Lightweight solutions in the area of springs and shock absorbers

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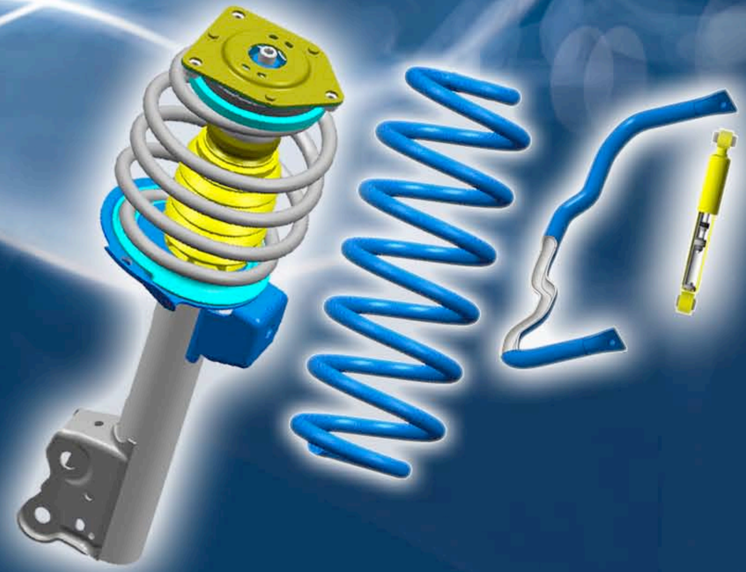
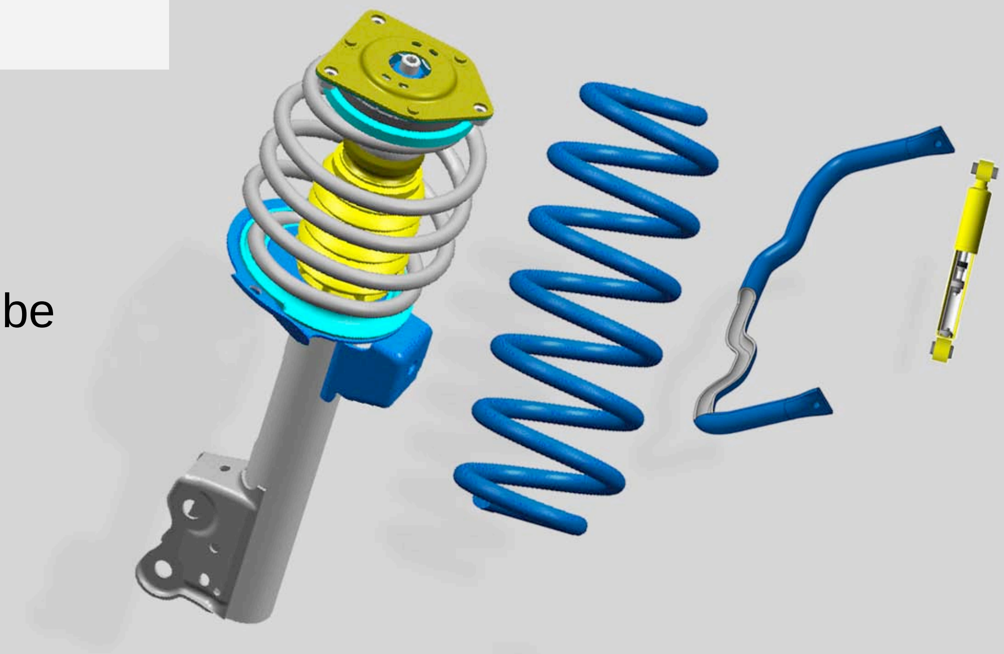


A Company of
ThyssenKrupp
Technologies

ThyssenKrupp Bilstein of America

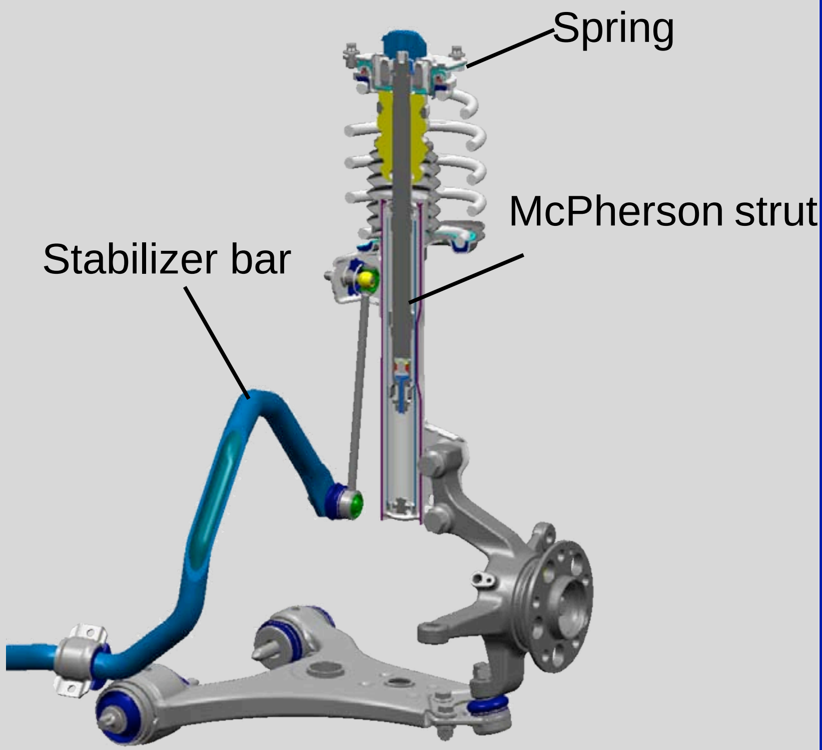
Agenda

- Motivation
- Lightweight strut
- High-strength springs
- Lightweight stabilizer bar
- Substituting monotube for twin-tube shocks
- Conclusion



Motivation

- Reduce weight while maintaining part functionality
- Reduce unsprung masses
- Improve initial suspension response
- Increase ride comfort
- Reduce fuel consumption
- Contribute to meeting our customers' CO_2 targets



McPherson front axle (A/B class)

▶Reduced fuel consumption and enhanced functionality for passenger cars

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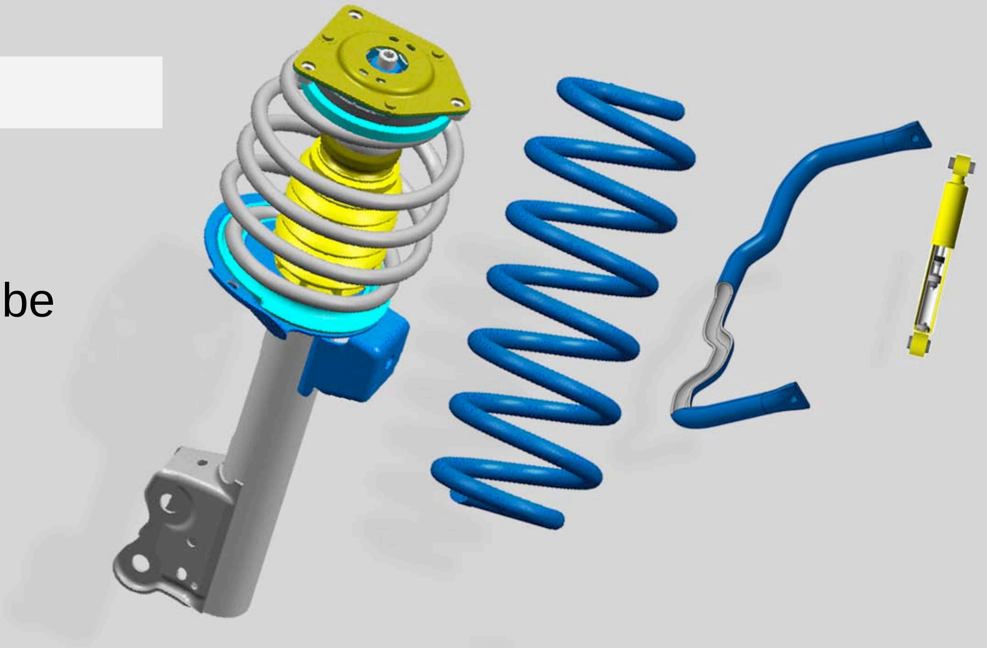
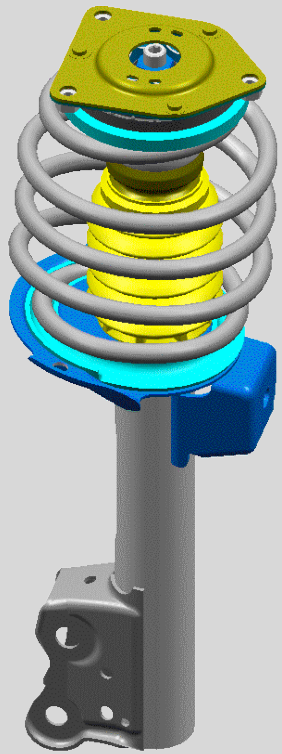


Lightweight strut

Use of high-strength steels and assembled piston rods

- McPherson struts: compact, low-cost spring damping systems
- Fitted in approx. 85% of all cars
- Average total weight approx. 6 kg, the steel share of the shock absorber (w/out spring) is approx. 2.5 kg
- Structural components can be built up to 20% lighter using high-strength steels
- Hollow assembled piston rods allow a weight reduction of up to 40% versus solid designs
- In total, shock absorber weight can be reduced by approx. 25% without sacrificing functionality

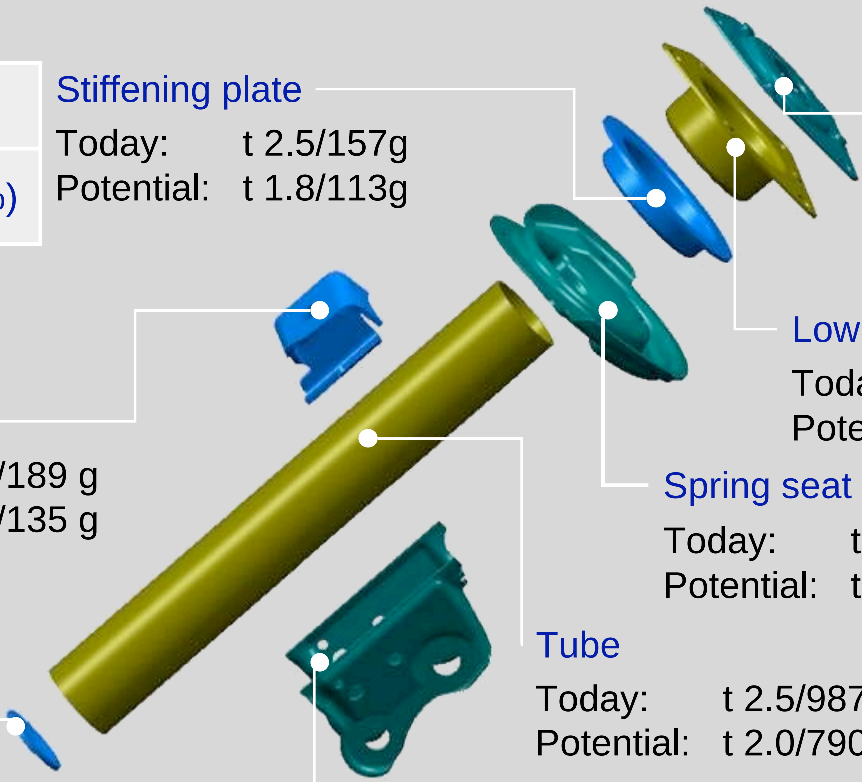


McPherson strut

Lightweight strut

Estimated potential for a McPherson strut

Today:	2,476 g
Potential :	1,895 g (approx. -24%)



Stiffening plate
Today: t 2.5/157g
Potential: t 1.8/113g

Upper housing part
Today: t 2.0/163 g
Potential: t 1.5/122 g

Lower housing part
Today: t 2.0/237 g
Potential: t 1.5/178 g

Upper holder
Today: t 3.5/189 g
Potential: t 2.5/135 g

Spring seat
Today: t 2.5/396 g
Potential: t 1.8/285 g

Tube
Today: t 2.5/987 g
Potential: t 2.0/790 g

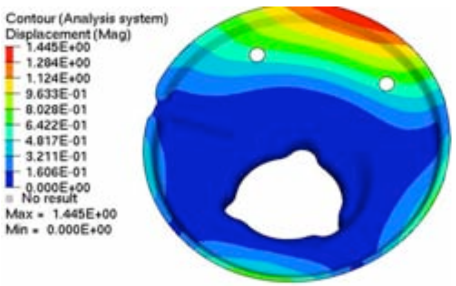
Base
Today: t 3.0/37 g
Potential: t 2.0/24 g

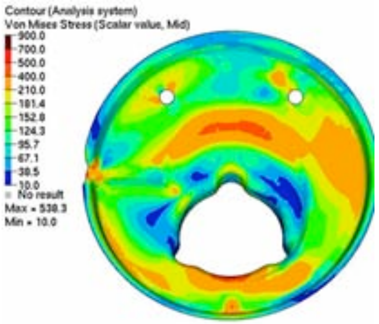
Bracket
Today : t 2.5/310 g
Potential : t 2.0/248 g

Lightweight strut

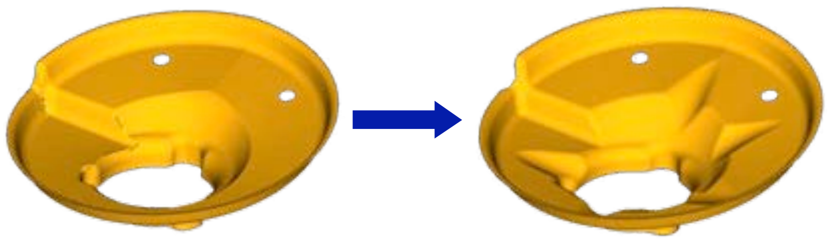
Process steps for weight reduction

Step 1: FEM analysis of as-is part (DD13 / t=2.5)



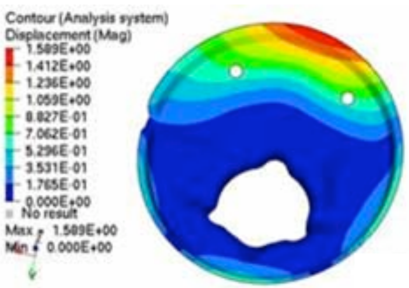


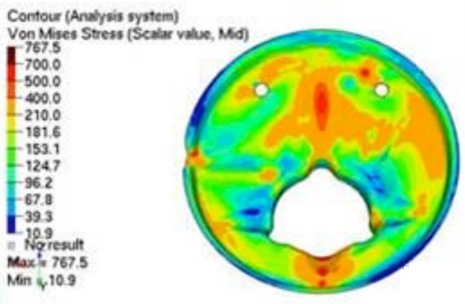
Step 2: Optimize geometry



Material from t=2.5 to 2.0 / additional stiffener beads

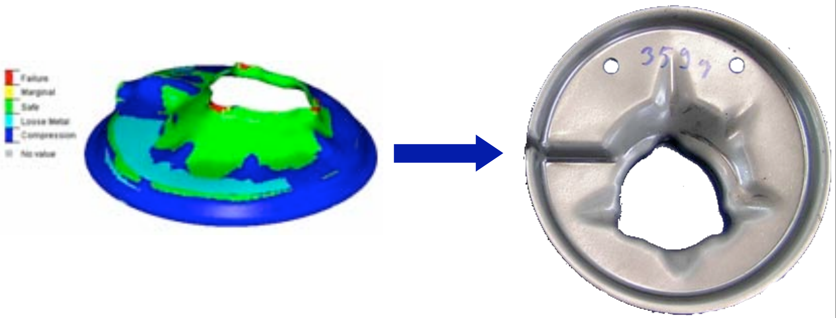
Step 3: FEM analysis of new high-strength steel part





Material: DP-W® 700 / t=2.0

Step 4 & 5: Forming simulation & prototyping

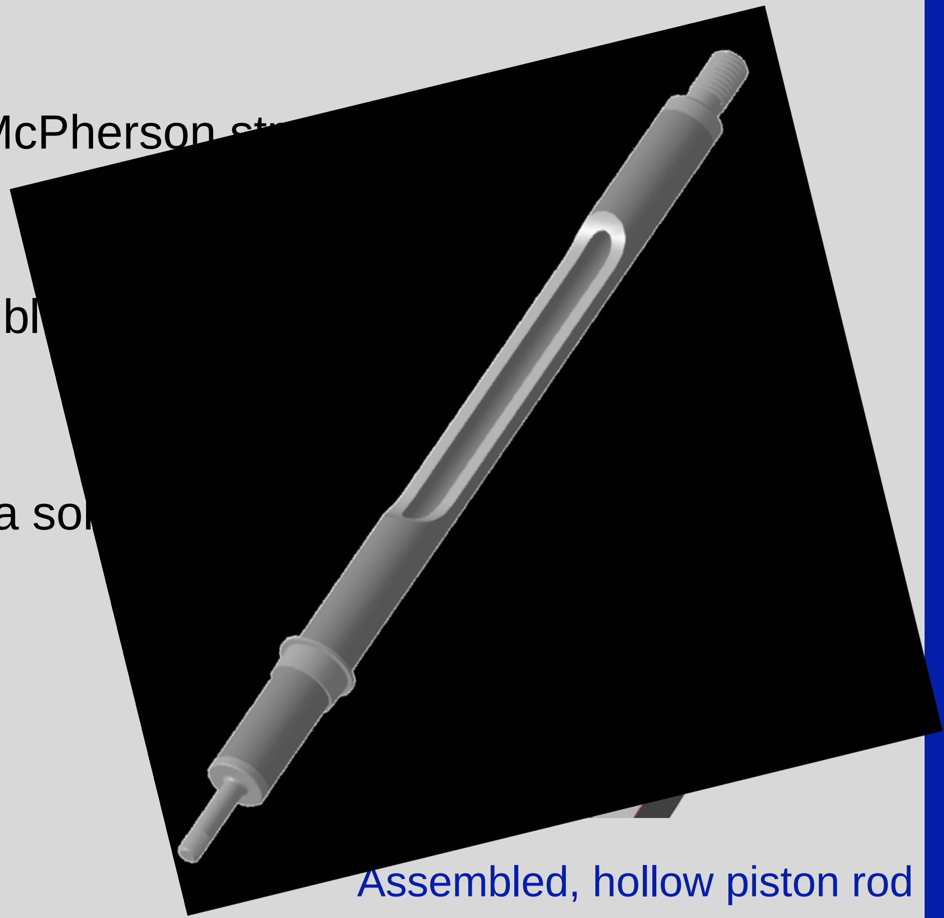


Prototype of DP-W® 700 (455 g => 359 g = -21%)

Lightweight strut

Hollow, assembled piston rods/tailored orbitals

- To meet wheel control requirements, McPherson st
  use
  piston rods with a diameter > 18 mm
- Weight reduction of approx. 40% possibl
  hollow, assembled piston rods
- Tenons are welded to hollow rod
- Flexural strength almost equivalent to a so



Assembled, hollow piston rod

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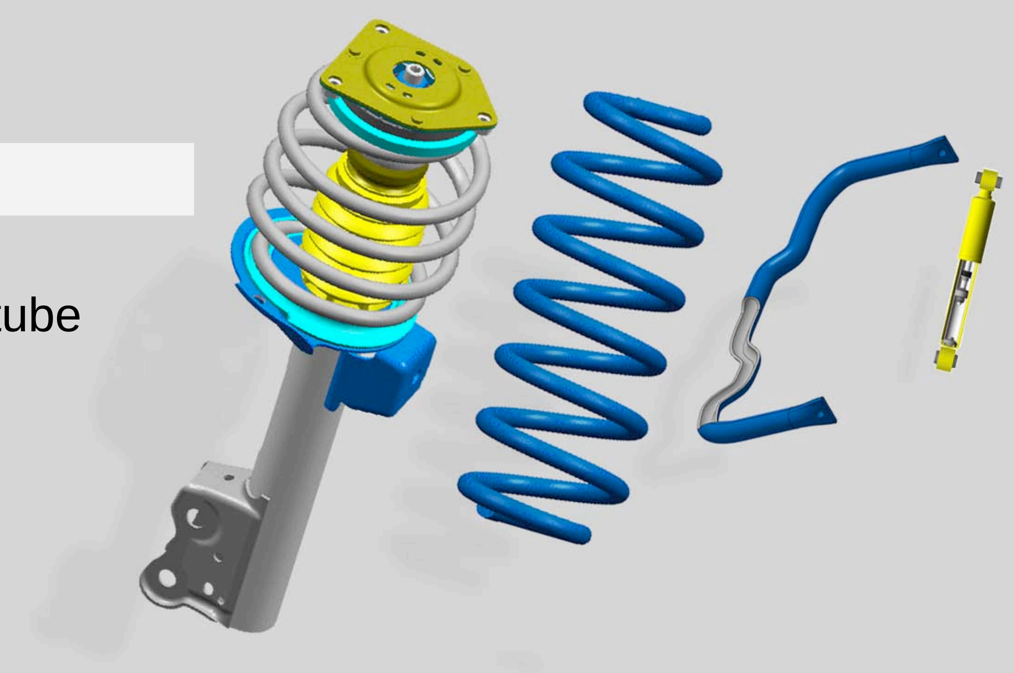
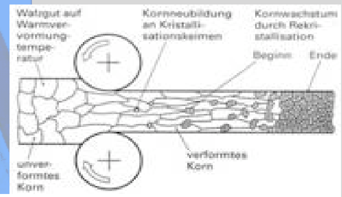
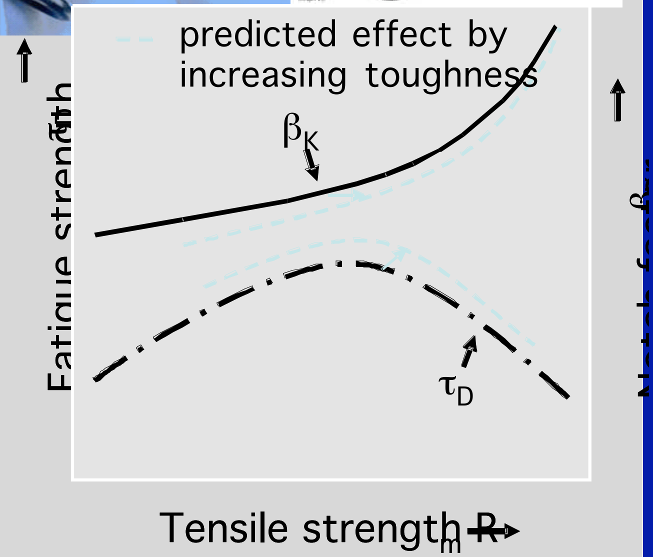


High-strength springs

ThermoTecSpring®

- Thermomechanical forming increases the strength
  (~2200 MPa) and the toughness of the spring material
- Process suitable for hot-formed cylindrical springs
- Weight reduction with same lifetime: approx. 15%
- Increased toughness enables the spring material to
  withstand higher stresses
- Wire diameter, number of coils and thus block length
  can be reduced
- The process was validated in principle on a test facility at ThyssenKrupp Bilstein of America
  ThyssenKrupp Bilstein Suspension

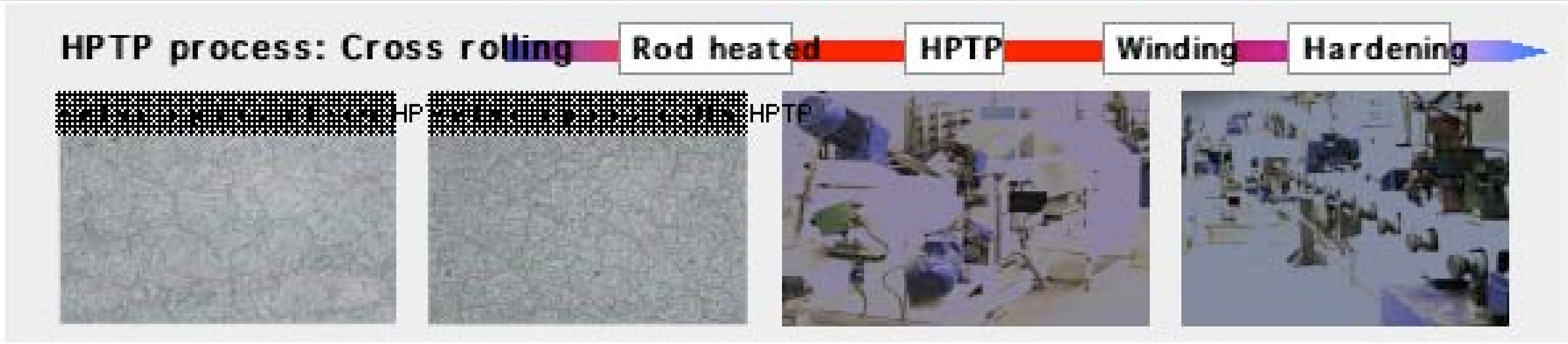




High-strength springs

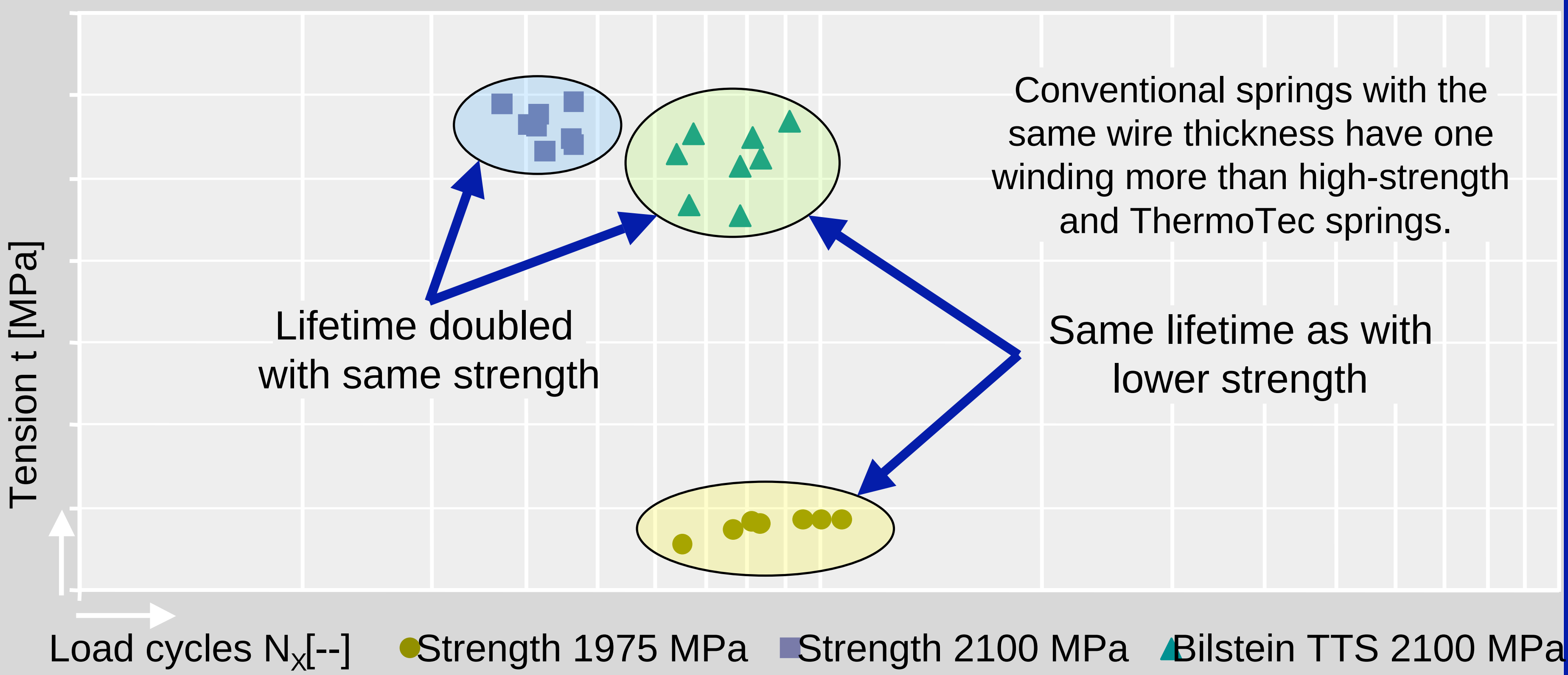
High-Performance Thermotec Process

- High toughness through fine martensitic microstructure
- High strength (Rm = 2100 - 2200 MPa) with outstanding ductility
- High strength allows significant reduction in spring weight with same lifetime
- Complete process effected without additional heating



High-strength springs

ThermoTecSpring® – Comparison of lifetimes



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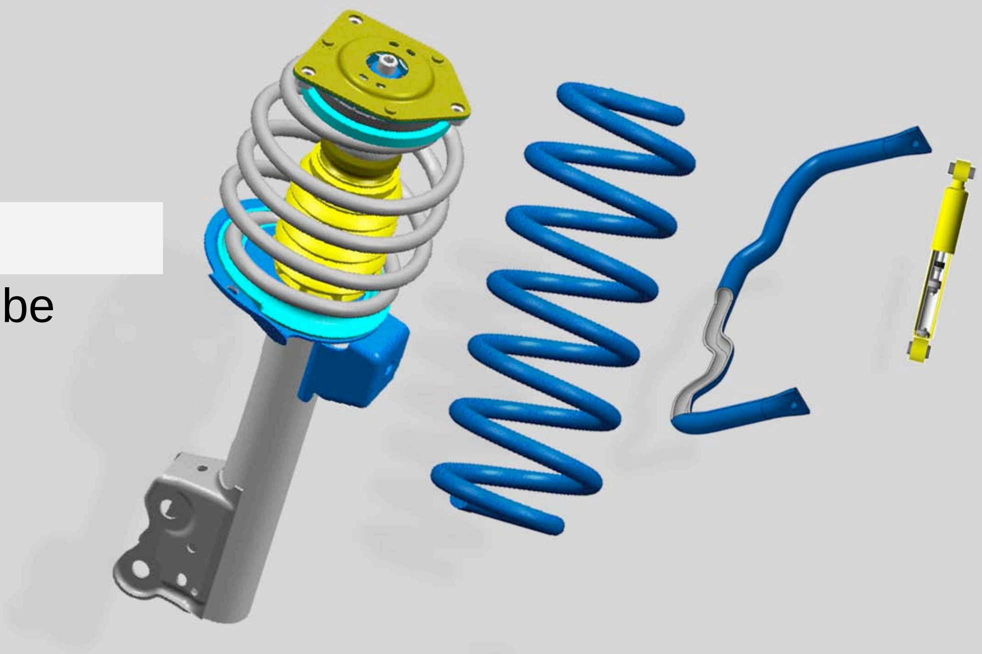
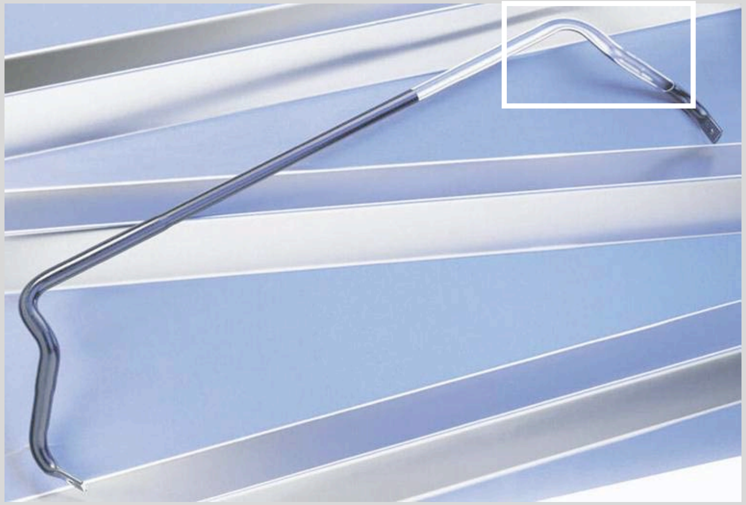
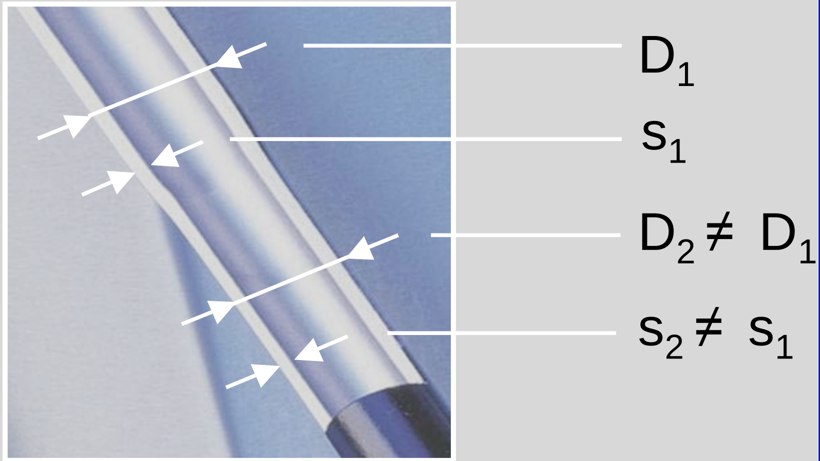


Lightweight stabilizer bar

Rotary-swaged tubular stabilizer bars





- Rotary-swaged tubular stabilizer bars permit weight reductions of approx. 40% compared with solid designs
- Stress-optimized tube geometry by means of FEM computations (varying wall thicknesses)
- High-strength material (Rm = 1800 MPa)
- Internal blasting for highly stressed stabilizer bars to create residual compressive stresses in the edge zone of the tube inner surface

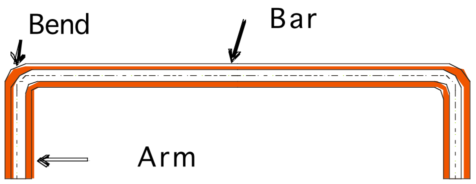
▶ Process already in production use

Lightweight stabilizer bar

Tubular stabilizers with varying wall thicknesses

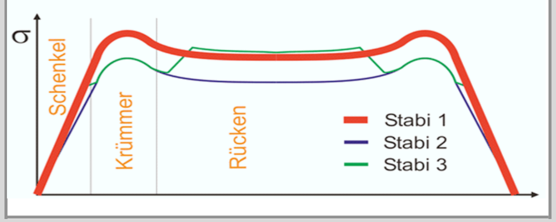
Stabilizer bar 1

- 1 const. diameter



$c_{Stabi} = c_{Stabi,\ target}$ ✓

$\sigma_{Bend} > \sigma_{Bend,\ perm}$

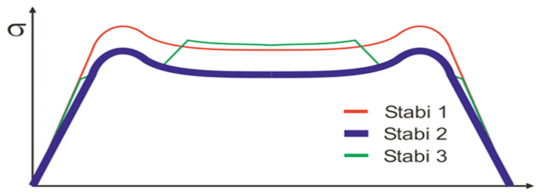


Stabilizer bar 2

- const. diameter (greater than 1)

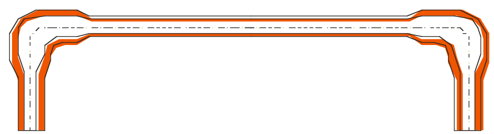
$c_{Stabi} > c_{Stabi,\ target}$

$\sigma_{Bend} < \sigma_{Bend,\ perm}$ ✓



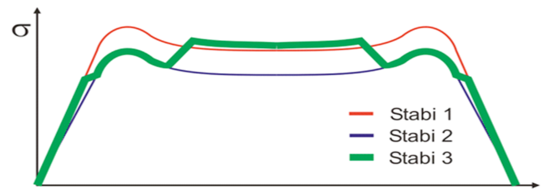
Stabilizer bar 3 – rotary swaging

- Diameter and wall thickness in bend as 2
- Bar and arms: diameter and wall thickness lower than or same as 1



$c_{Stabi} = c_{Stabi,\ target}$ ✓

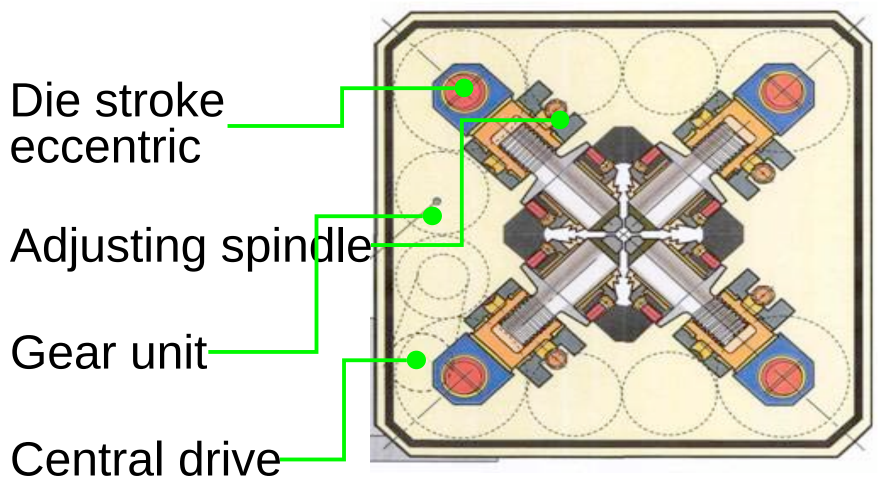
$\sigma_{Bend} < \sigma_{Bend,\ perm}$ ✓

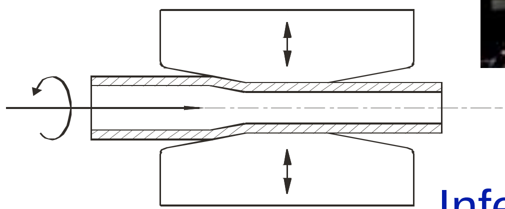


Lightweight stabilizer bar

Rotary swaging process

- The contours are produced by rotary swaging
- Axial feeding of the rotating workpiece takes
  place in parallel with the radial die closing
  movements
- This produces tubes with optimized wall thickness and diameter
- The tube is then processed on a CNC cold
  bending machine to form a stabilizer bar,
  with internal blasting and hardening if required





Infeed rotary swaging

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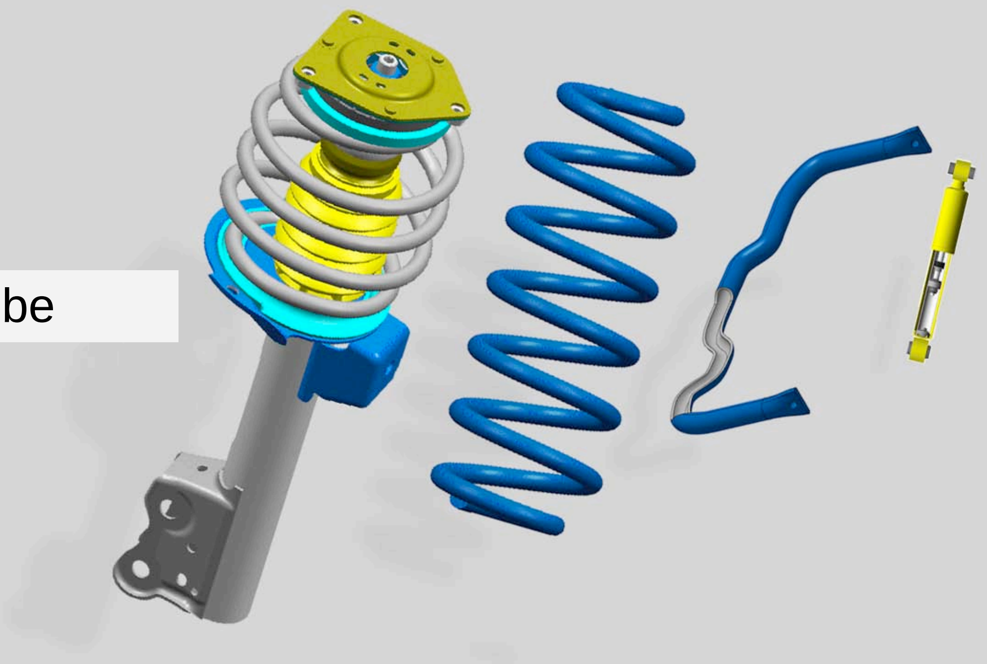
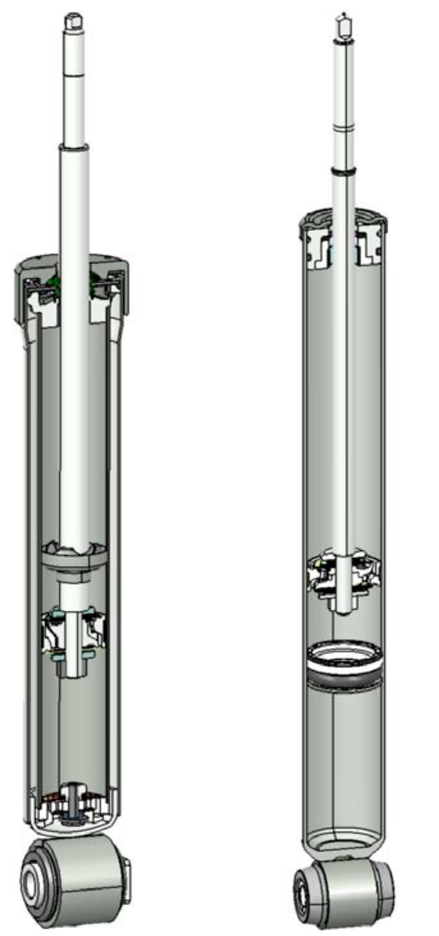


Substituting monotube for twin-tube shocks

Weight reduction through system change

- Substituting monotube shock absorbers for twin-tube shocks allows a weight reduction of up to 60%
- Steel monotube shocks are available in system diameters of 30, 36 and 46
- The aluminum 46 diameter system is production-ready and in use



Twin-tube Monotube

Examples:

- OEM shock 1600 g, system size 27/11, twin-tube, steel
- Bilstein lightweight shock 1000 g, system size 30/11, monotube, steel
- Bilstein lightweight shock 750 g, system size 30/11, monotube, aluminum

Substituting monotube for twin-tube shocks

Weight comparison monotube shock vs. twin-tube shock

Part	Monotube shock	Twin-tube shock
Piston rod	Neutral	Neutral
Piston system	Neutral	Neutral
Bottom valve	Not applicable	Required
Inner tube	Not applicable	Wall thickness 1.1 … 1.5 mm
Oil volume	Lower*	Higher
Outer tube	Also piston bearing surface 1.3 … 1.7 mm	Outer tube Wall thickness 1.0 … 2.0 mm
Length	Longer due to gas chamber	Lower

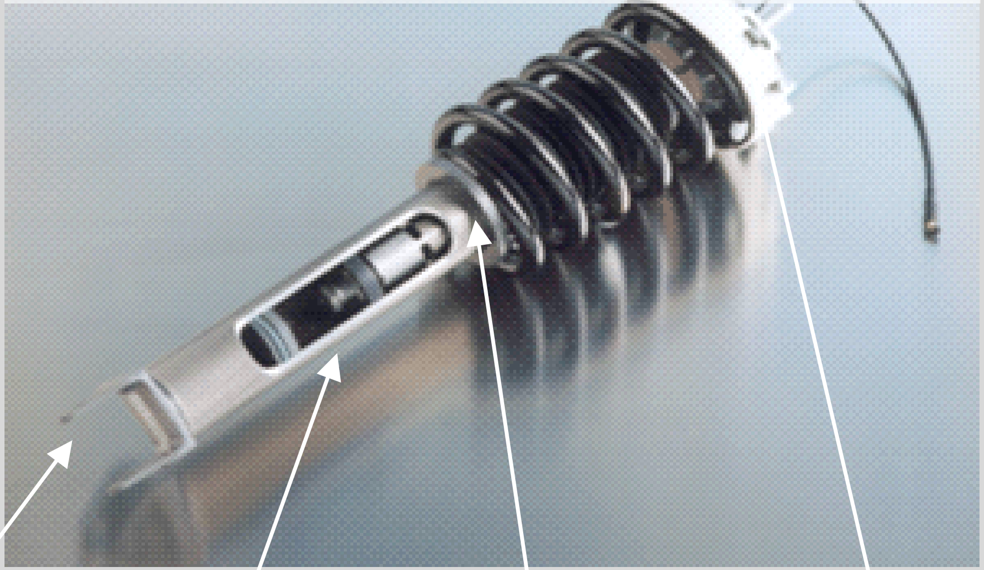
* with same piston diameter

Substituting monotube for twin-tube shocks

Use of aluminum in monotube shocks

- In production use at several OEMs (System 46/14)
- Specific density 2.7 kg/l (cf. steel 7.8 kg/l)
- Increased wall thickness necessary due to
  lower strength
- Fork and tube joined by friction welding

Bilstein aluminum monotube shock absorber



Friction-welded aluminum fork

Aluminum spring plate

Aluminum outer tube

Aluminum upper valve housing

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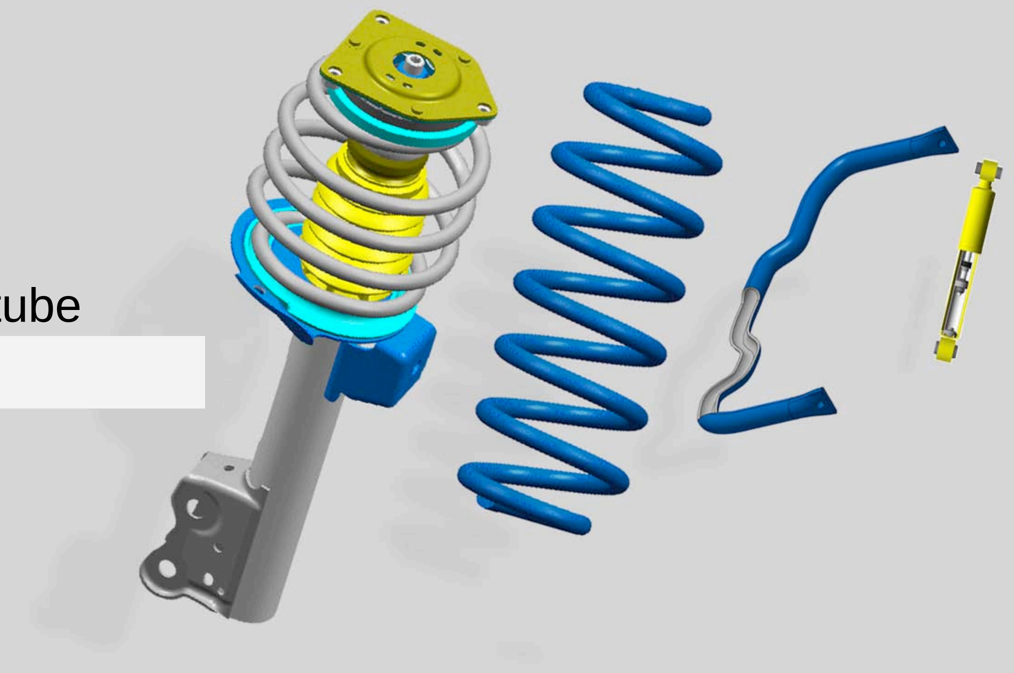
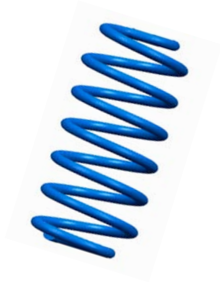


Conclusion

Bilstein lightweighting portfolio

	Strut	Spring	Stabilizer bar	Shock absorber
Example mid-size car				
Lightweighting technology	High-strength steels Hollow piston rods	TTS (ThermoTecSpring®)	Use of rotary-swaged tubular stabilizer bars	Substituting monotube for twin-tube shocks
Production:	2.5 kg	2.5 kg	4.0 kg	1.6 kg
Weight reduction:	~ 24%	~15%	~40%	~60%

Weight saving for mid-size car using Bilstein lightweight elements approx. 7 kg

Lightweight solutions in the area of springs and shock absorbers