Modern stainless steel solutions for road and rail

Metalforum Poznan

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Wolfgang Gebel
Stainless EMEA
Outokumpu

June 4th, 2014

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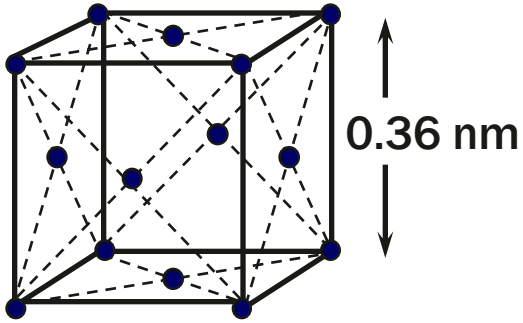
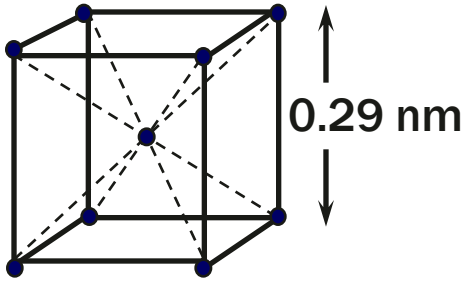
The stainless steel families

Lattice types and microstructures

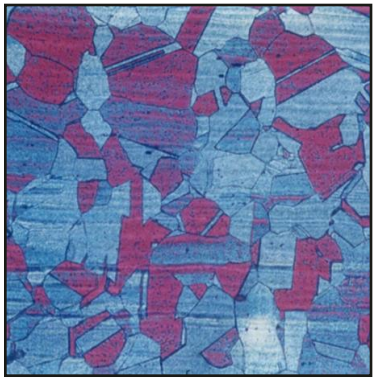
Face-centered cubic



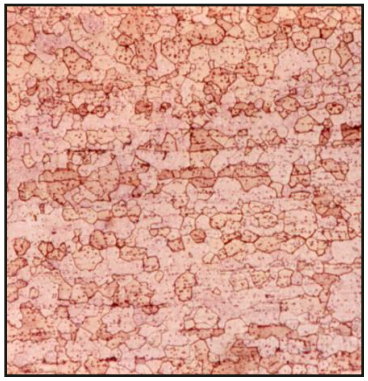
Body-centered cubic



Austenite



Ferrite



Alloying elements and heat treatment determine the crystal structure.

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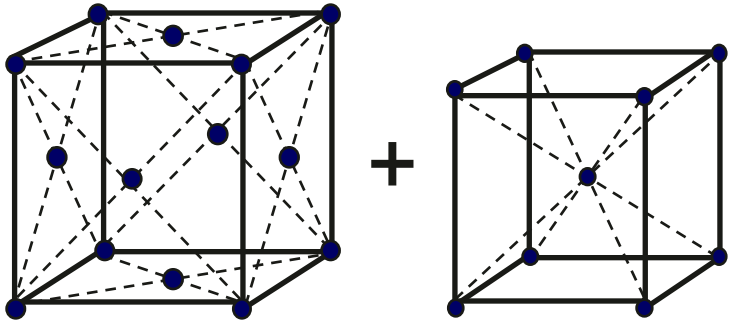
The stainless steel families

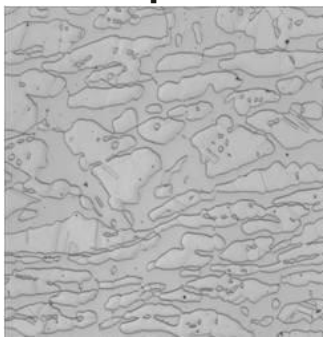
Lattice types and microstructures

Duplex

(Face-centered cubic + Body-centered cubic



Duplex



Different lattice types lead to different material properties.

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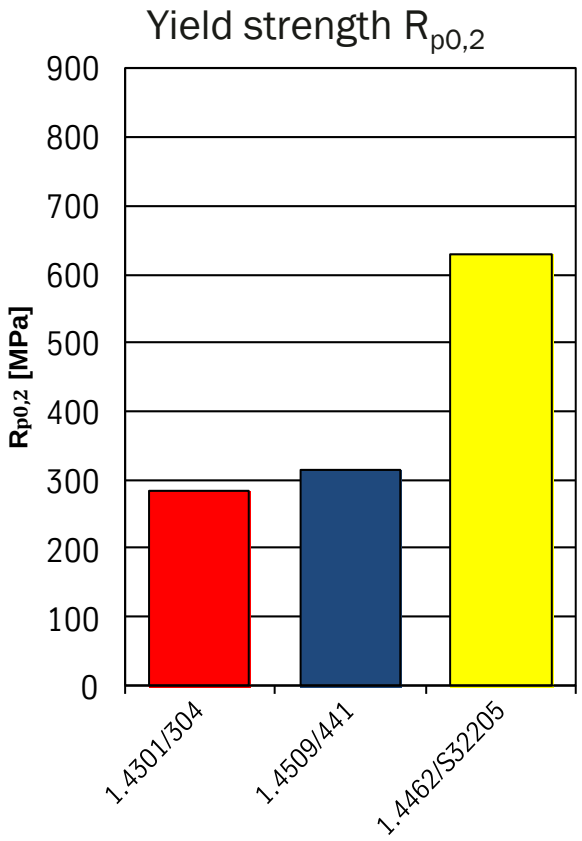
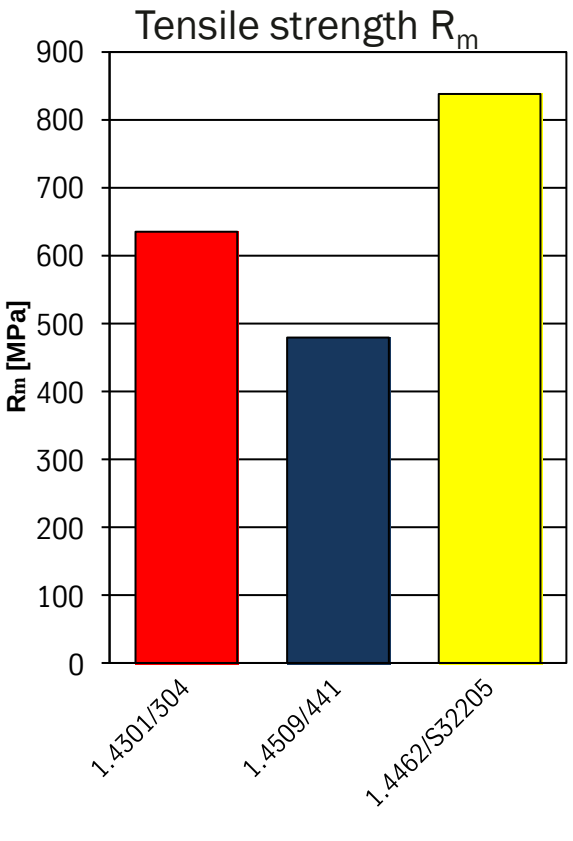
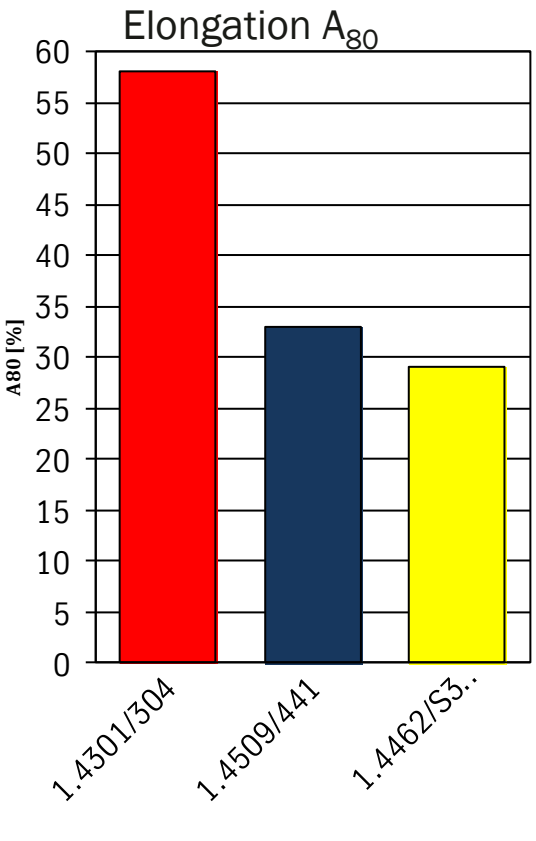
Mechanical properties, 2B finish







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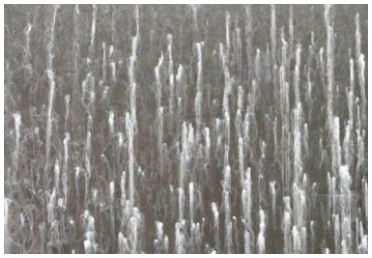
What materials are usually used for the construction of rail cars?

reinforced plastics



aluminium alloys

carbon steels and low-alloy steels

stainless steels

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Ferritic and Duplex stainless steel grades for light weight constructions

Chemical compositions (typ.values) in mass-%

Steel grades EN 10088 ASTM A240 OTK name	C	N	Cr	Ni*	Mo	Mn	others	$Rp_{0,2}$ [MPa] Min values according to EN 10088	Alloy surcharge May 2014 [€/t]
1.4003 S40977	0,02	0,02	11	0,5	< 0,1	< 1,5	-	> 320	387
1.4600 S40977 Ti	0,02	0,02	11	0,8	< 0,1	< 2,0	Ti	> 375	appr. 415
1.4589 S42035	0,04	0,01	14	1,6	0,25	< 1,0	Ti	> 420	576
1.4162 S32101 LDX 2101	0,02	0,22	21,5	1,5	0,3	5,0	Cu	> 530	677
1.4362 S32304 2205	0,02	0,10	23	4,8	0,3	< 1,5	Cu	> 450	915

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**Reducing of Nickel results in cost savings.*

Austenitic stainless steel grades for light weight constructions

Chemical compositions (typ.values) in mass-%

Steel grades EN 10088 ASTM A240 internal	C	N	Cr	Ni*	Mo	Mn	others	$Rp_{0,2}$ [MPa] Min values according to EN 10088	Alloy surcharge May 2014 [€/t]
1.4301 304	0,04	0,04	18,1	8,0	< 0,5	-	Cu: <0,4	> 230	1186
1.4318 301 LN	0,02	0,14	17,7	6,5	< 0,5	< 2,0	-	> 350	1012
1.4376 / H400	0,04	0,2	17,4	4,1	< 0,5	6,8	-	> 400	1030

**Reducing of Nickel results in cost savings.*

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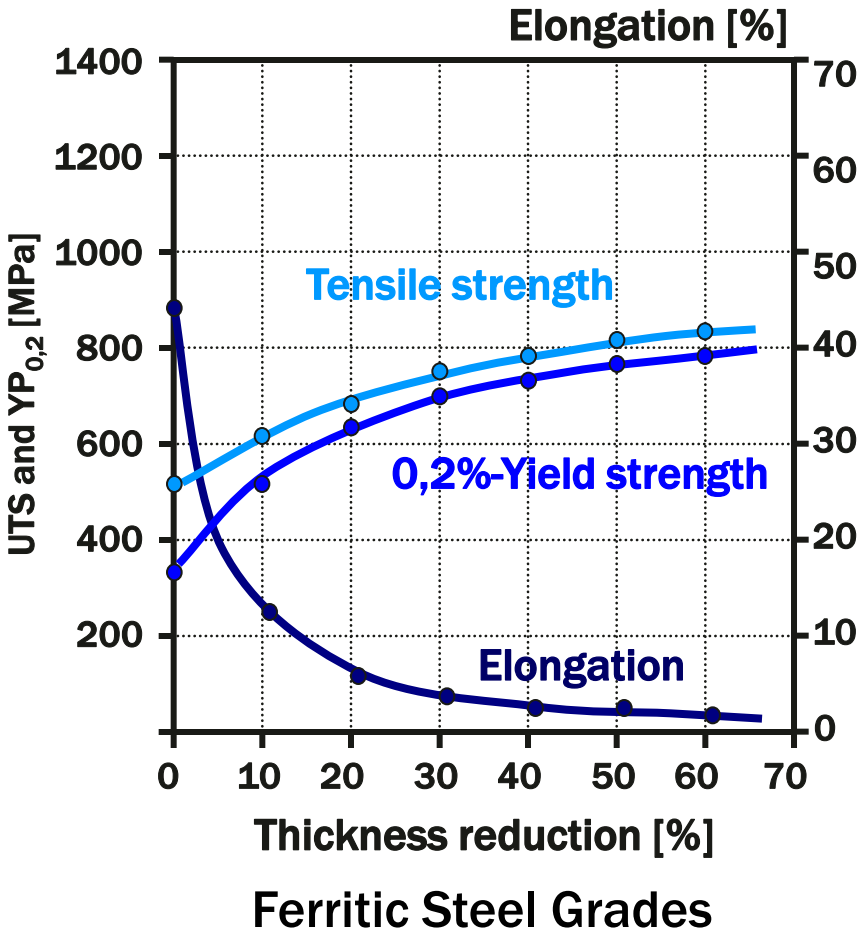
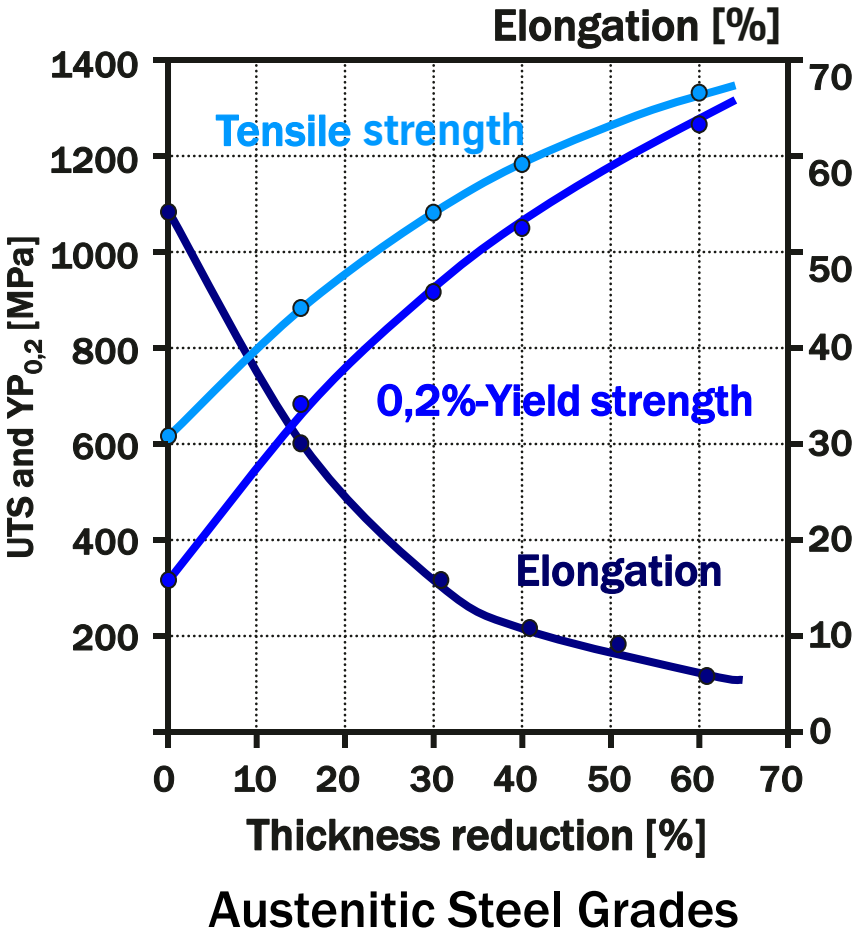
Stainless steel grades

Work hardening effect



Ferritic Steel Grades



Austenitic Steel Grades

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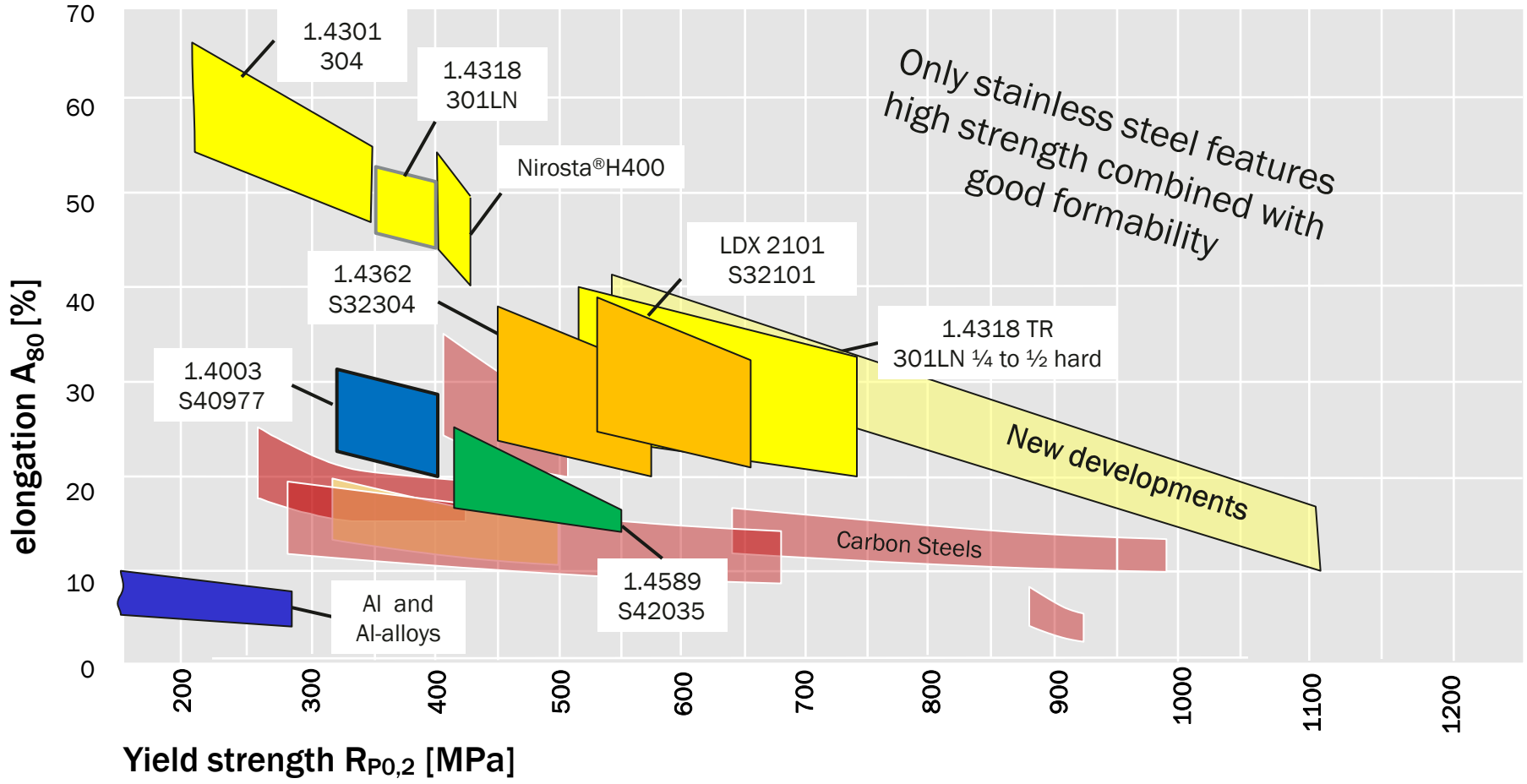
Properties of stainless steel grades for railway vehicles in comparison to carbon steels and Aluminum



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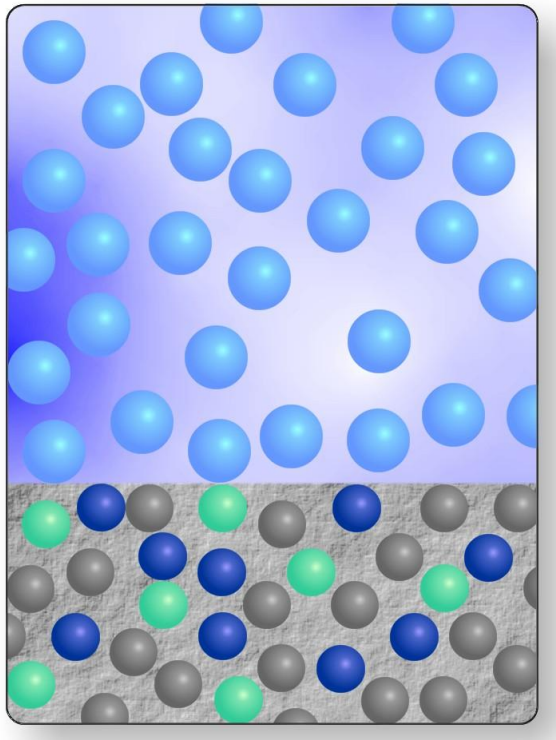
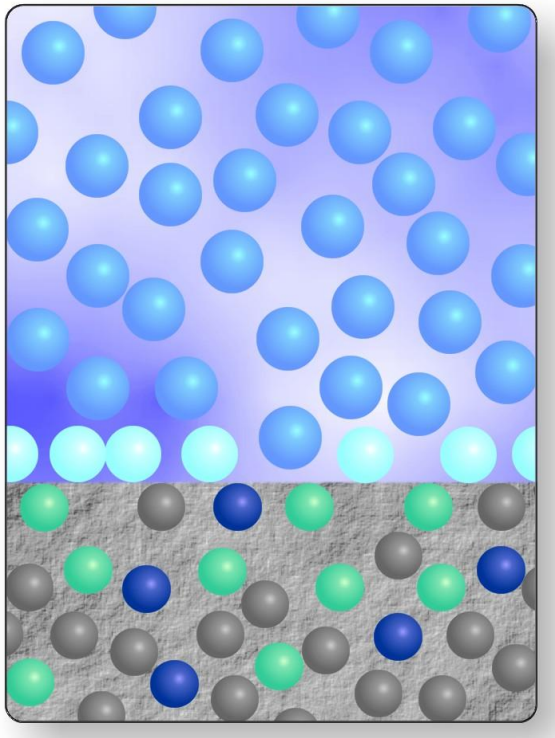
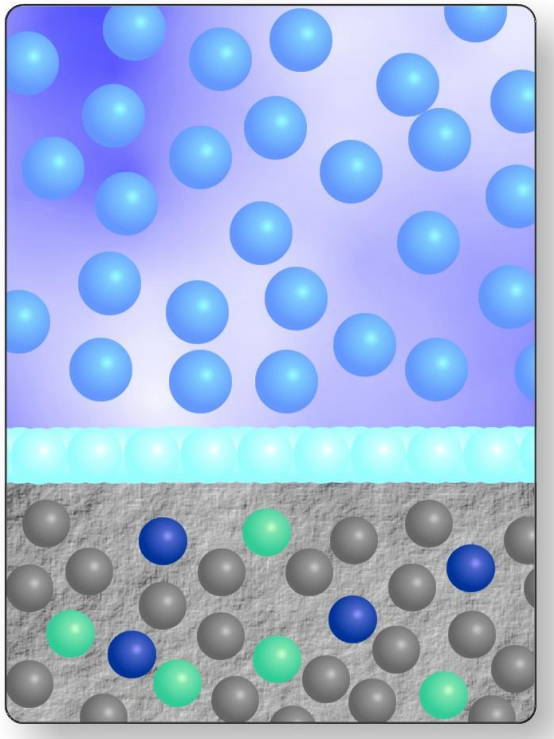
Why stainless steel does not show red rust? Self-passivation effect



Initial state:
Fe with embedded
Cr atoms



Chromium reacts with oxygen from the air, the passive layer is formed (self-passivation)



Compact passive layer of chromium oxide

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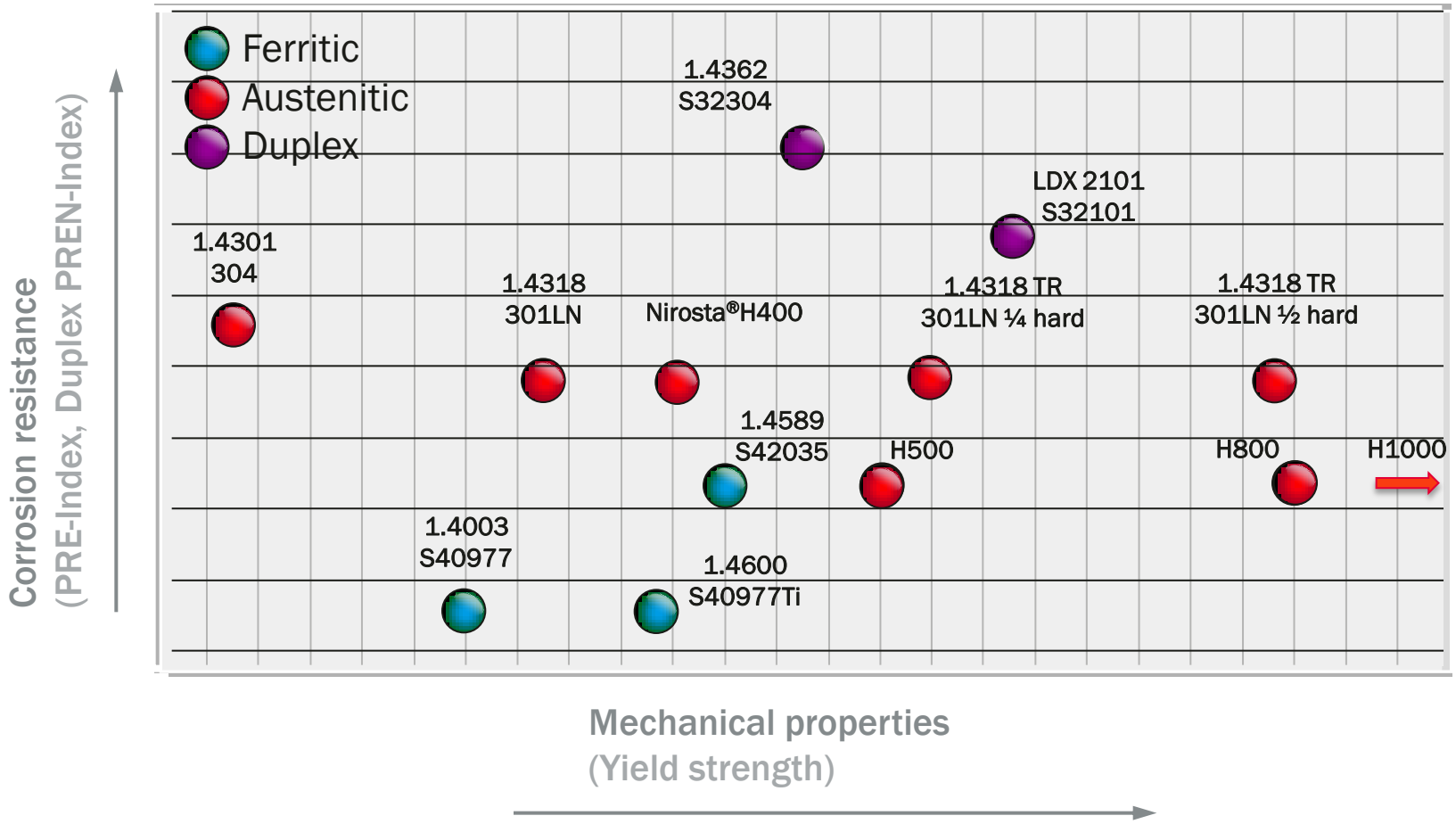
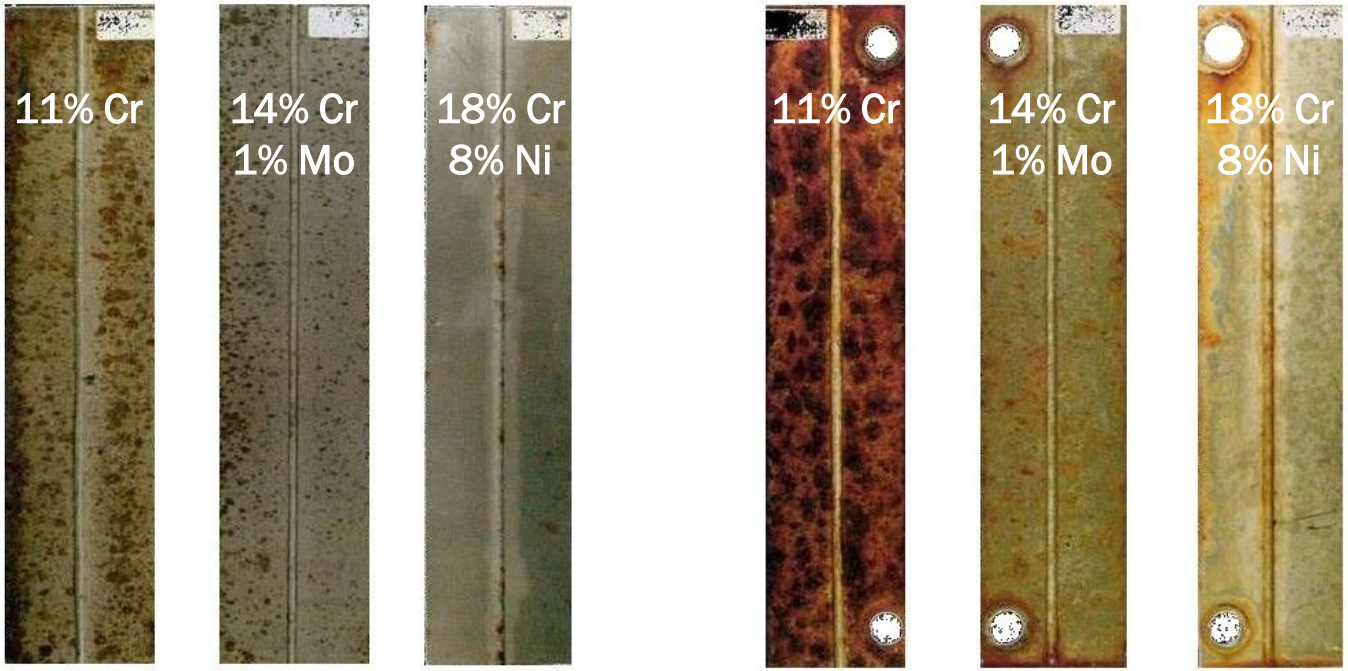
Spectrum of Stainless Steels for transportation systems



Corrosion attack of different steel grades after one year exposure



1.4003	1.4589	1.4301	1.4003	1.4589	1.4301
S40977	S42035	304	S40977	S42035	304

Atmospheric exposure
(Cuxhaven, sea side)

Maritime exposure
(Helgoland island, swash zone)

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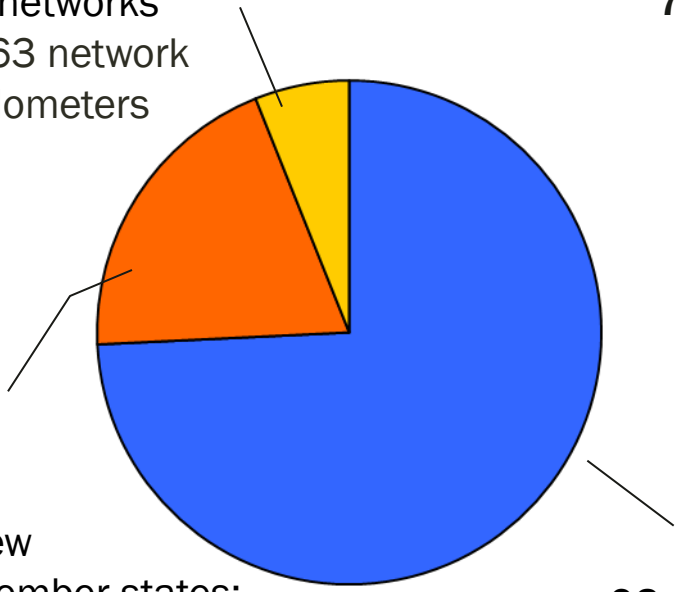
Light Rail Vehicles

other European states;
8 networks
263 network kilometers

Total network 7.303 km



new member states;
26 networks
2.122 network kilometers

EU 15;
98 networks
4.918 Network kilometers

Reference: Stadler Rail

Reference: Metro, light rail and tram systems in Europe, Errac UITP, 2009

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Implemented projects in ferritic grades, Light Rail Vehicles

Bombardier, Flexity, new Light Rail Vehicle of Krefeld city, 2010
Ferritic steel stainless grade: 1.4003 / S40977, painted

Reference: Stadtwerke Krefeld AG

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Implemented projects in ferritic grades, Light Rail Vehicles

Stadler, Tango, new Light Rail Vehicle of Basel city, 2008
Ferritic steel stainless grade: 1.4589 / S42035, painted

Reference: Stadler Rail und Badische Zeitung

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Implemented projects in ferritic grades, Metros

Berliner S-Bahn, Bombardier (former LEW Hennigsdorf), ongoing since 1990
Ferritic steel stainless grade: 1.4589 / S42035, painted

Reference: Wikimedia Commons, Creative Commons

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Implemented projects in austenitic grades, Metros

Strong growing in Asia demands stainless steel for Metro vehicles

Metro Delhi, Bombardier, 2010
Austenitic steel stainless grade: 1.4318 / 301LN; 1.4307 / 304L brushed

Reference:Bombardier Transportation

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Implemented projects in austenitic grades, Metros

Hamburger Hochbahn DT5, 2009
Austenitic stainless steel grade: 1.4318 / 301LN,
side panel: 2G (grain 320 + brushed)

Reference: Hamburger Hochbahn

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Commuter and Regional Trains, Double-deck Coaches, ferritic grades

Double-deck Coaches of German Railways, Bombardier, ongoing
Ferritic steel grade: 1.4003 / S40977, painted

Reference: Wikimedia Commons, Creative Commons, RsVe

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Commuter and Regional Trains, Multiple Units (MU), ferritic grades

Talent, Bombardier

Coradia Lint, Alstom

Commuter and Regional Trains, Electric and Diesel Multiple Units, ongoing
Ferritic steel grade: 1.4003 / S40977, painted

Reference: Wikimedia Commons, Creative Commons

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1.4600 for ore/coal railway cars

Steel grade:	1.4600/1.4003 Ti (≈S40977Ti)
Surface finish:	1D
Gauge:	3.00-8.00 mm
Customer:	Sandvik (Australia)
End use:	Railway cars (mining)
Demands:	Corrosion resistant, weldable
Benefits:	Cost-effective, weldable stainless steel

Australian ore / coal railway car
Ferritic stainless steel grade: 1.4600 / S40977 Ti

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Example of a city bus made of ferritic stainless steel 1.4003 / S40977

Reference: Solaris bus and coach

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Selection criteria for materials

Why is stainless steel the ideal material for railway vehicles?
Certainly because of it`s corrosion resistance, but additionally there is a wide range of different useful properties, which cannot be offered for low cost.

	stainless steels	Carbon steels	Aluminium alloys
Design	++	++	++
Construction	++	++	++
Corrosion resistance	++	-	o
Weight, energy consumption, wear, lifecycle	++	+	+
Repairing feasibility	+	+	-
Experience	o/+	+	-
Mechanical loading cases	++	+	- -
Price	o	++	o
Lifecycle costs	++	-	+

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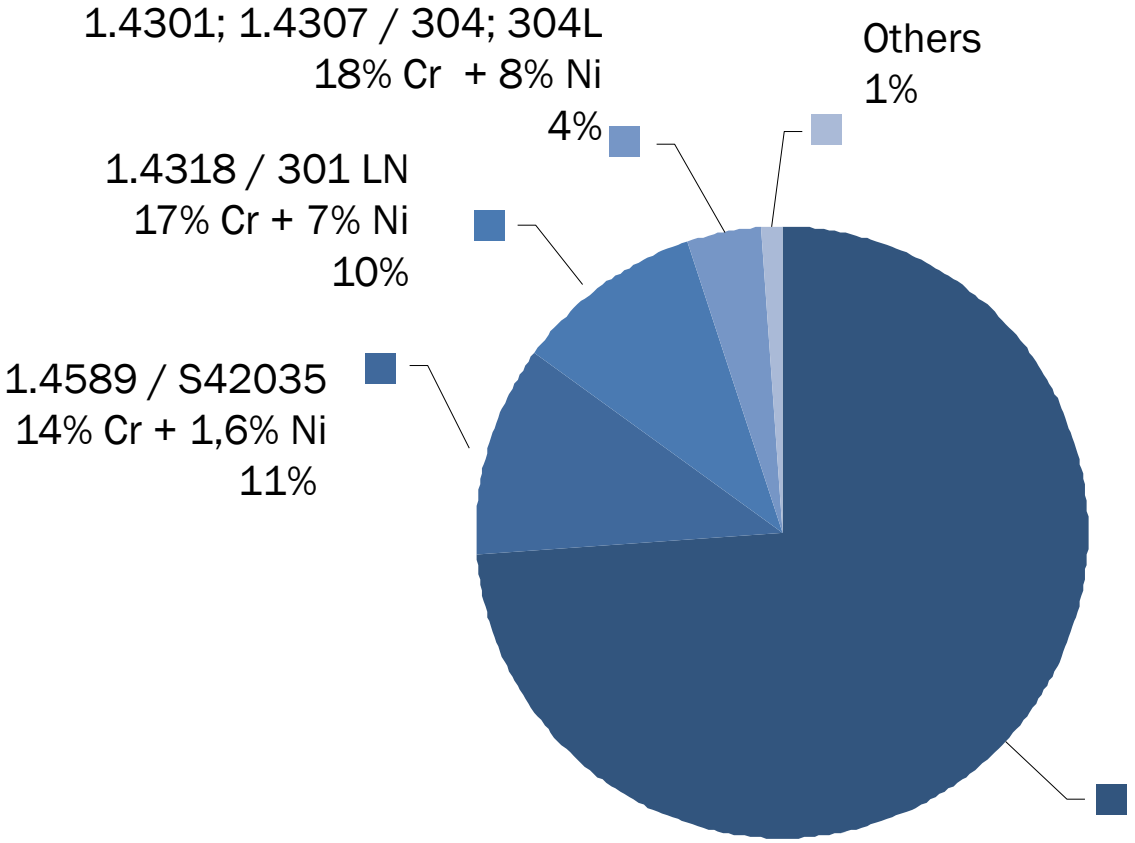
Actual distribution of steel grades for railway vehicles in Europe



Résumé for today:
Biggest volume for the

- cheapest steel grade with
- the lowest light weight capability and
- lowest corrosion resistance

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Some arguments for stainless steels from the press releases of our customers

Light weight

- 10 % weight reduction results in 7 % energy saving for a metro system
- weight reduction results in a life time increase for wheel rims.

Corrosion

- Stainless steel bodies are more expensive but they are durable and have low maintenance costs.
- A life-time of over 30 years without harmful corrosion attacks
- Car bodies made of stainless steel are very sustainable.

Manufacturing

- Good weldability.
- Also in case of an accident vehicles are easy to repair.

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Some arguments for stainless steels from the press releases of our customers

Low-floor vehicles

- A lot of aggregates have to displaced onto the roof.
- 30 % of the length consists of doors.

Both results in a very high pressure of the body, especially under oscillating loads. Therefore high strength stainless steels are the best choice for the construction.

Recyclability

Bodies of stainless steel vehicles are totally recyclable without any loss in quality of the steel grade. Every standard stainless steel grade is a recycled material.

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OEM´s have more than 15 years of experience with austenitic steels (H400)

Lightweight solution by:
high mechanical strength and
high ductility properties.

- Advantage of the material:
  Excellent formability because of limited space.
- Lightweight potential: 20% weight saving by reduction of thickness
- Better fatigue behavior.
- Almost the same hardness in the weld seam and in the base material.

Audi A8

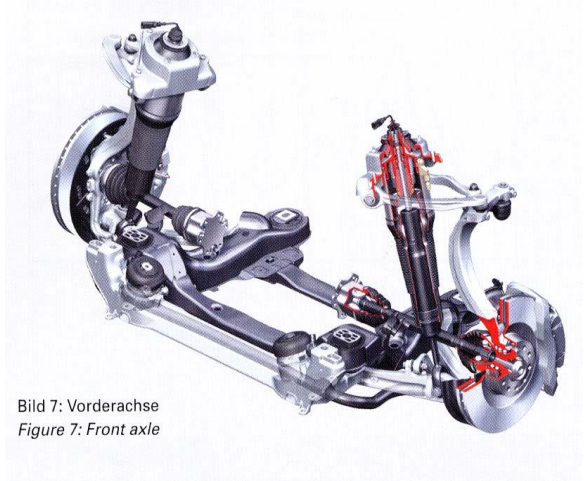

Bild 7: Vorderachse
Figure 7: Front axle

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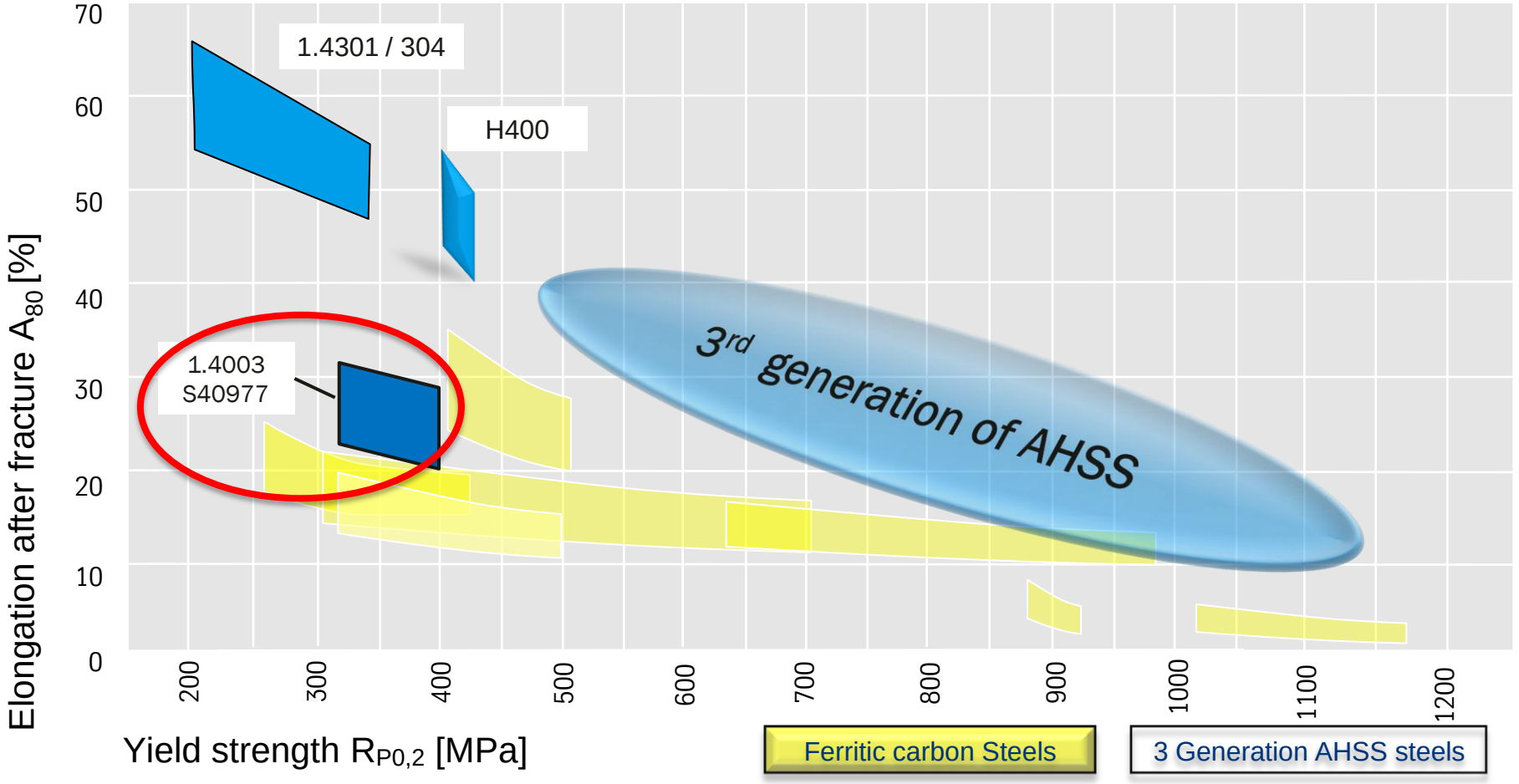
Demand of all car manufacturers:
3rd Generation AHSS (Advanced high strength steel)



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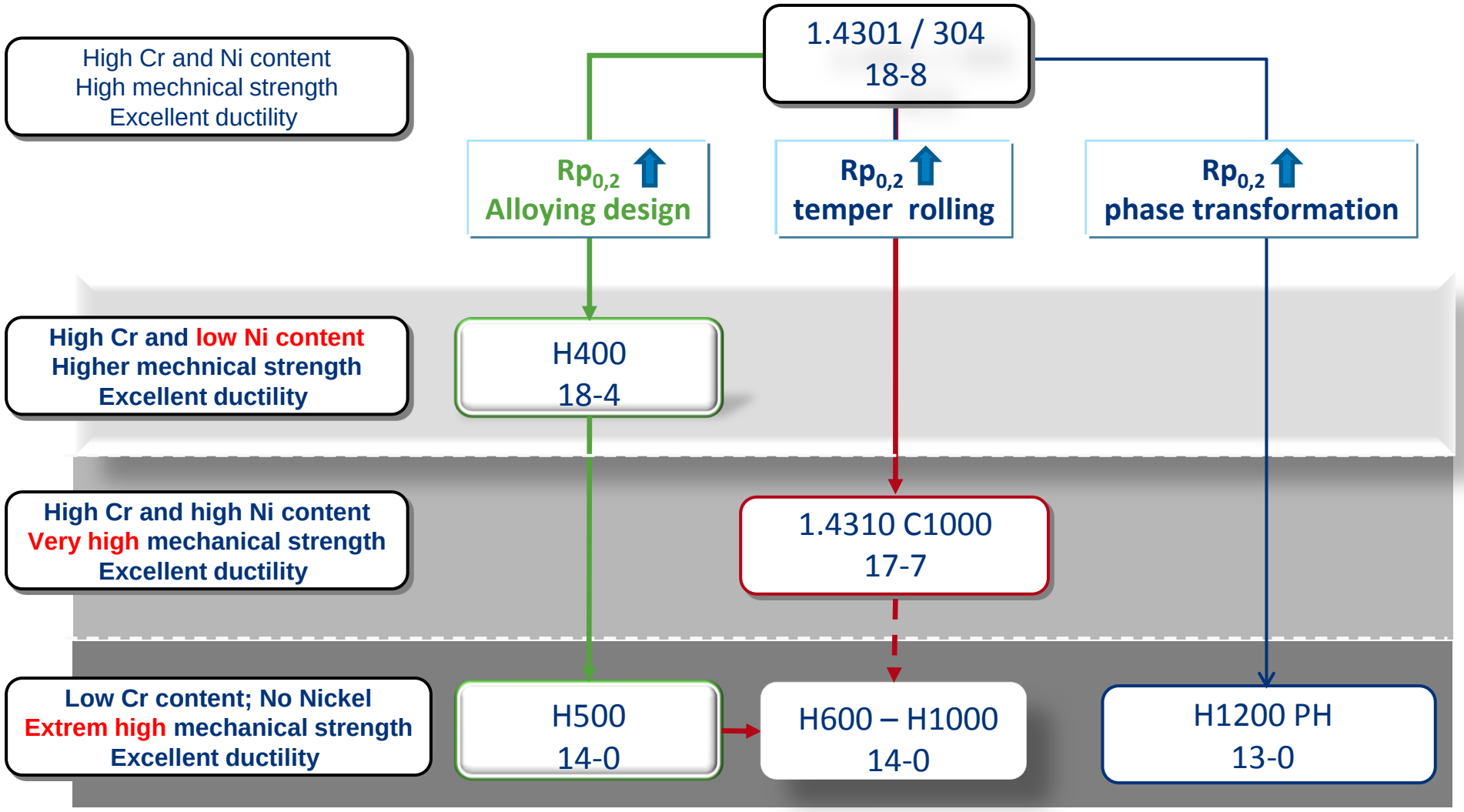
Cost effective light weight material



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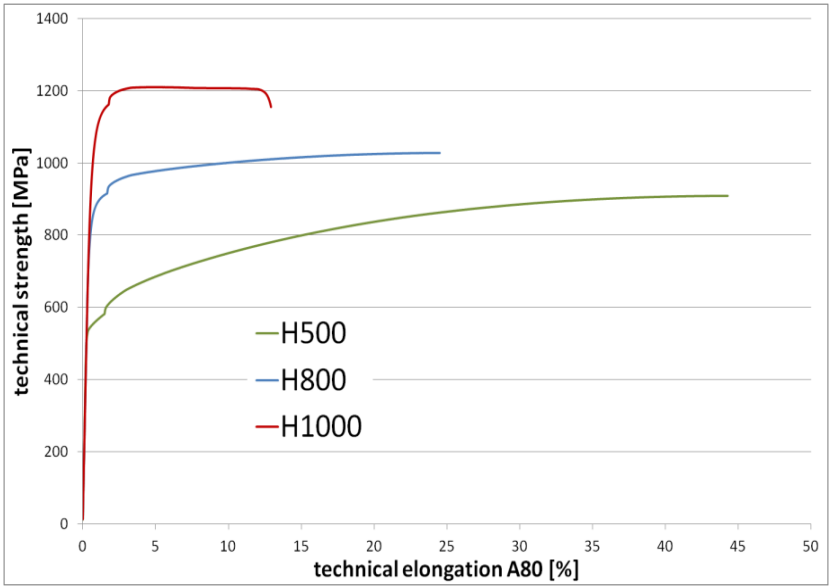
Our material design strategy – H500

and its temper-rolled variants H800 / H1000

- Ni-free Cr-Mn austenitic stainless steel
- Ni substituted by Mn, C and N

	C	Mn	Cr	Ni	N	Mo	PRE*
H500 (H800 / H1000)	0.31	16.0	14.20	0.45	0.30	0.03	19

*PRE = %Cr + 3.3 x %Mo + 16 x %N



	$R_{p0.2}$ [MPa]	R_m [MPa]	A_{80} [%]
H500	540	910	45
H800	780	1000	33
H1000	990	1200	16

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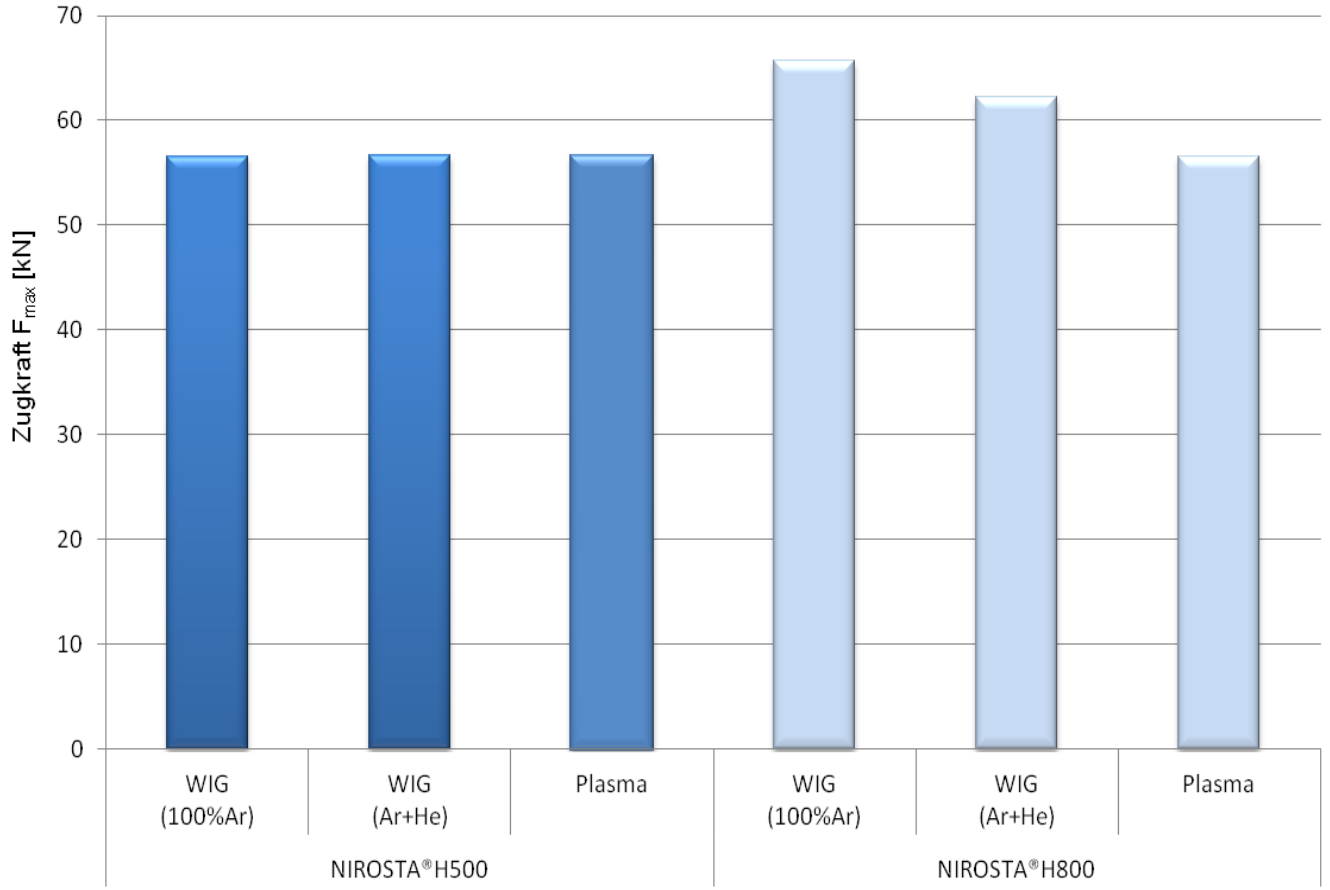
TIG welding

Quasistatic tensile test



NIROSTA®H500 –H500

NIROSTA®H800 –H800

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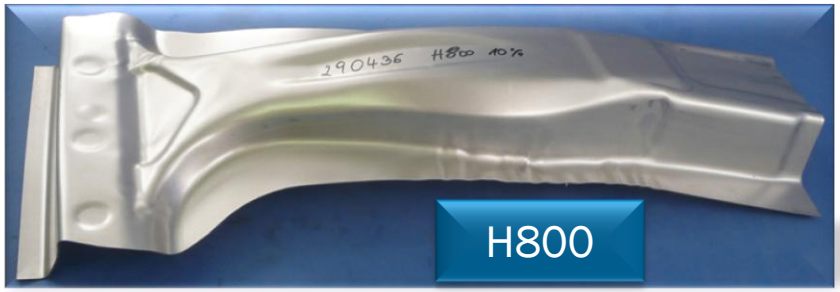
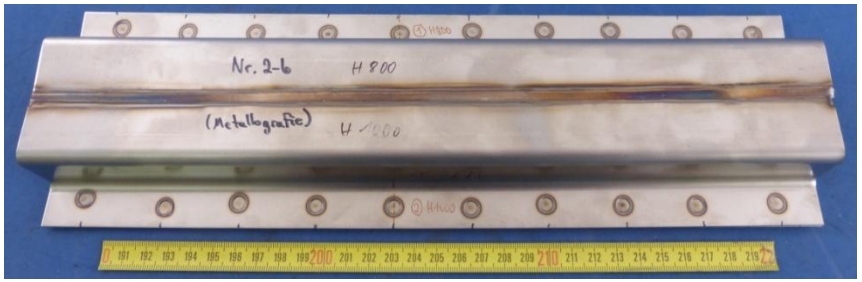
Material is now commercially available



Vari-Form: H800 Hydro formed

Crash behaviour

- dynamic three point bending test:
  - Drop height h = 2,50m
  - Drop mass m = 57,90kg
  - Speed v_0 = 24,50km/h



Video: TIG tailored H800 / H1000 (1,5mm) with closing plate HC340LA+ ZE

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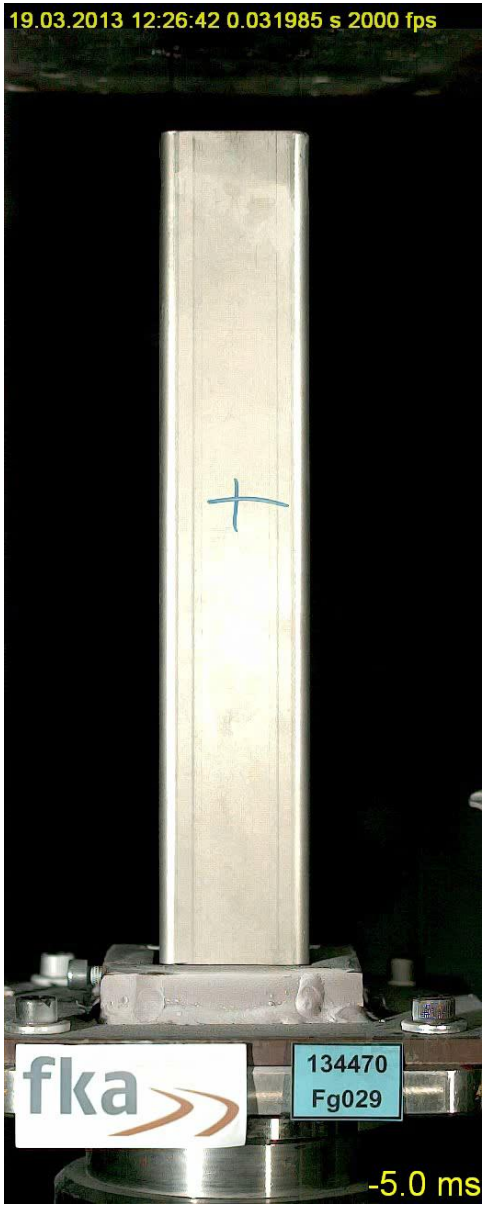
Crash behaviour

- axial crash test with rectangular tube:
  - Drop height h = 4,00m
  - Drop mass m = 433kg
  - Speed v_0 = 30,73km/h

TIG welded H800 (1,5mm)



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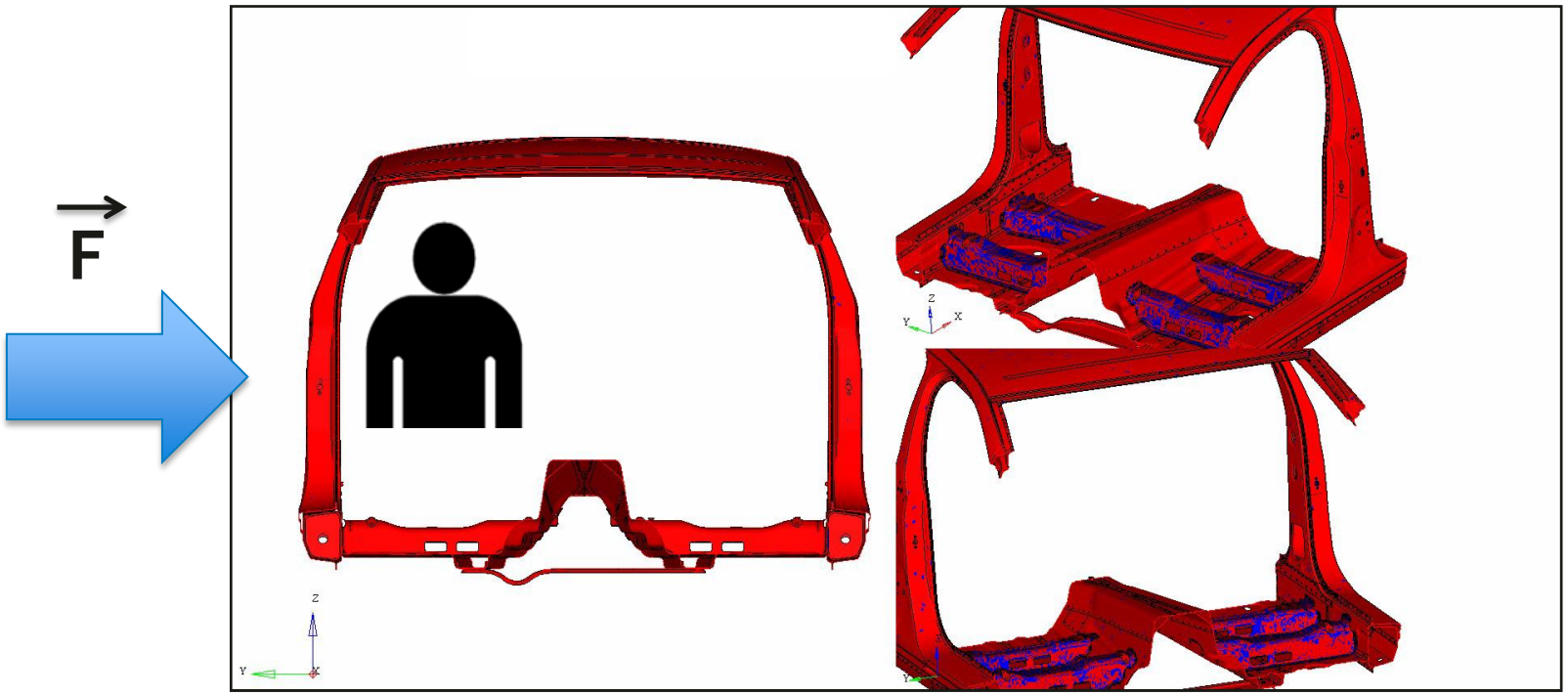
Crash behavior of the B-Pillar comparison between C-steel grade with Rm = 1600 MPa; t=1.7mm and H1000; t=1.1mm



Not optimized in design for austenitic steels

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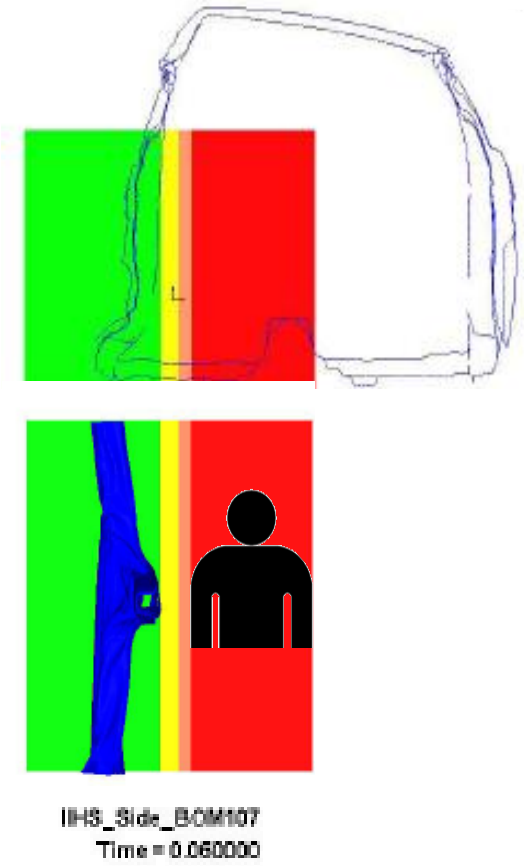
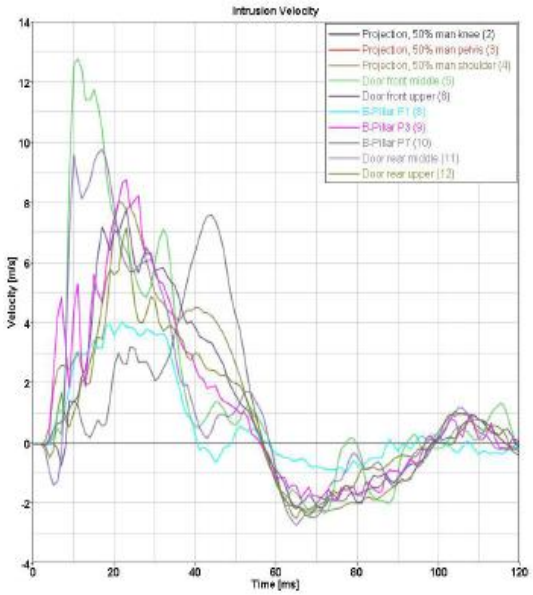
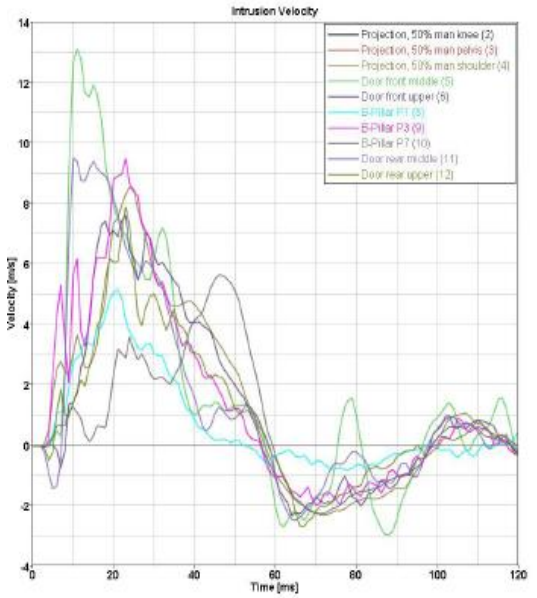
Interpretation of the IIHS schematic view

C-steel grade with Rm = 1600 MPa; t=1.7mm and H1000; t=1.1mm – max. Intrusion





C-Steel grade
Rm=1600 MPa, t=1.7mm



H800
t=1.1mm

Same safety for passengers with reduced thickness

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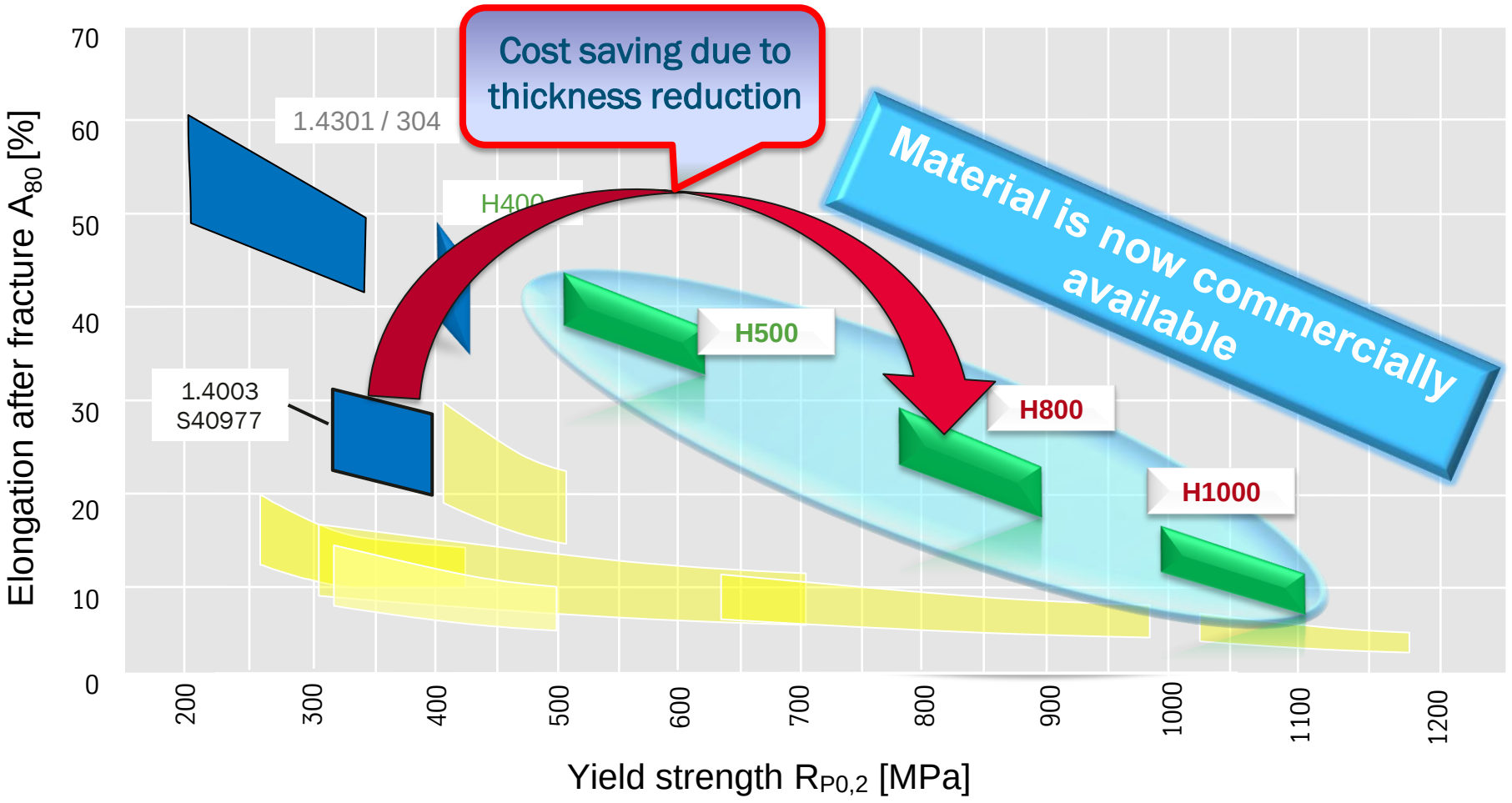
CrMn-Steels - Solution for 3rd Generation AHSS

Between 30-50% light weigt potential compared to ferritic grades



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We estimate that more than 300 kg weight reduction is possible by replacing 1.4003 with H800

Ferritic stainless steel 1.4003 / S40977 in rectangular tube construction before painting

Reference: Solaris bus and coach

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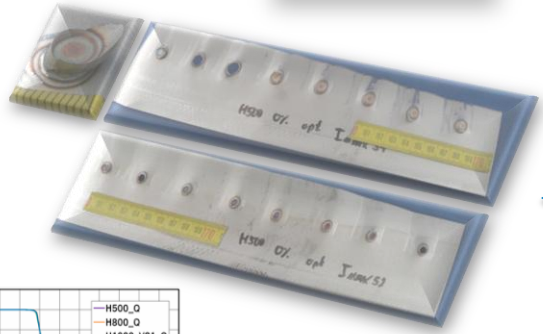
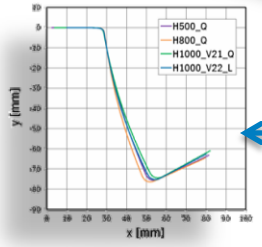
Excellent processability in press plant, assembly plant and painting shop.

On the road	ED Coating	Assembling line	Stamping plant	Sheet conditioning	Simulation
Crash	Stone chipping	Spot welding	Formability	Hole expansion	Crash
Fatigue	Paint bonding	Spotweld adhesive	Press force		Formability
Corrosion	Adhesive Bonding	MIG	Tribology		
Recycling	Contact corrosion	MIG solder	Springback		
		Laser	Trim Egde		
		Clinch	Critical press form		
			Formability		





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Conclusion

New MnCr steels from Outokumpu Nirosta

- Ready for delivery
- First small series in application and OEM enabling processes started
- High joinability for a lot of joining procedures and material partners

CrMn steels for more security, more complexibility, higher crash absorption and lightweight potential

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Many thanks for Your attention

All statements as to the properties or utilization of the materials and products mentioned in this presentation are for the purpose of description only. Guarantees in respect of the existence of certain properties or utilization of the material mentioned are only valid if agreed upon in writing.

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