# High-strength steels for chassis and exhaust components – Application related developments and materials at Benteler Automotive

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## Outline

- Benteler Group
- Materials at Benteler Automotive
- Application related materials and developments - Chassis
- Application related materials and developments - Structure
- Application related materials and developments - Exhaust
- Summary



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Under the strategic management holding, Benteler International AG, the operative business is organized into the three legally independent business divisions  within Benteler Deutschland GmbH.

Benteler International AG

Benteler Deutschland GmbH

Benteler Automotive

Benteler Stahl/Rohr

Benteler Distribution

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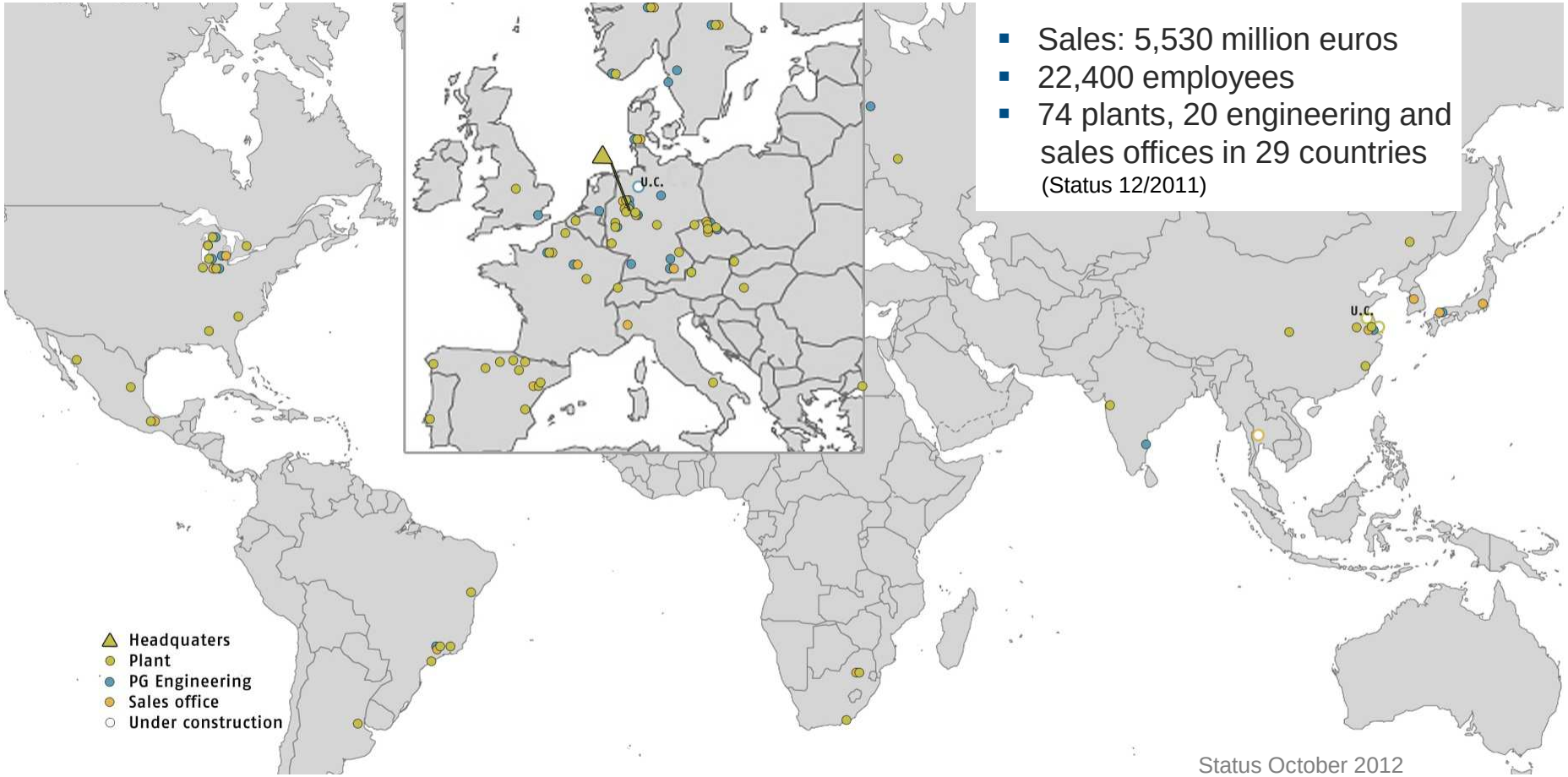
## Worldwide activity – Benteler Automotive 2012




- Sales: 5,530 million euros
- 22,400 employees
- 74 plants, 20 engineering and sales offices in 29 countries
  (Status 12/2011)

Status October 2012

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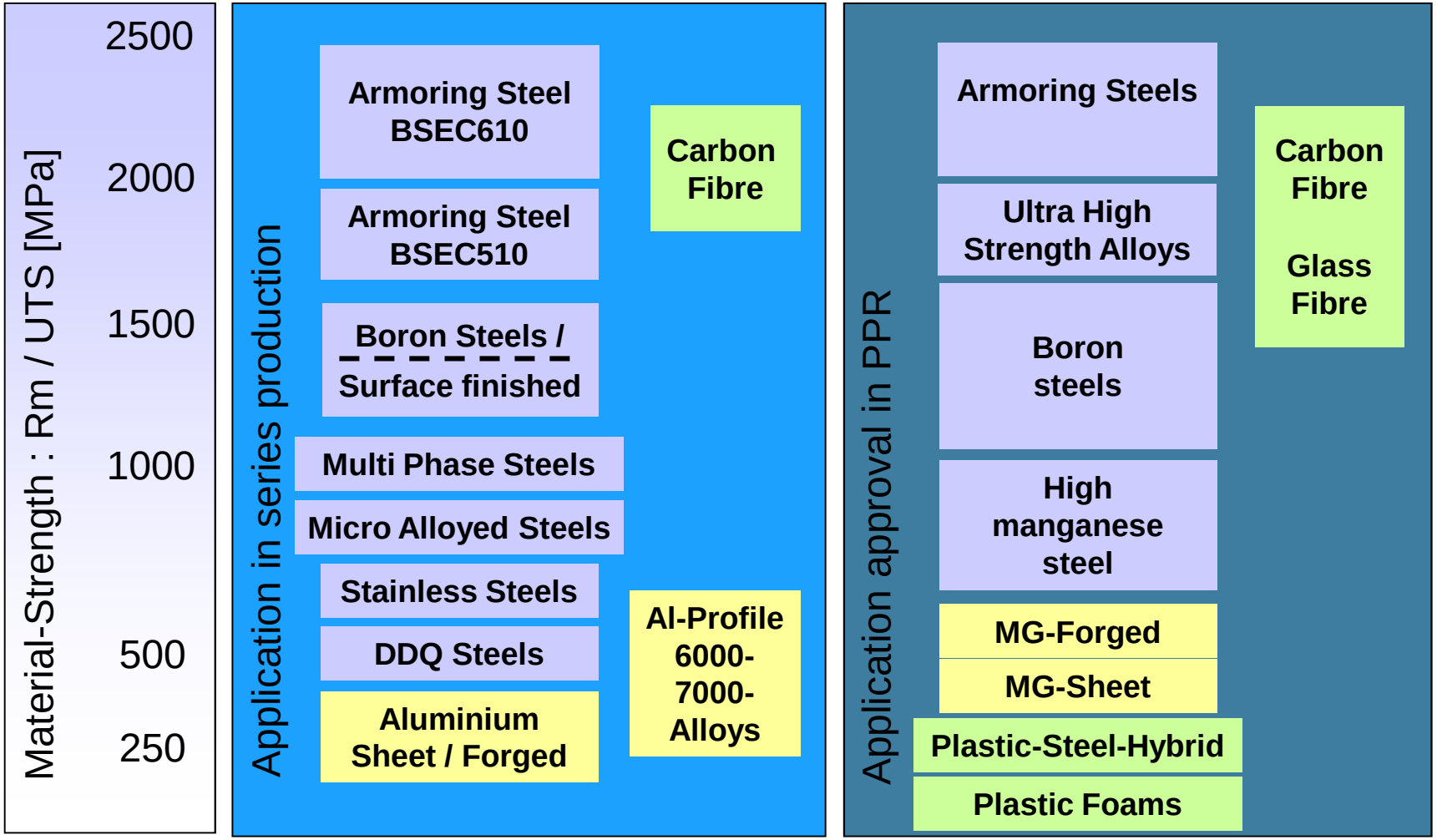
## Materials overview



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## Overall application related material requirements

**High strain rate behavior**
- Dynamic strength
- Remaining strain
- Ballistic resistance

**Mechanical – technological properties**
- Strenght
- Hardening behavior
- Formability
- Modulus
- Ductility
- Thermo-mechanical properties
- Quench propertries

**Fatique behavior**
- Fatique strength
- Wöhler diagramms
- Crack initiation and - growth

**Surface properties**
- Surface defects
- Roughness

**Machinability**
- Die-cutting
- Laser-cutting
- Drilling

**Material price**
- Basic price
- Alloying costs

**„Logistic“ propterties**
- Available dimensions
- Tolerances
- Available semi-finished parts
- Worldwide availability and quality

**Joining properties**
- Weldability
- Brazeability
- Other joining technologies

**Corrosion resistance / Coatability**
- Zinc-coating
- Cataphoretic painting
- Plasma nitriding
- Hot- / wet corrosion properties



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## Requirement – Formability of high strenght steels

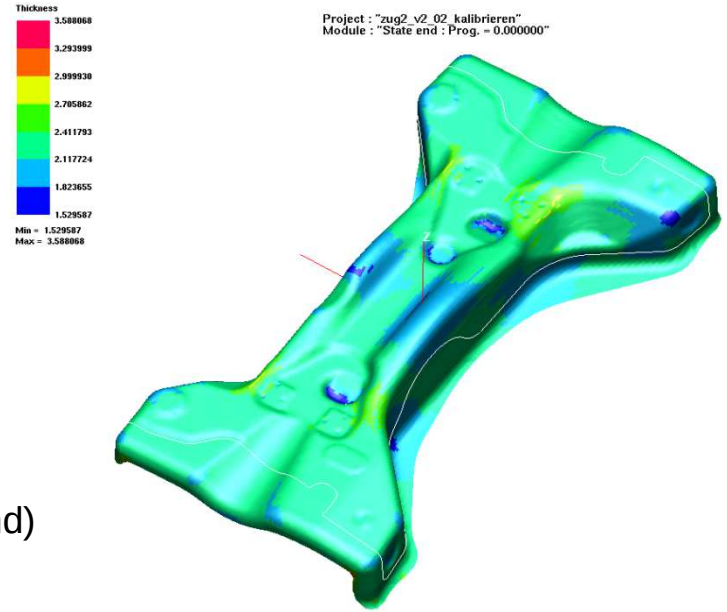
- Formability (including thinning) is a key parameter regarding the produceability of Benteler Automotive products

- Consistently determined characteristic values are needed for for forming simulations

- Influence  of material characteristics along die- or laser-cutted holes and edges has to be considered for lifetime prediction

- Increasing the formability of high strength steels desired

- Reduction of the variance of mechanical properties (heat dependend)







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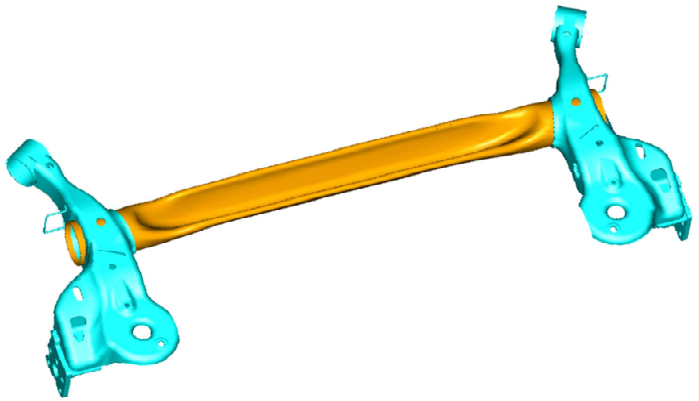
## Requirement – Dimenional tolerances of high strenght steels

**Example: Roll-rate of compound crank rear axles**

- **Influencing factors:**
- Axle kinematics
- Shear center of the torsion profile
- Effective torsion lenght
- Thickness of the torsion element



**Influence of thickness torenances**

Basis for analytical estimation: B-segment vehicle (VW) (closed profile, D=115mm, t=2,4mm)

| t [mm] | Δ |
|---|---|
| 2,40 | - |
| 2,45 | 4,04% |
| 2,50 | 8,19% |
| 2,55 | 12,43% |
| 2,60 | 16,77% |
| 2,65 | 21,21% |

Increasing the sheet thickness of the torsion element results in highly variing roll-rates and therefore considerable effects on the vehicle dynamics (over-/ under steering)

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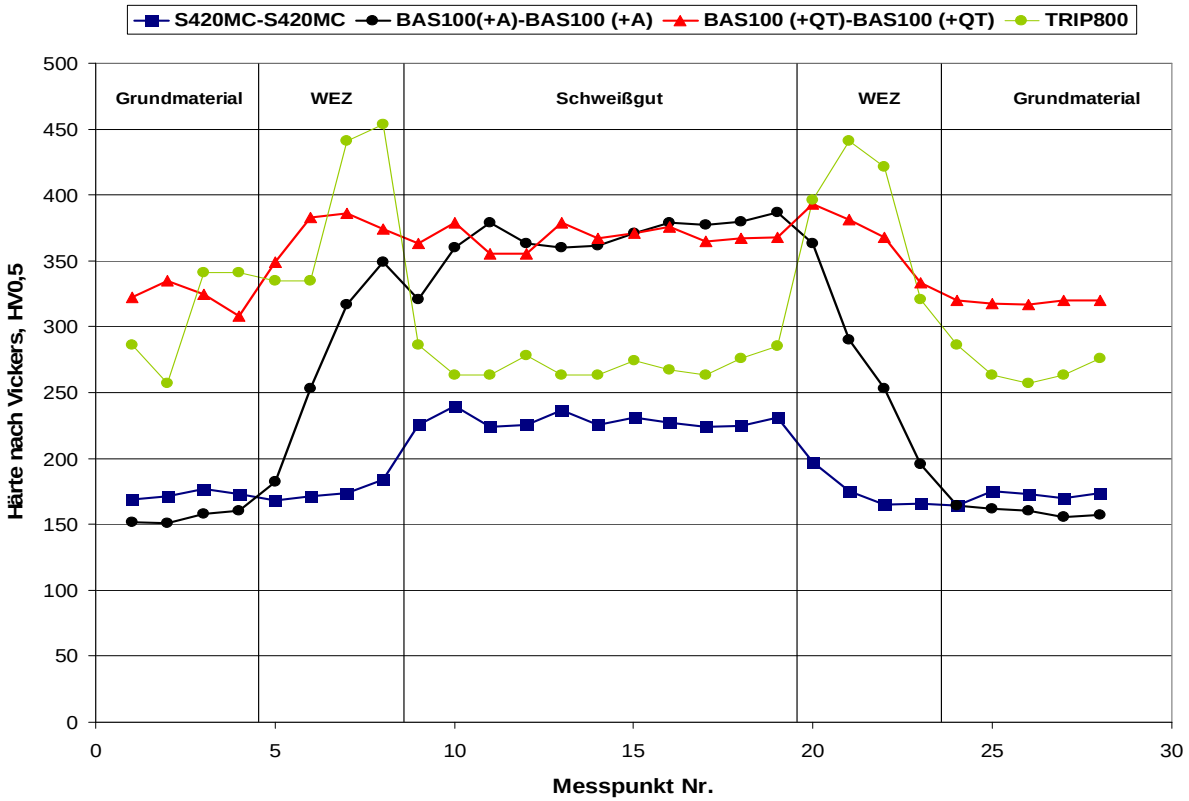
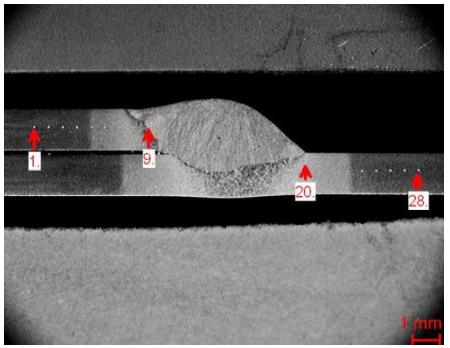
## Requirement – Weldability of high strength steels




MAG-weldseam
Consumables:
G4Si1 (S420MC/TRIP800)
ESAB13.31 (BAS100)

- Maximum allowable hardness within weldseam and heat affected zone is limited by OEMs
- Reduction of hardness steps by changing chemical compositions or annealing parameters
- Further examination of hydrogen embrittlement required



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## Requirement – Corrosion resistance of high strength steels

Increasing requirements regarding corrosion resistance and weight reduction

➔ Standard cataphoretic painting not allways sufficitent

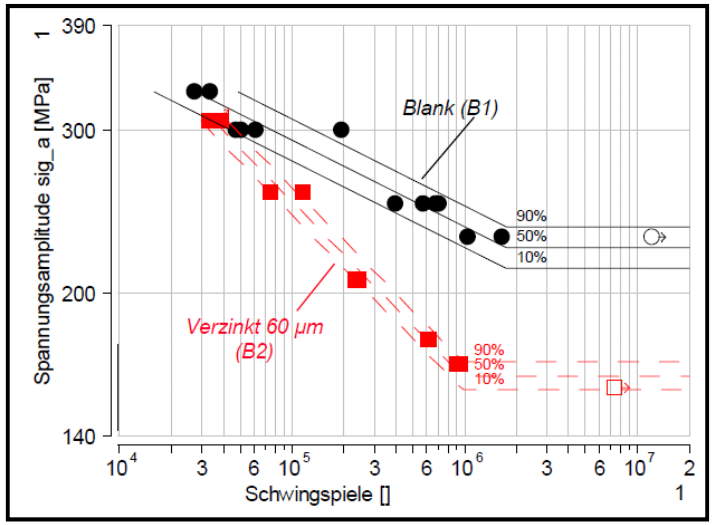
Possible alternatives

➔ Zinc coating (strip)

- ➢ Weldseams highly affected

➔ Zinc coating (part)

- ➢ Reduction of fatique strength
- ➢ Weight increase
- ➢ Hydrogen embrittlement?
- ➢ LME-risk?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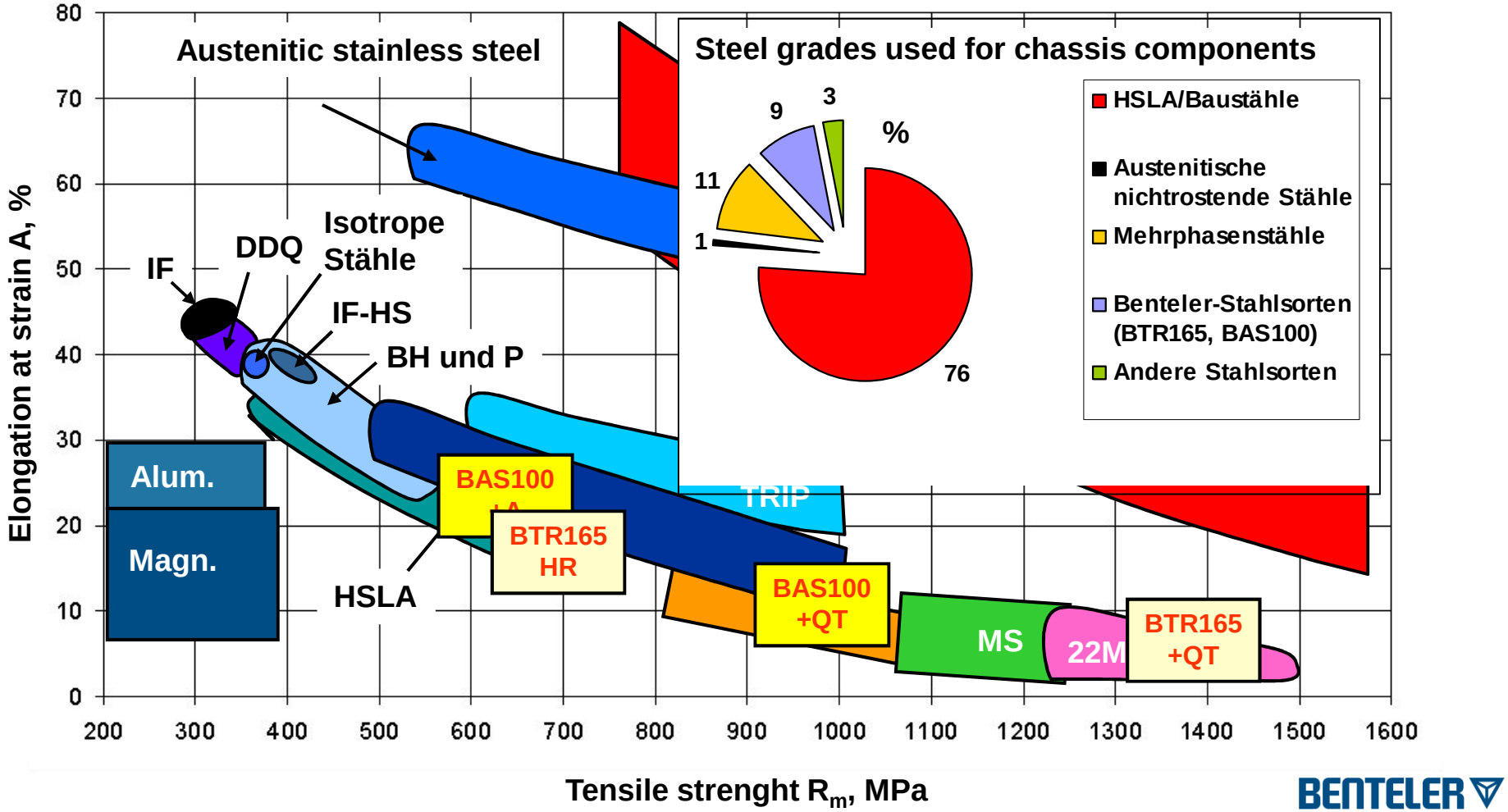
## Requirement – mechanical properties of high strength steels



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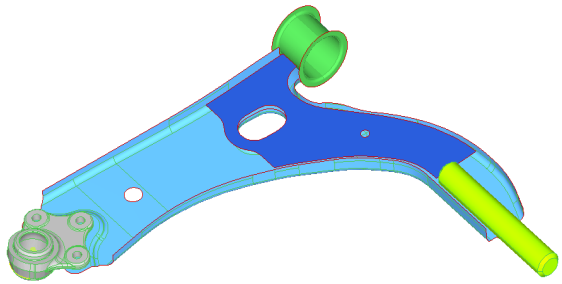
## Steel grades used for chassis components – HSLA / mild steels

**Grades:**
Micro-alloyed and mild steels ($R_e$: 315 – 650 MPa)

**Products:**
Cross member, suspension arms, compound crank rear axles, tube components

**Advantages / Disadvantages:**
+ Low carbon content (weldability – hardness steps)
+ Strength / formability ratio
+ Minimal variation of mechanical properties within rolled strip
+ Different strength levels available
+ Worldwide available (Hot- and cold rolled strip)
- Reduced formability and springback for high-strentgh grades

**Development trends:**
- Further reduction of grain- and precipitation size (Nano-Hiten)
- Perlite-free variants showing increased formability(HSM650HD)





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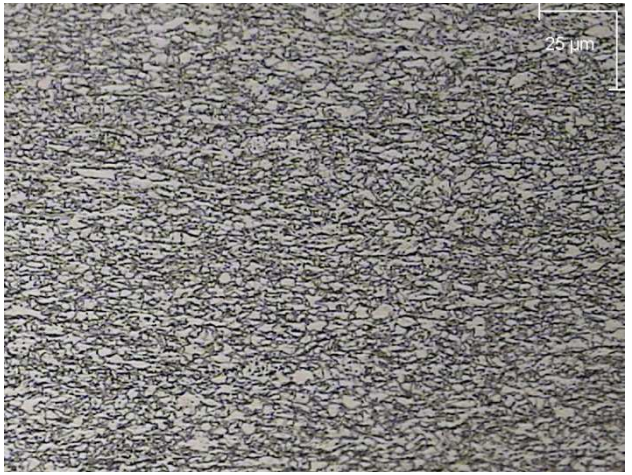
## Steel grades used for chassis components – multiphase steels

**Grades:**
F/B540, F/B590, F/B780, SZBS800, CP-W800, DP450

**Products:**
Suspension arms, reinforcements

**Vorteile/Nachteile:**
Similar to HSLA / mild steel
+ Improved formability and hardening potential
+ Significant bake-hardening effect
+ Improved hole expensionalbility (FB)
- Wordwide availability(different concepts DP/TRIP)
- Springback for HSS-grades
- Weldeability for TRIP-steel
- Hot rolled strip availability for DP/TRIP

**Development trends:**
- Further optimization of F/B-grades
- Reduction of C-content of TRIP-steels

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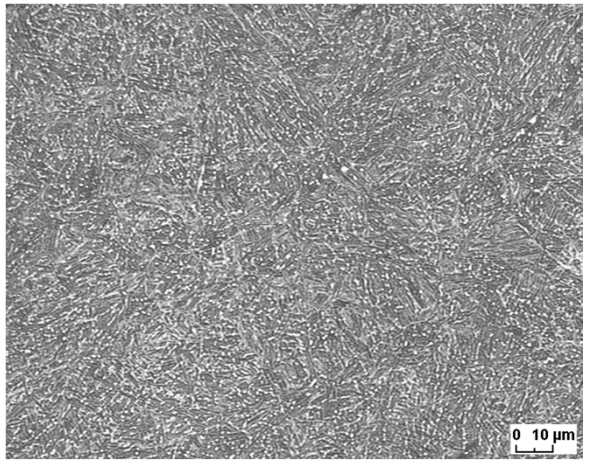
## Steel grades used for chassis components – air hardening steels

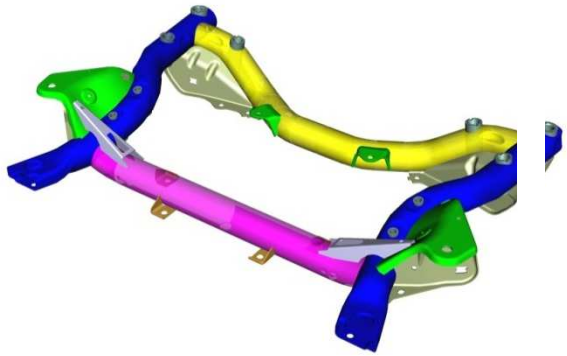
**Grades:**
BAS100, BNX120 ($R_e$: 700 Mpa – 850 MPa)

**Komponenten:**
Front subframe

**Vorteile/Nachteile:**
+ High formability in the not hardenend condition combined with high strength of hardened parts
+ No significant hardness steps within the heat affected zone
- Alloying costs (Mo und V)
- Wordwide availability

**Development trends at Benteler:**
- Optimization of mechanical properties and availability



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## Competitor to steel - Aluminium grades used for chassis components

| Component | Alloys | Condition | Strenght | Elongation at break |
|---|---|---|---|---|
| *Extruded profiles* | EN AW-6060<br>EN AW-6005A<br>EN AW-6063 | T6 bzw. T5 | $R_e$ > 225 MPa<br>$R_m$ > 270 MPa | $A_5$ > 8% |
| *HF welded tubes* | EN AW-5454<br>EN AW-5457 | H111 | $R_e$ > 100 MPa<br>$R_m$ > 230 MPa | $A_5$ > 20% |
| *Casted parts* | EN AC-42100 | T6 | $R_e$ > 190 MPa<br>$R_m$ > 230 MPa | $A_5$ > 2% |
| *Sheets for pressed parts* | EN AW-5454<br>EN AW-5457 | H111, H22<br>and higher | $R_e$ > 200 MPa<br>$R_m$ > 270 MPa | $A_5$ > 11% |
| *Forged parts* | EN AW-6062<br>EN AW-6110<br>(Cu limited) | T6 | $R_e$ > 370 MPa<br>$R_m$ > 400 MPa | $A_5$ > 9% |

High strength: 300-400 MPa ($R_m$)
Ultra high strenght: > 400 MPa ($R_m$)



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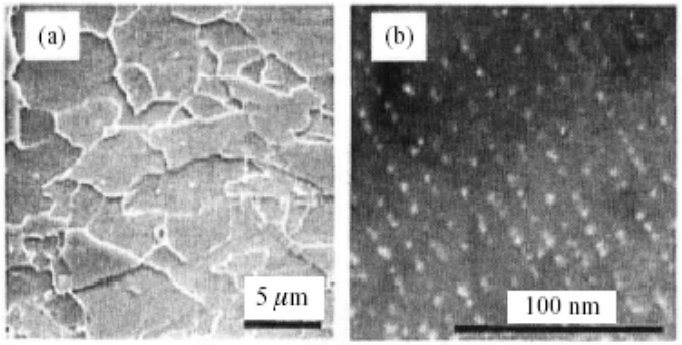
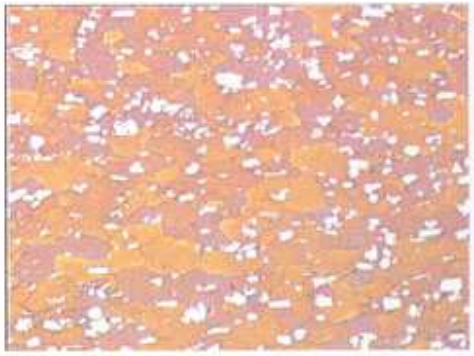
## Potential future steel grades for chassis components

### NANO-HITEN, TWIP - steels



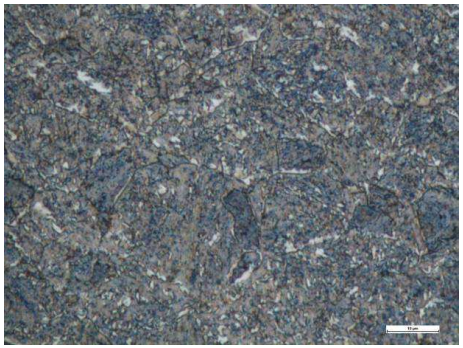

*Reference: JFE, Japan*

### Steels showing increased elastic modulus



*Reference: ArcelorMittal*

### „Low cost“- air hardening steel, Bainite



*Reference: Microstructure of the BSR05-10 (air hardened)*

? ? ?



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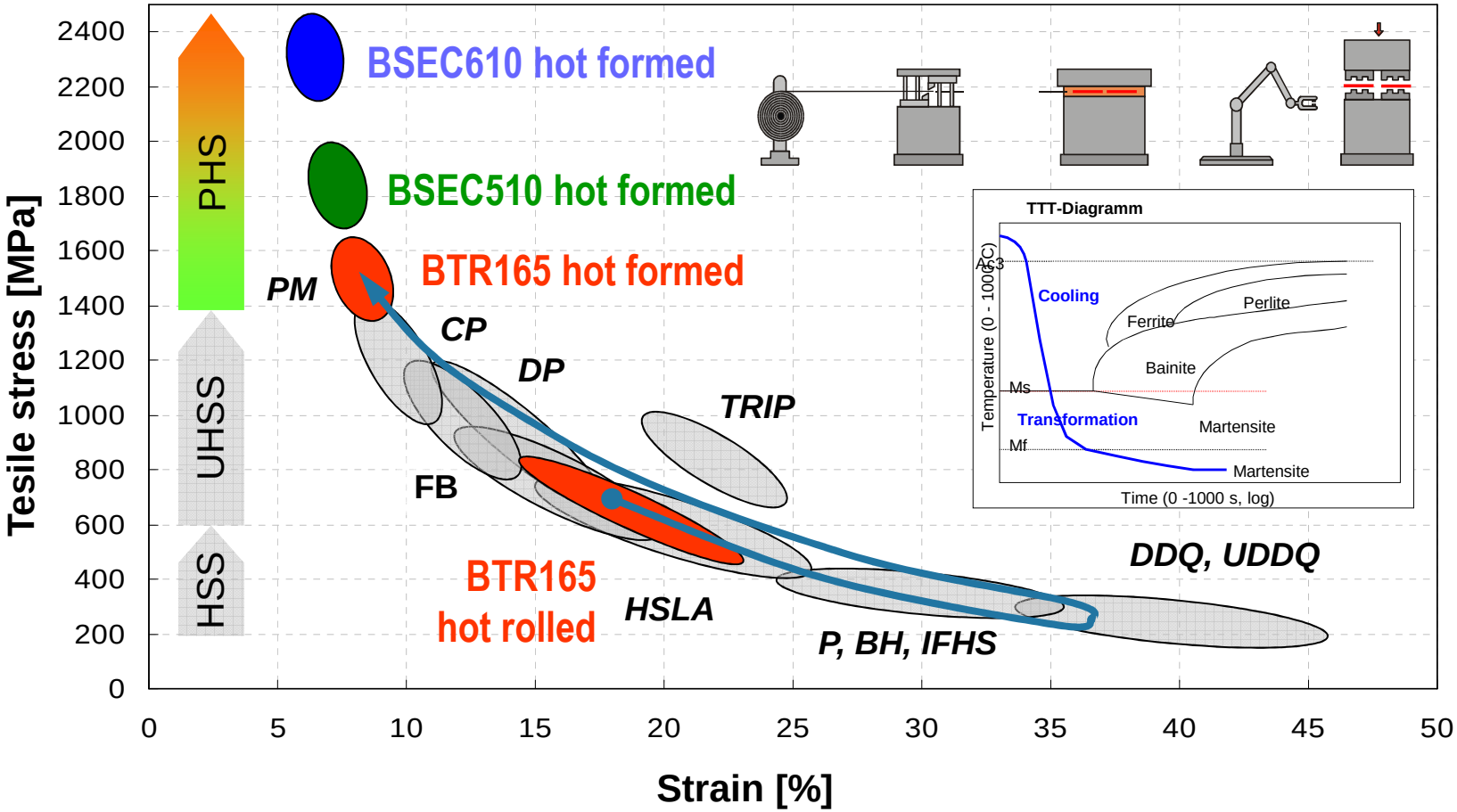
## High strength steels for hot formed structural components and ballistic protection systems



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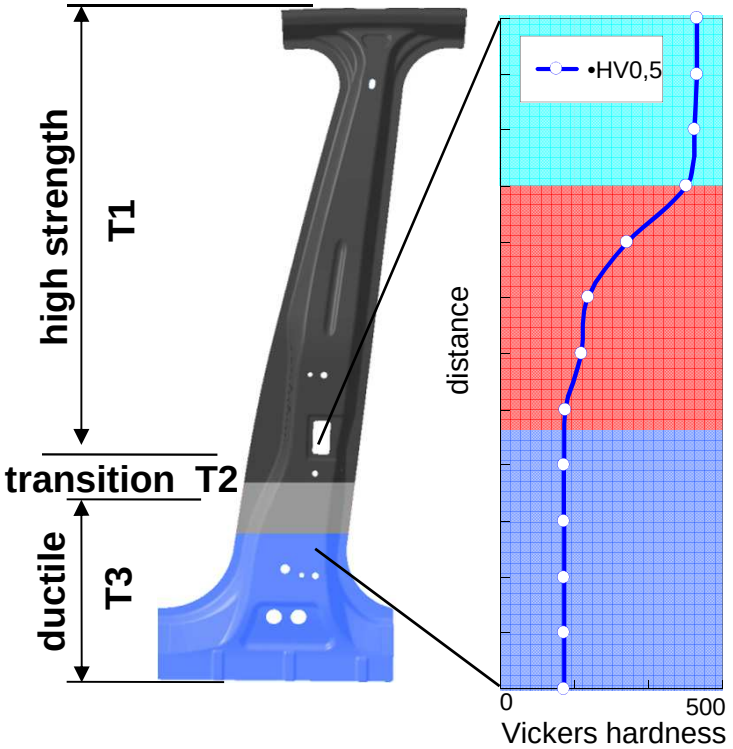
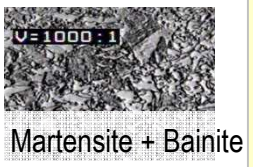
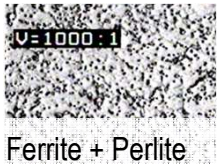
## Partial hardening of high strength steels for structural components








**advantage:**

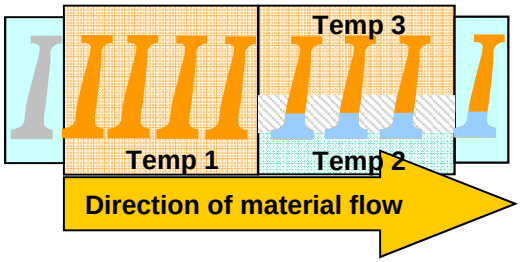
strength optimized design properties:

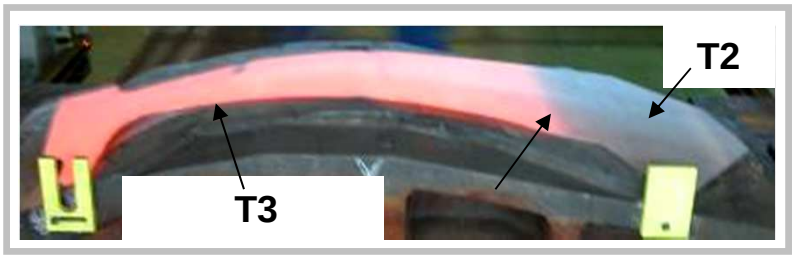
| | quenched sec.: | soft sec.: |
|---|---|---|
| $R_{m:}$ | 1450 MPa | 550 MPa |
| $R_e$: | 1100 MPa | 400 MPa |
| ε (A5): | > 6 % | > 20% |

⇨ good crash performance

⇨ weight reduction

⇨ Part integration



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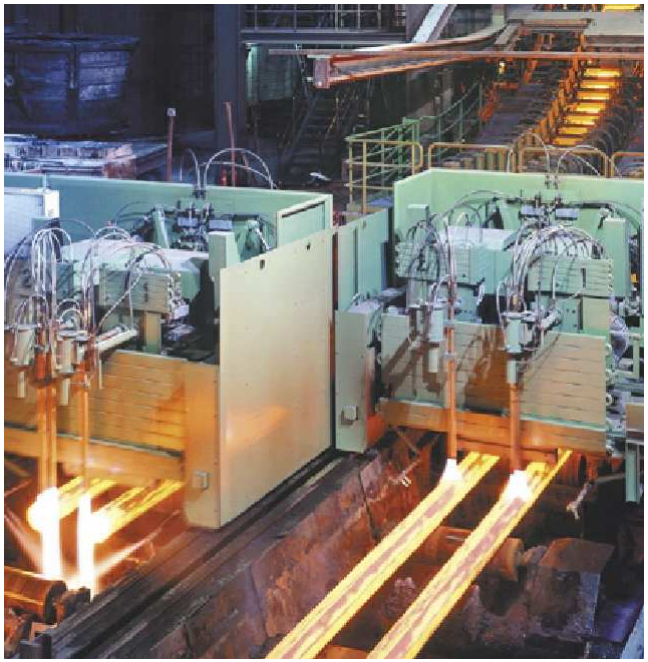
## Hot formable ultra high strength steels for ballistic protection components



**Benteler steel plant Lingen**

**Benteler Security Steel (BSEC) // C – Cr – Ni – Mn based**

**BSEC-grades available**

| | Hardness [HB] | Impact work [J] | Application |
|---|---|---|---|
| **BSEC450** | 410 - 480 | 40 - 60 | Floor parts |
| **BSEC510** | 480 - 550 | 25 - 40 | Vehicle protection up to STANAG I |
| **BSEC610** | 570 - 640 | 10 - 15 | Vehicle protection up to STANAG III |
| **BSEC+** | Surface hardened BSEC-grades for additional ballistic resistance | | |

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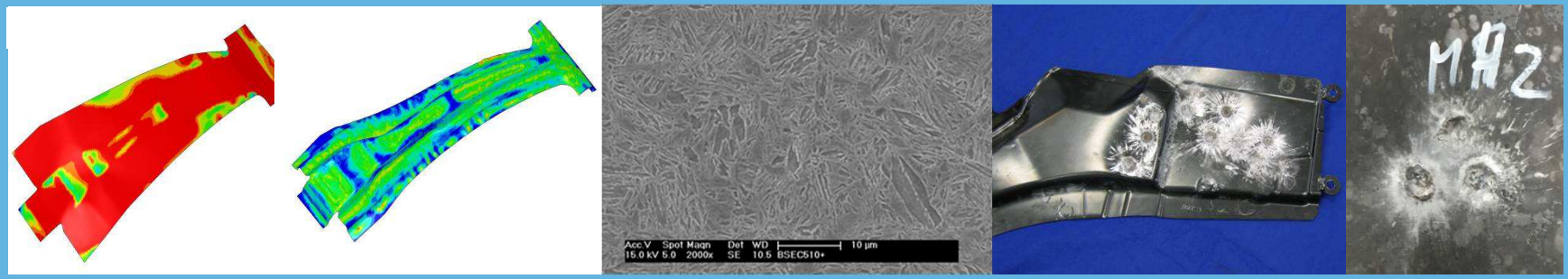
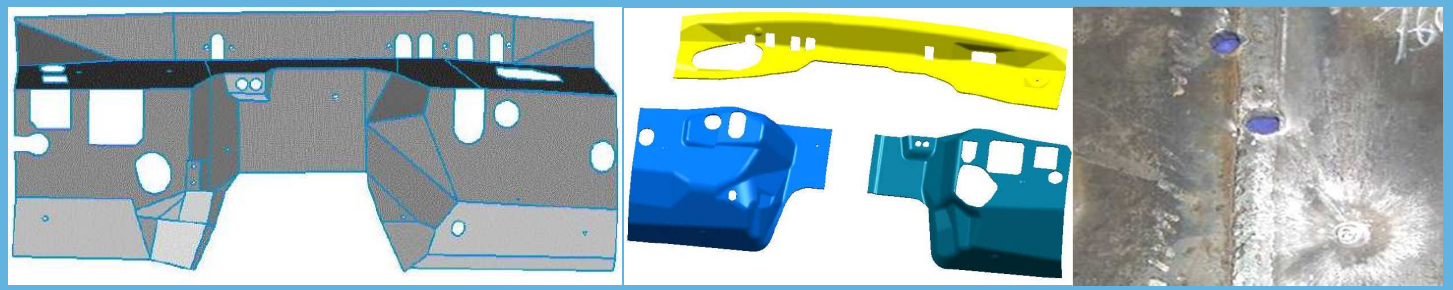
## Hot formable ultra high strength steels for ballistic protection components




Ballistic protection up to t = 20 mm by fully martensitic microstructure



Parts integration / avoidance of constructional vulnerabilities

**Development trends at Benteler:**

- Reduction of alloying costs
- Reduction of CEV

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## High Temperature Resistant Ferritic Steel for Exhaust Application

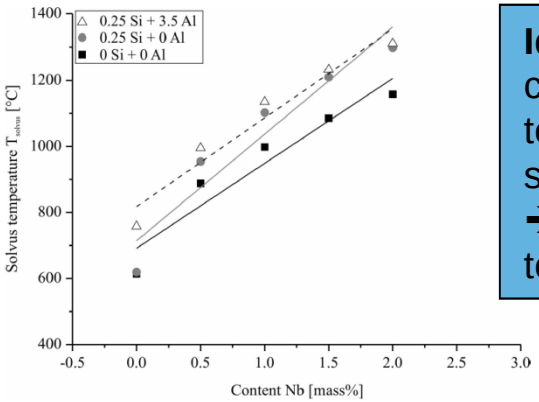

*Reference:* *ThyssenKrupp Nirosta*

**BMBF-Project**

JÜLICH FORSCHUNGSZENTRUM · BEHR · RUB · BENTELER Automotive

**Objective:** Development of high temperature resistant (quasistatic and thermo mechanical fatique) ferritic stainless steel for exhaust applications, based on Laves – phase precipitation

➔ Close the gap regarding high temperature mechanical properties between austenitic and ferritic stainless steel at cost of ferritc steels




**Idea:** Manipulation of laves phase and carbonitride precipitation behavior and solvus temperatures by molybdenum-, tungsten-, silicon- and niobium content

➔ Reliable grain stabilization up to application temperatures of 950°C

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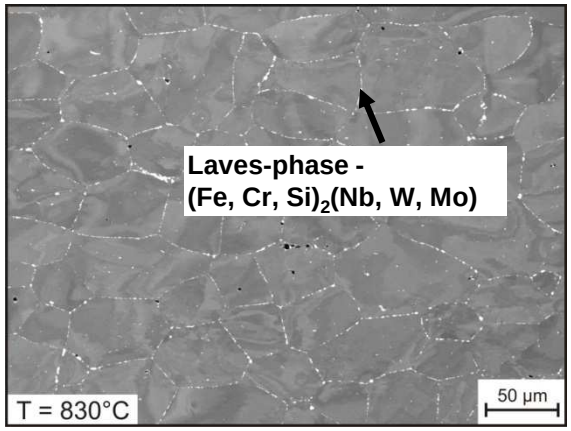
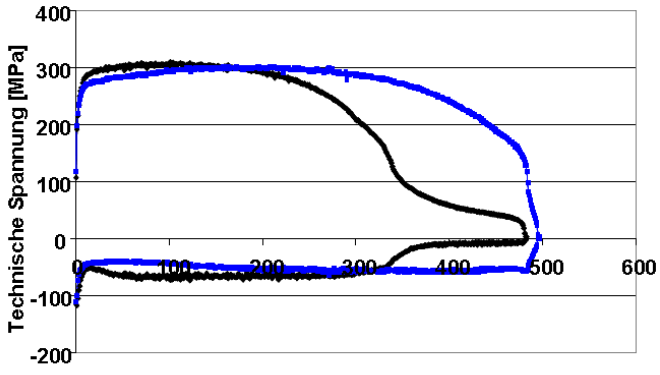
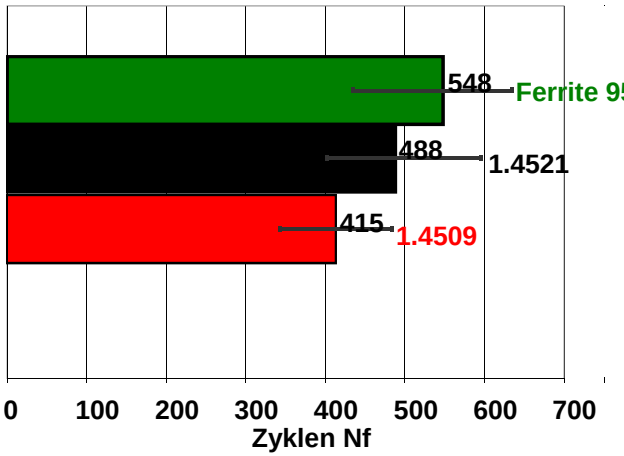
## High Temperature Resistant Ferritic Steel for Exhaust Application

| Ferrite950 | C | Si | Mn | Cr | Mo | W | V | Nb | Ti | N |
|---|---|---|---|---|---|---|---|---|---|---|
| ma-% | < 0,02 | ≈ 0,6 | ≈ 0,4 | ≈ 18 | ≈ 0,5 | ≈ 1,5 | ≈ 0,1 | ≈ 0,8 | < 0,1 | < 0,05 |




Ferrite 950 grade: Laves phase and carbonitrides precipitates stabilize grains up to 1000°C
Thermo-mechanical properties significantly improved
Excellent wet- and hot corrosion resistance
➔ Potential material for components exposed to high exhaust temperatures (downsized engines)

**Development activities at Benteler:**
- Further validation tests on prototypes (manifolds, pipes, converter)



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## Summary

**Chassis components**

- Steel grades with different mechanical strenght will be the first choice for many chassis components
- HSLA and mulitphase steel are predominantly used
- For components, where rigidity is most important, an increase of the elastic modulus is desired

**Hot formed structural components and ballistic protection systems**

- Partial hardening of MnB – steel grades allows for tailoring mechanical propteries within a wide range
- Hot formable ultra high strength steels are used for ballistic protection systems
- The reduction of alloying costs while maintaining strenght-ductility characteristics is attempted

**Exhaust components**

- Chromium oxide based austenitic and ferritic stainless steel grades are predominantly used for exhaust components
- Ferritic stainless steel Ferrite 950 is a potential material for closing the gap between austenitic and ferritic stainless steels

**FVK / Aluminium**

- FVK (glass / carbon) are getting more and more important for chassis (e.g. leave-spring) as well as structural components (e.g. reinforcements) – Joint venture Benteler – SGL
- Aluminium (5xxx / 6xxx ) is increasingly used for chassis and strucutral components – Benteler Aluminium Systems