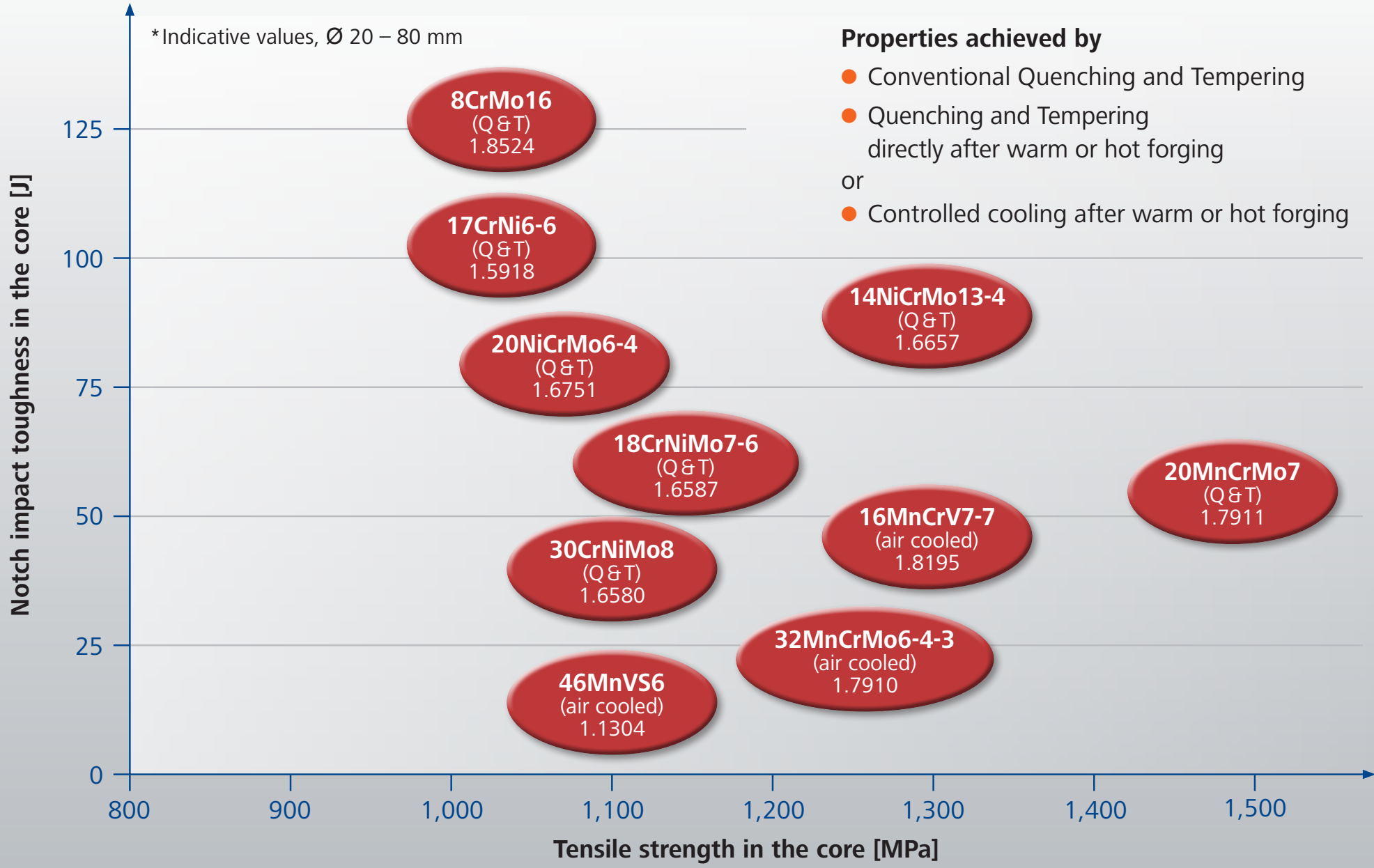
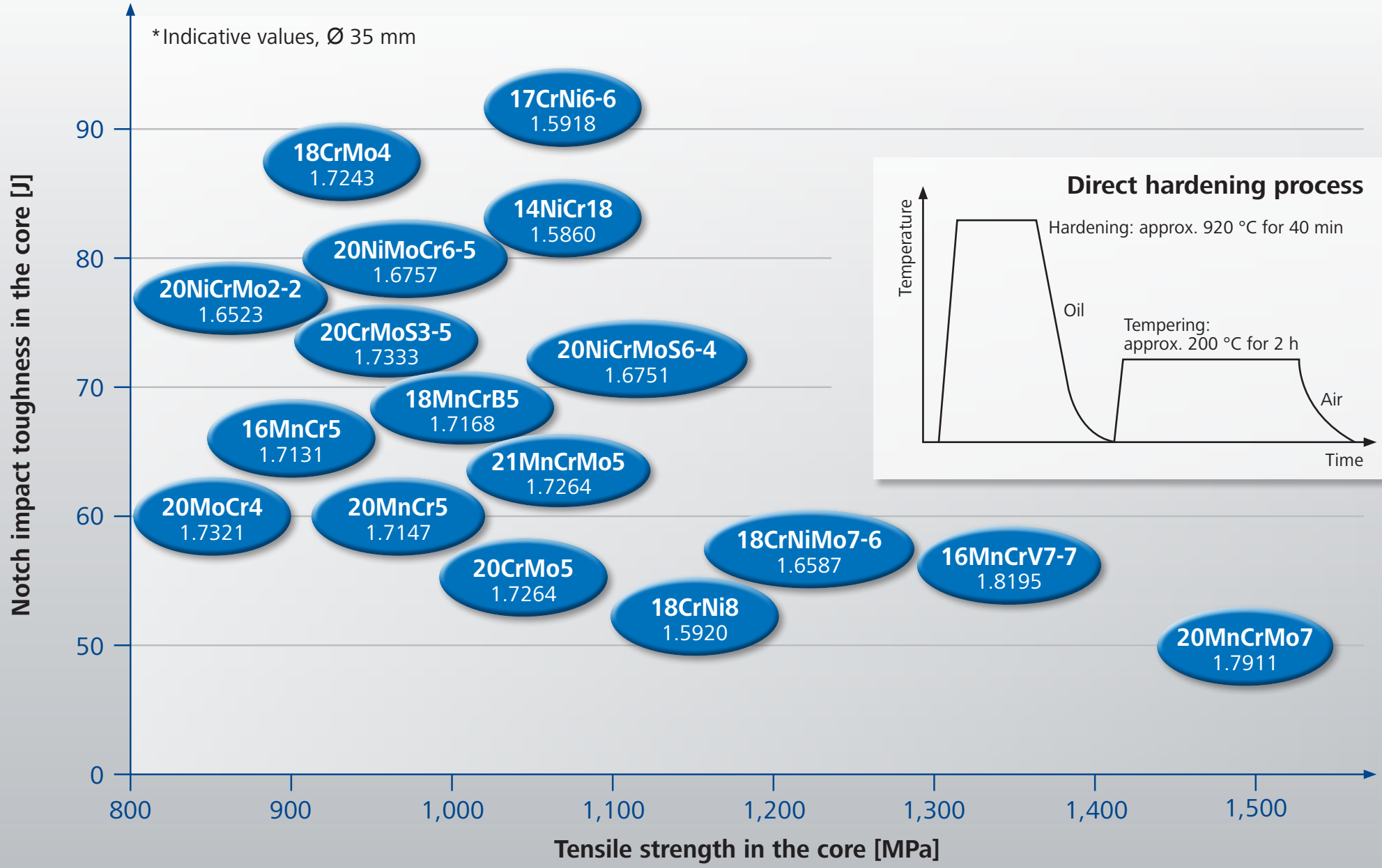


Family Tree "Carburizing Steels"*



Family Tree "Quenched and Tempered Steel"*

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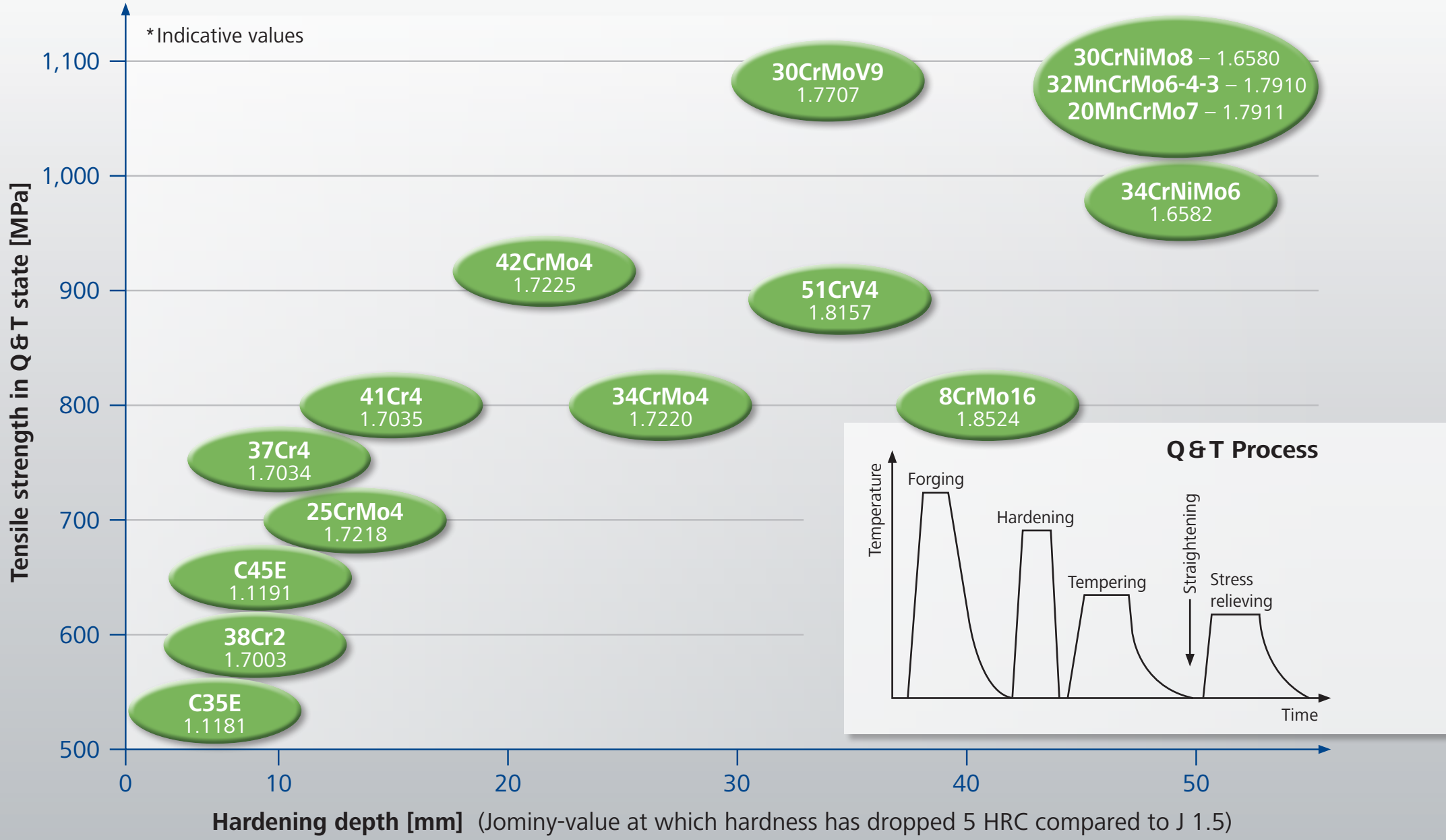


Lightweight Design with High-Strength AFP Steels

Lightweight Design in the Engine

Connecting Rod

Series

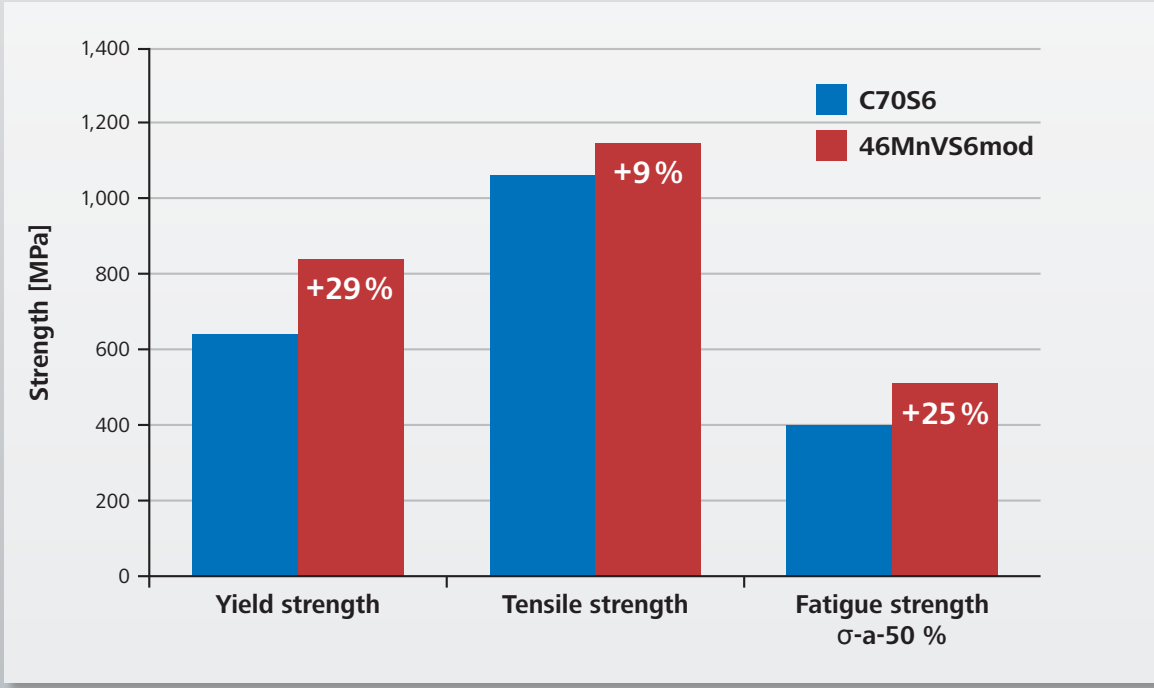
- C70S6
- Shaft cross section 119 mm²

Δm = 28 g (10 %)

Potential

- 46MnVS6mod
- Shaft cross section 92 mm²

- Increase of strength properties **due to optimized micro-alloying concept**
- Shaft cross section of a connecting rod is reduced **from 119 mm² to 92 mm²** at a **constant safety factor** especially due to an **increased fatigue strength**



Sources: GMH, Mahle Motorkomponenten GmbH

Higher-Strength Steel for Lighter Transmissions

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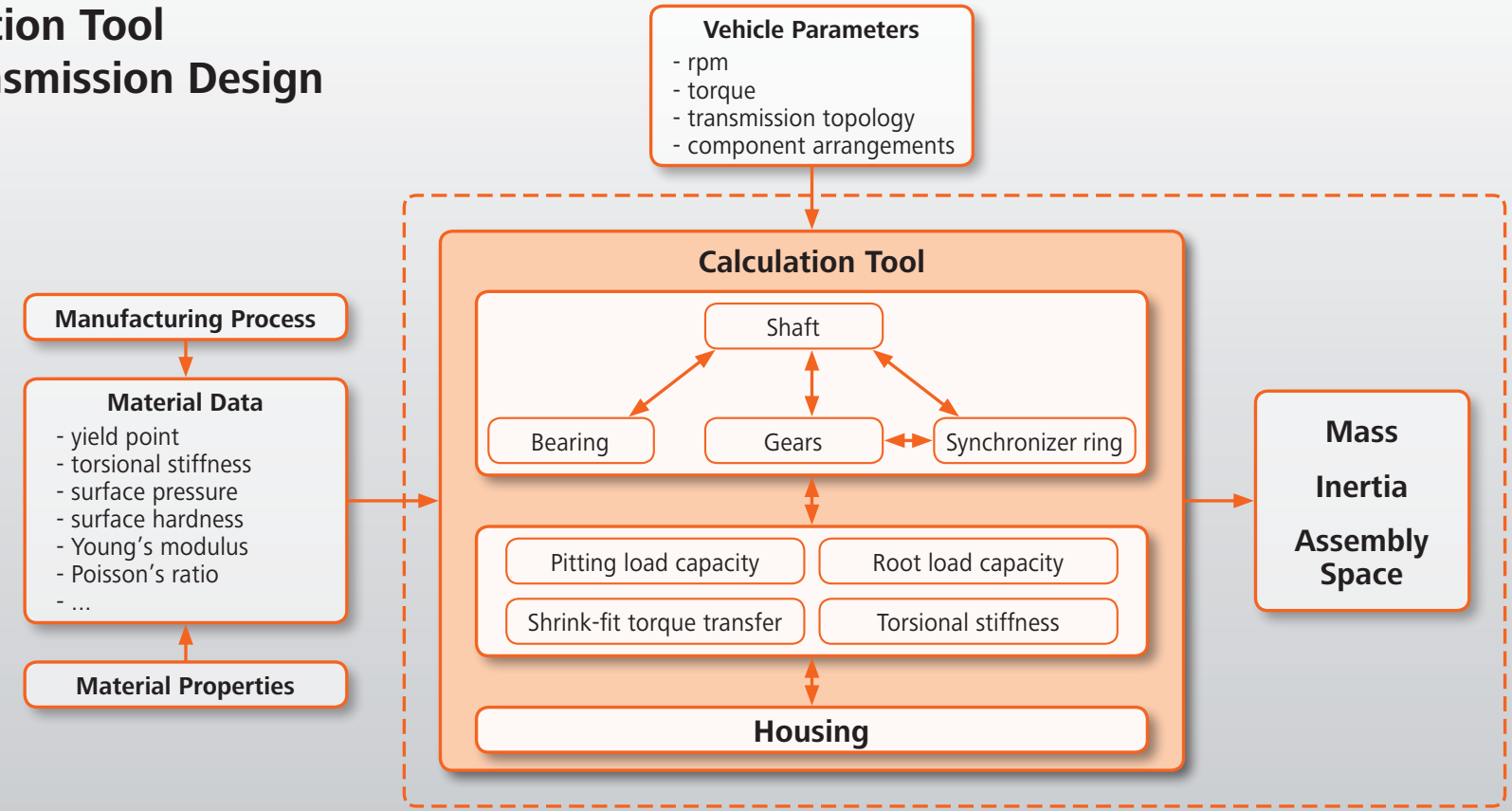
Calculation Tool for Transmission Design



- Generation of a model for estimated design / weight calculation of transmissions
- Model generated and compared for:
  - 6-speed manual transmission light commercial vehicle, 20MoCr4 / 25MoCr4
  - 6-speed double-clutch transmission passenger car, 20NiMoCr6-5
- Assessing the influence of the mechanical parameters on the transmission design
- Analysis of the real influences of higher-strength steels
- Assessment of the "soft factors" from the transmission standard ISO 6336, Part 5

Higher-Strength Steel for Lighter Transmissions

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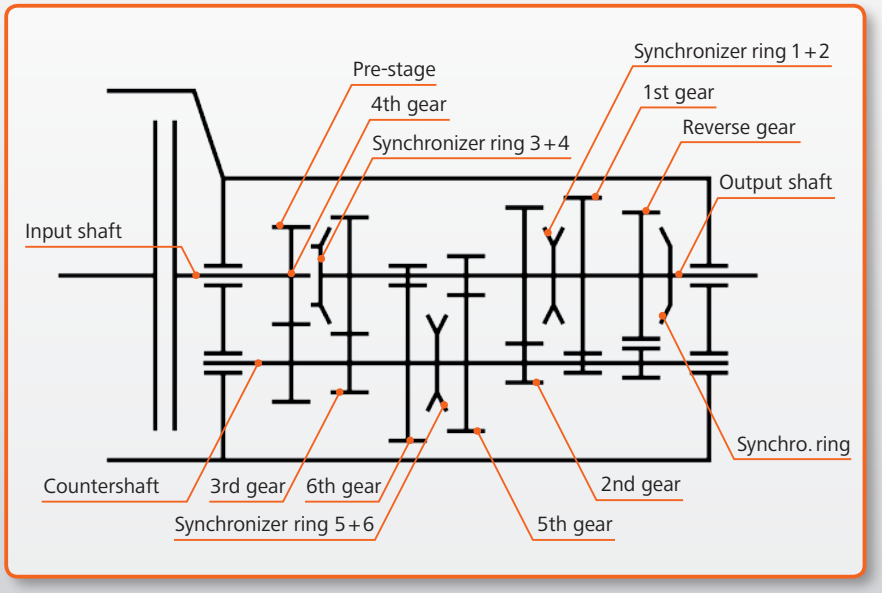
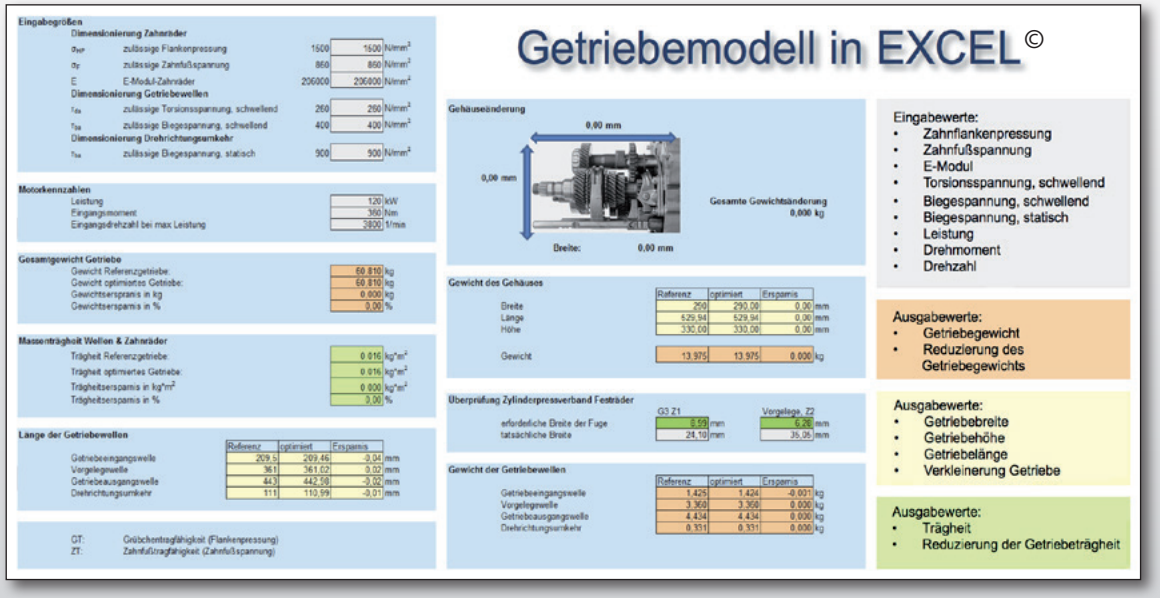
Lightweight Transmission through Alternative Materials



Transmission components to be calculated with the material **20NiMoCr6-5** used in the passenger car



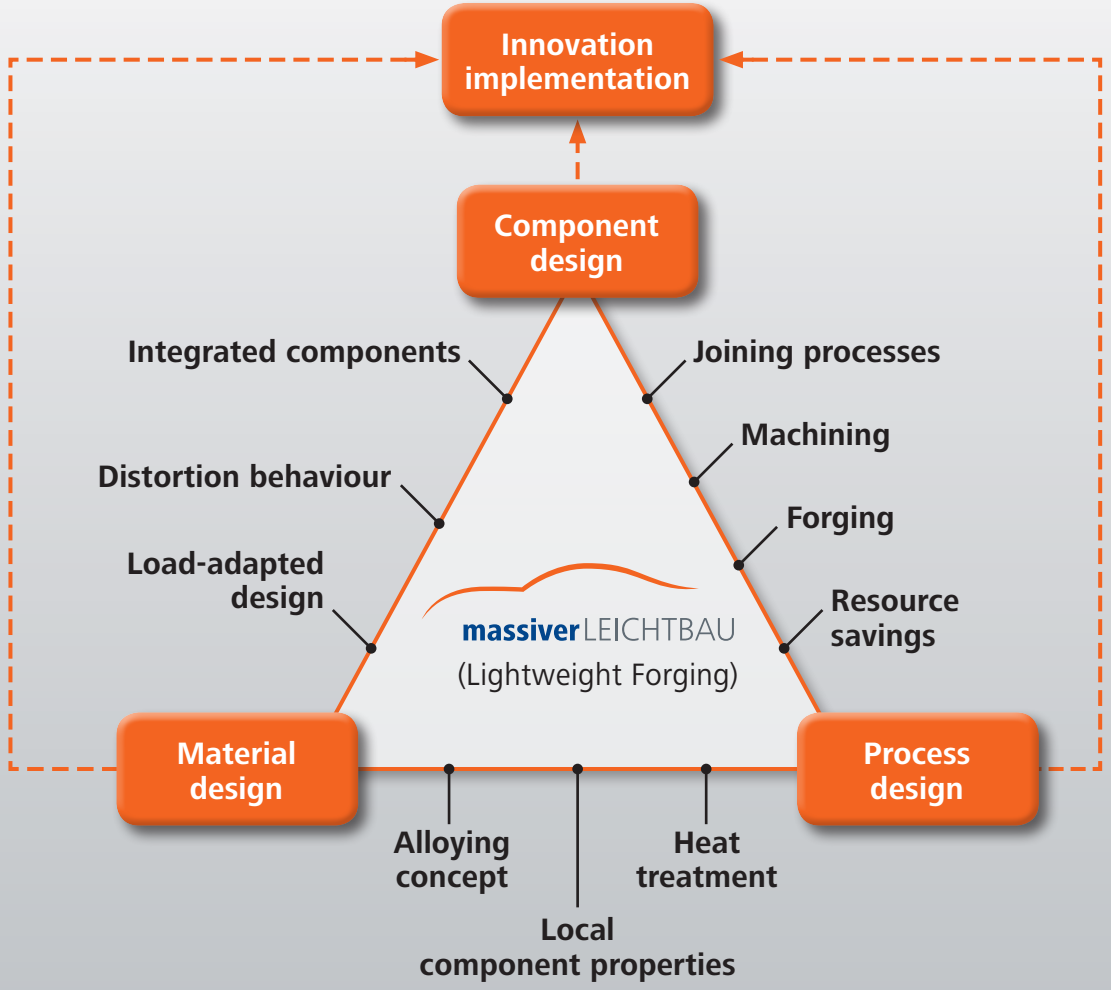
Generation of a model for estimated design / weight calculation of transmissions (in German)

- If the material properties of **20NiMoCr6-5** are used in the transmission model of the light commercial vehicle, a weight-savings potential of **2.45 kg** is generated
- Additional costs for higher-strength steel lead to **weight savings of less than €1 per kg**
- Besides this, the model shows that a further increase in the strength of transmission steels could lead to additional weight savings

Sources: Karlsruher Institute of Technology (KIT), IPEK – Institute of Product Engineering at KIT

Outlook …

The “Lightweight Forging” Research Network



The Research Network “Lightweight Forging – Innovation Network for Technological Progress in Part, Process and Material Design for Forged Parts in Automotive Technology” was generated from the idea competition “Leading Technologies for SMEs” of the Federal Ministry for Economic Affairs and Energy / Pre-Competitive Cooperative Industrial Research (BMWi-IGF) via the German Federation of Industrial Research Associations (AiF).

▶ Goal: Using new steel materials as well as part designs and production methods to render even the vehicle powertrain lighter – from the engine to the transmission and wheel bearings, while nevertheless fulfilling the most stringent service life requirements.

Outlook …

The Research Associations

The Research Network has been supported since 01.05.2015 by …

FOSTA Research Association for Steel Application (Forschungsvereinigung Stahlanwendung e. V.) – Lead Institution

Heat Treatment and Material Engineering Association (Arbeitsgemeinschaft Wärmebehandlung und Werkstofftechnik e. V., Bremen)

Research Association for Drive Technology (Forschungsvereinigung Antriebstechnik e. V., Frankfurt)

Research Association of Steel Forming (Forschungsgesellschaft Stahlverformung e. V., Hagen)

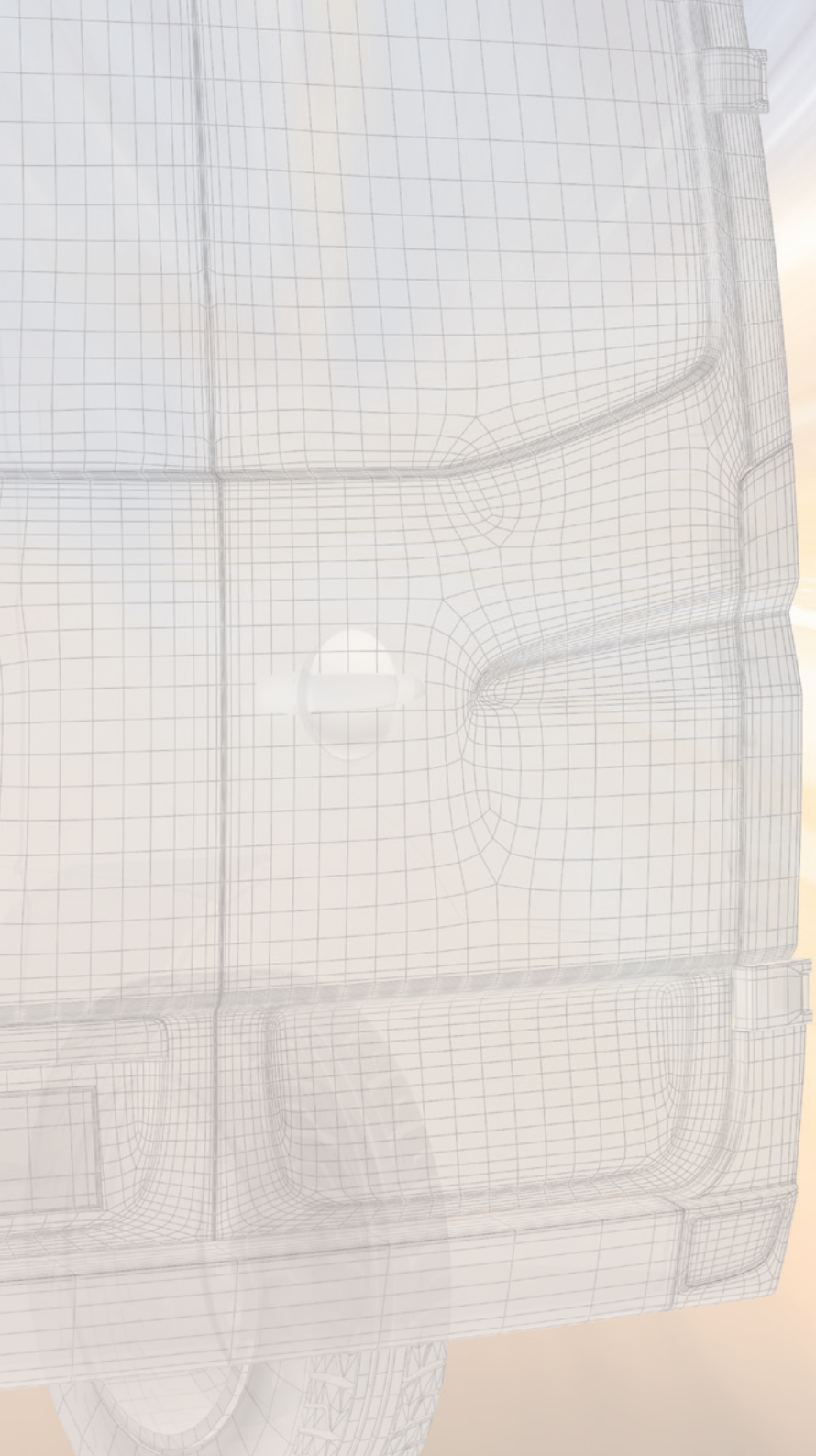
… from funds of the Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie – BMWi) via the German Federation of Industrial Research Associations (Arbeitsgemeinschaft industrieller Forschungsvereinigungen "Otto von Guericke" e. V. – AiF). The duration of the undertaking is 3 years.

Additional lightweight design potential based on the results from Phase I and II may be expected in approx. two years. Further results will be guaranteed once scientific validation of the dynamic load of new materials has been obtained from the five research projects started in May 2015. The Lightweight Forging Initiative anticipates more weight-optimization possibilities from the Research Network.

Transfer of Findings

- Current information at **www.lightweightforging.com**
- Publications
- Presentation events
- Customer Conference “Lightweight Forging in Vehicles”
  on 31 May and 1 June 2016, Mövenpick Hotel Stuttgart Airport & Messe
- **Contact:**
  Industrieverband Massivumformung e. V.
  Dorothea Bachmann Osenberg
  Telephone: +49 2331 958830
  E-mail: info@massiverleichtbau.de

Notes



The Lightweight Forging Initiative –
a cooperation of the Steel Institute VDEh (Stahlinstitut VDEh) and
the German Forging Association (Industrieverband Massivumformung e. V.)

Further information: **info@massiverLEICHTBAU.de** and **Tel. +49 2331 958830**
as well as on the Internet at **www.lightweightforging.com**