

Latest 3rd GEN AHSS and 2nd GEN Press Hardened Steels: solutions to new automotive challenges



ArcelorMittal

Dr. Ahmed BELHADJ,
*Global R&D Automotive product,
New product manager*

St Quentin En Yvelines

October 2019

$$\frac{\partial f_{i,j}(\vec{x}, \vec{c})}{\partial x_i} = \sum_{k \neq i} c_{k,j}$$



The right formula
for the steels of the future

3^{ème} édition

AUTOMOTIVE
CONNECTION 2019

9 & 10 OCTOBRE 2019

ST QUENTIN EN YVELINES (LA FERME DU MANET)

Exposition B2B & Conférences dédiées à l'innovation dans l'industrie Automobile

Introduction

ArcelorMittal as a key partner for the automotive industry

- › ArcelorMittal helps carmakers meeting the geographical and technology challenges
- › ArcelorMittal is not only a global steel supplier, we are also a **global steel solution provider** for the automotive industry thanks to:
 - › Our technological know-how and leading position in **Advanced High Strength Steels (AHSS)**
 - › Close relationships with our customers across the world, often working with them from the vehicle **design stage**
 - › Continuing investment in **Research & Development**
 - › Our ability to provide **highly engineered solutions** that help make vehicles lighter, safer and more fuel-efficient
 - › **Global availability** of our advanced steels

ArcelorMittal is a global steel solution supplier

Global Research and Development – 2018 key figures

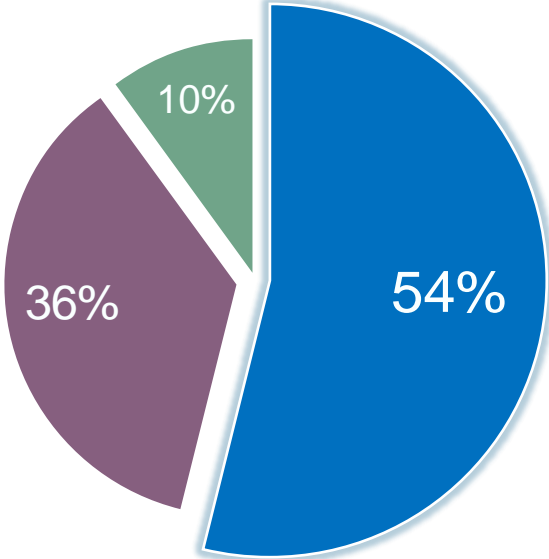
1500+
researchers

\$290m
spending

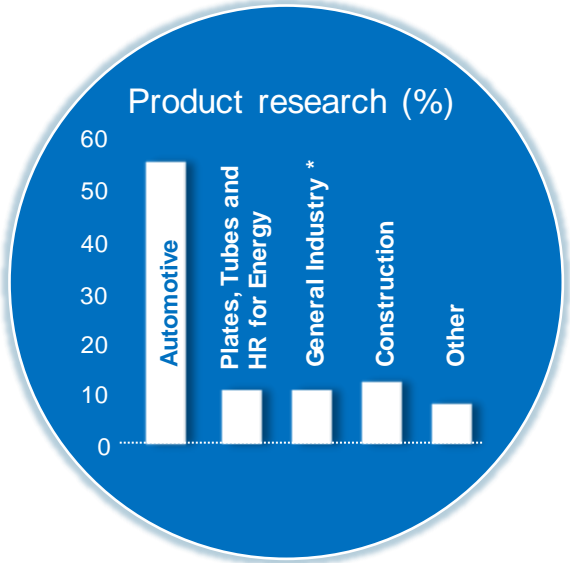
Comprehensive portfolios and programmes

11
research centres

Budget spending by focus area



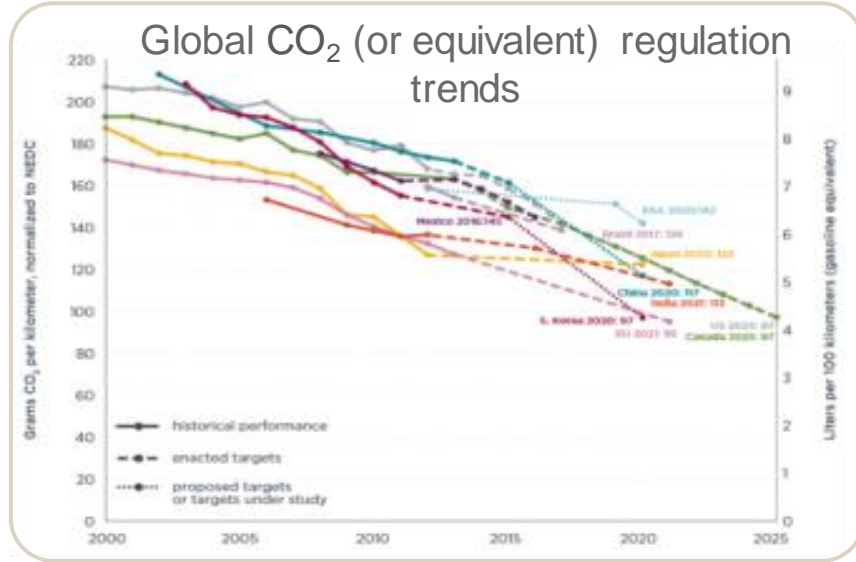
- Product and Applications
- Process
- Exploratory breakthrough



R&D effort fully aligned with Group strategy: geography, value chain, product differentiation

Vehicle Light weighting through AHSS Steel Solutions

AM portfolio developed to support OEM to meet regulations



Source: icct

*Through constant innovation, **steel remains the material of choice** and to address >>increasing challenges of CO², NO_x ... regulations*

Maximum tensile strength of steel multiplied by 6 in 25 years

Usibor® 2000 and Ductibor® 1000 for hot stamping

3rd Generation AHSS Fortiform® for cold stamping

Laser welded Blanks for hot stamping

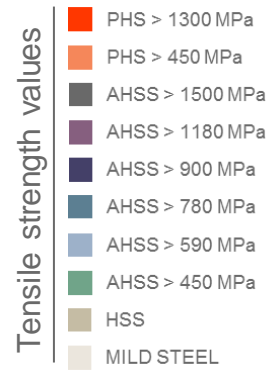
Usibor® 1500 and Ductibor® 500 for hot stamping

Dual Phase, TRIP Steels, Martensitic

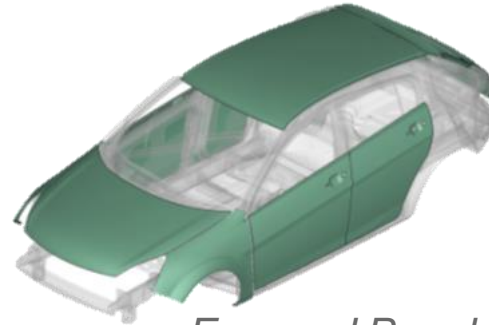
HSLA, High Strength Steels



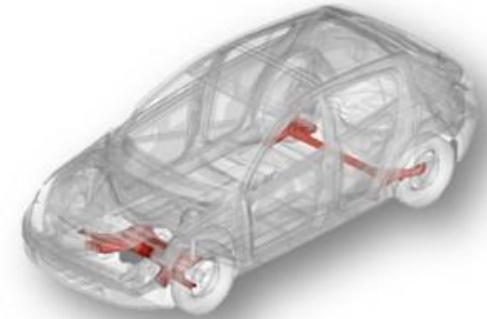
Innovative products to meet OEMs expectations for... ... BIW structure & chassis



BIW Structure



Exposed Panels

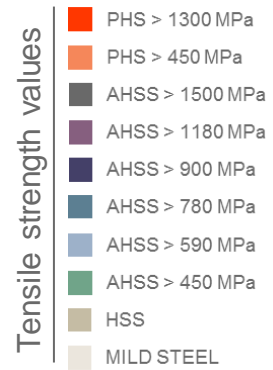


Chassis Structure

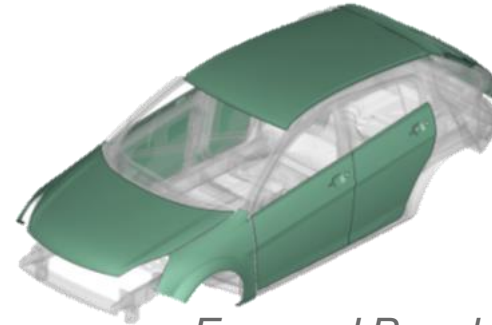
Emerging innovations: Hot stamping / Cold stamping / Coatings

Function	Products
High Strength + Crash Ductility for Hot Stamped parts	Usibor® 2000, Ductibor® 1000
Cosmetic corrosion for Wet Areas – Hot Stamping	Usibor® Ultraprotect
High strength + formability + crash ductility for Cold Stamped parts	Dual Phase DH, Fortiform®
High Strength for Roll Forming – Crash Forming – Bending	MartINsite®: 1200 / 1300 / 1500 / 1700
AHSS – Chassis	HR-CP980SF
Thin and formable panels + flexural stiffness solutions for exposed parts	FF280DP
Hydrogen control – Environment – Cost of corrosion	Jetgal® coating for AHSS
Cost of corrosion + formability on exposed panels	Forming grades + Zagnelis® Exposed
Corrosion resistance – Environment – Cost of corrosion – Chassis	Zagnelis® Protect coating for AHSS

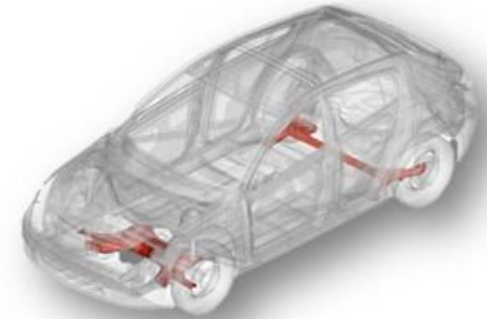
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BIW Structure



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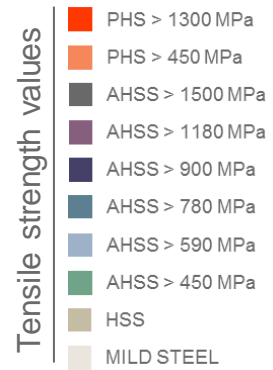


Chassis Structure

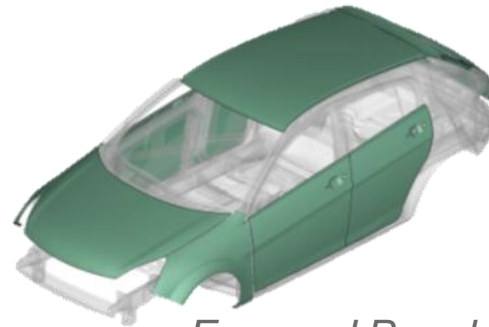
Emerging innovations: Hot stamping

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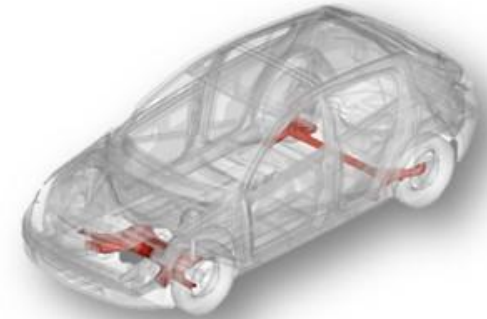
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BIW Structure



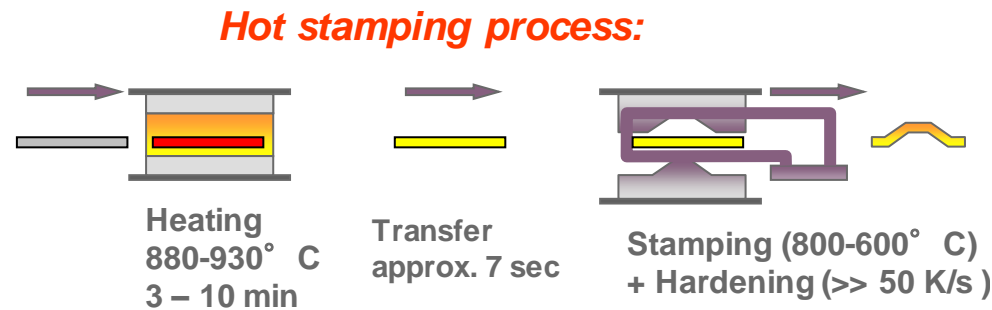
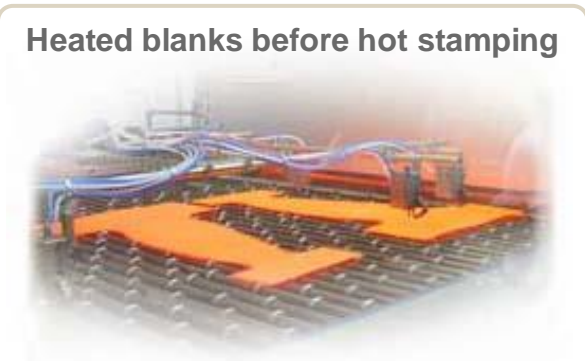
Exposed Panels



Chassis Structure

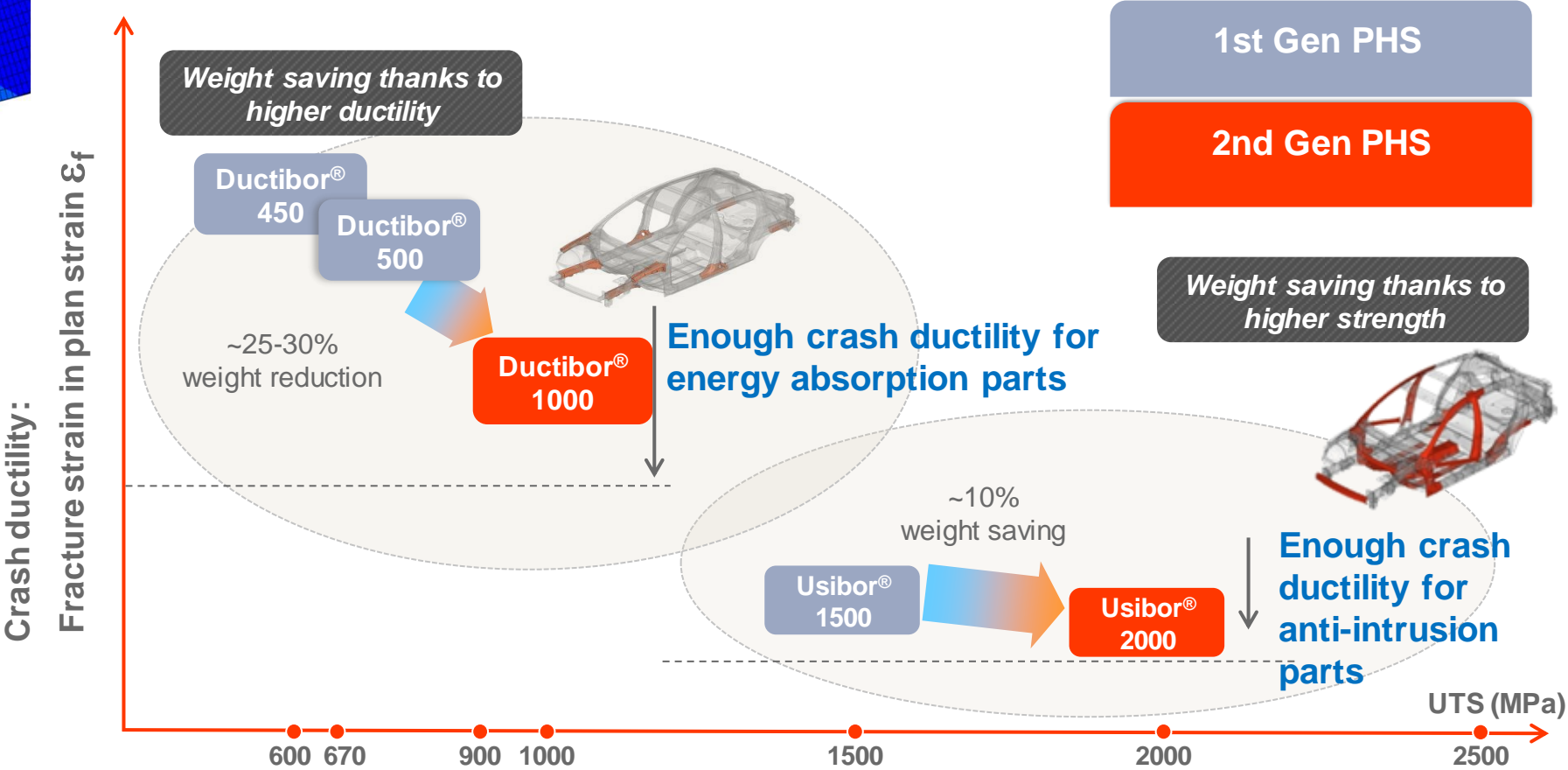
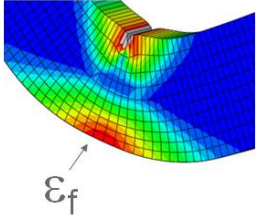
Emerging innovations: Hot stamping

Function	Products
High Strength + Crash Ductility for Hot Stamped parts	Focus on Usibor® 2000, Ductibor® 1000
Cosmetic corrosion for Wet Areas – Hot Stamping	Usibor® Ultraprotect



- Very high strength (up to 2000 MPa tensile strength)
- No springback, enabling complex parts
- Excellent corrosion resistance
- Huge weight saving potential for anti-intrusion parts (up to 30%)
- Tailored properties thanks to Laser Welded Blanks (LWBs), combining Usibor® with Ductibor®
- Very fast global growth

ArcelorMittal 2nd generation of AS-coated Usibor[®] and Ductibor[®]



ArcelorMittal 2nd generation of PHS steels already industrialized

Aluminised Usibor® 2000 and Ductibor® 1000 vs Usibor1500

Product	Test Method	YS MPa Min.	UTS MPa Min.	Typical TE % ⁽³⁾	Bend Angle ⁰ Min ⁽⁴⁾
Usibor® 1500 AISi	ASTM-L /ISO-L ⁽²⁾	1050	1400	5	50

Anti-Intrusion parts Usibor® 2000

- As heat-treated microstructure: martensitic
- Coating: AS150
- Thickness = 0.8 - 2.0 mm

Product	Test Method	YS MPa Min.	UTS MPa Min.	Typical TE % ⁽³⁾	Bend Angle ⁰ Min ⁽⁴⁾
Usibor® 2000 AISi	ASTM-L /ISO-L ⁽²⁾	1400	1800	5	45

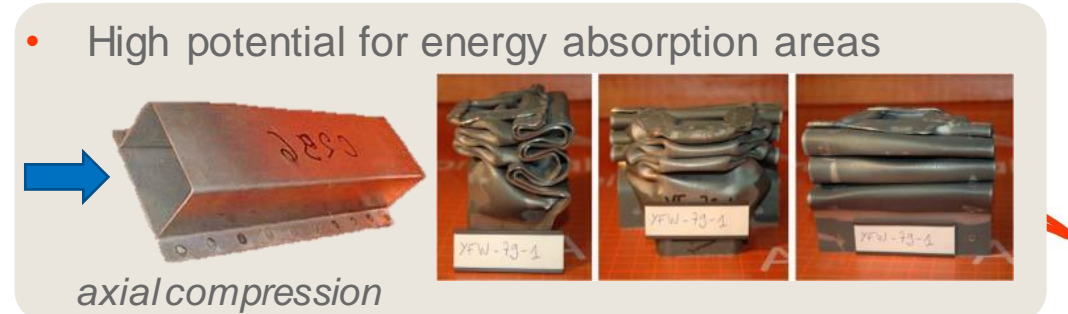
Energy absorption Ductibor® 1000

- Available as coils or as laser welded blank
- As heat-treated: predominantly martensite
- Thickness = 1.0 - 2.1 mm

Product	Test Method	YS MPa Min.	UTS MPa Min.	Typical TE % ⁽³⁾	Bend Angle ⁰ Min ⁽⁴⁾
Ductibor® 1000 AISi	ASTM-L /ISO-L ⁽²⁾	800	1000	6	80

Notes: ⁽²⁾ After Lab paint baking simulation; ⁽³⁾ Elongations are not indicative of failure in crash, relevant is the minimum bending angle. ⁽⁴⁾ Bending angle following the VDA238-100, referring to 1.5mm thickness test specimen.

- High potential to substitute Usibor® 1500 parts
- Can be associated with other grades of the Usibor® and Ductibor® family through Laser Welded Blanks (LWBs)



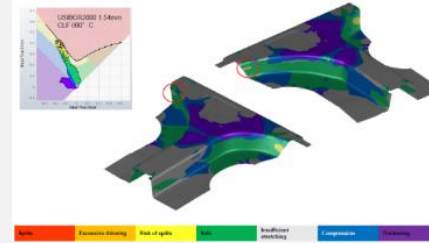
Usibor® 2000: Part Manufacturing

- ✓ Same Hot Stamping lines as Usibor1500+AS lines
- ✓ No geometrical restriction compared to Usibor1500 in terms of stampability
- ✓ Hydrogen control: DP < -5°C in blank heating furnace
- ✓ MP stabilities: cooling rate @ [400-200°C] > 40°C/s
- ✓ Laser Trimming

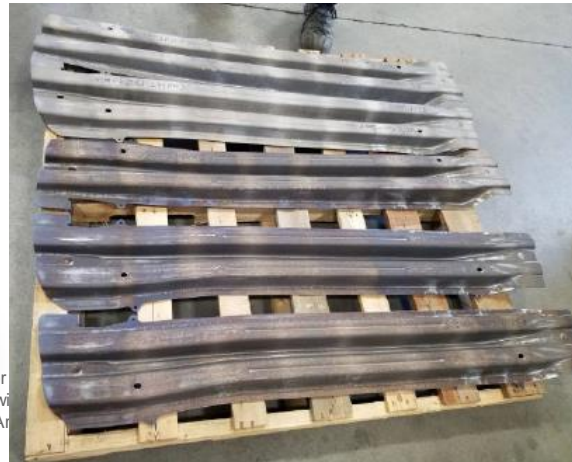
Laboratory:
FE simulation
fits
experiments



FE simulation



Industrial trials: Many Hot Stampers confirmed part feasibility



Usibor[®] 2000 Challenges overcome : Key properties

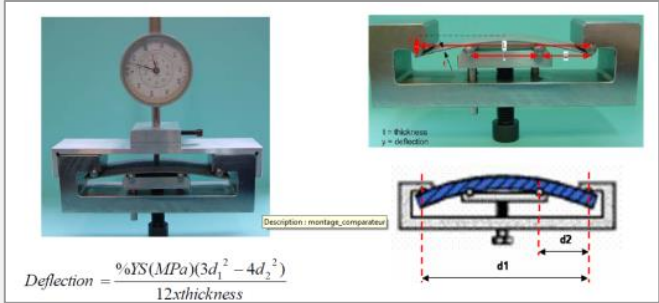
No observed stress corrosion cracking thanks resistant metallurgy and the safe behavior of the AS coating

Components are tested in the CCT chamber

Material	Component State		State after 6 cycle
Usibor 2000 AISi + BH	Unpainted	w/o scratches	No crack
Usibor 2000 AISi	E-coated	w/o scratches	No crack
		with scratches	No crack

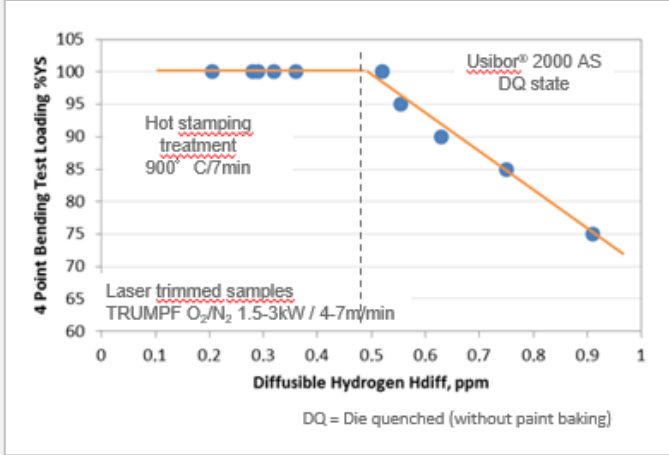
Good Resistance against delayed fracture

- The 4 points bending

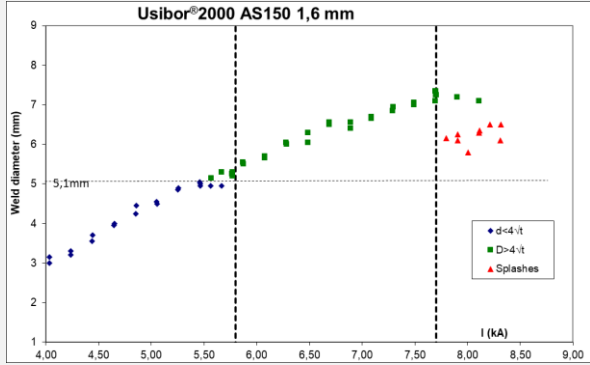


$$\text{Deflection} = \frac{\%YS(MPa)(3d_1^2 - 4d_2^2)}{12 \times \text{thickness}}$$

Usibor[®] 2000 Ok at an applied stress of 100% YS without post degassing heat treatment when dew point remains < -5° C in blank heating furnace



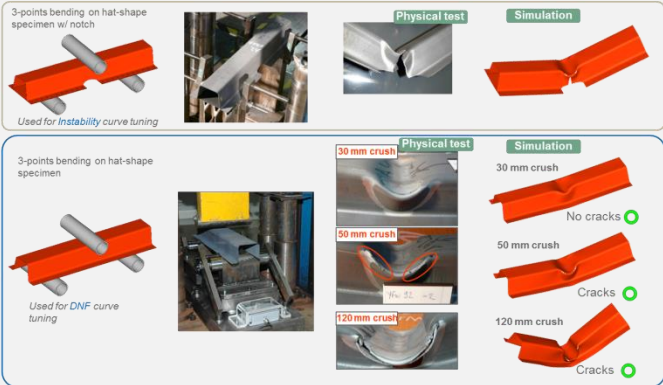
✓ same welding range than Usibor 1500 AS



Unpainted omega After corrosion



E-coated omega After corrosion



✓ Numerical simulation to demonstrate that most of the Usibor[®] 1500 applications can be considered in Usibor[®] 2000 ⇒ Usibor[®] 2000 satisfying crash ductility has already been validated by several carmakers

Ductibor® 1000 : Part manufacturing

Highlight: Robustness of the mechanical properties in real industrial parts

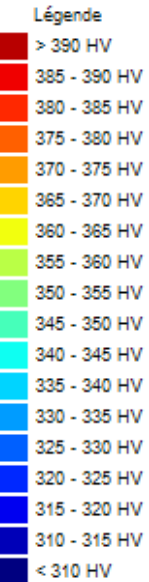
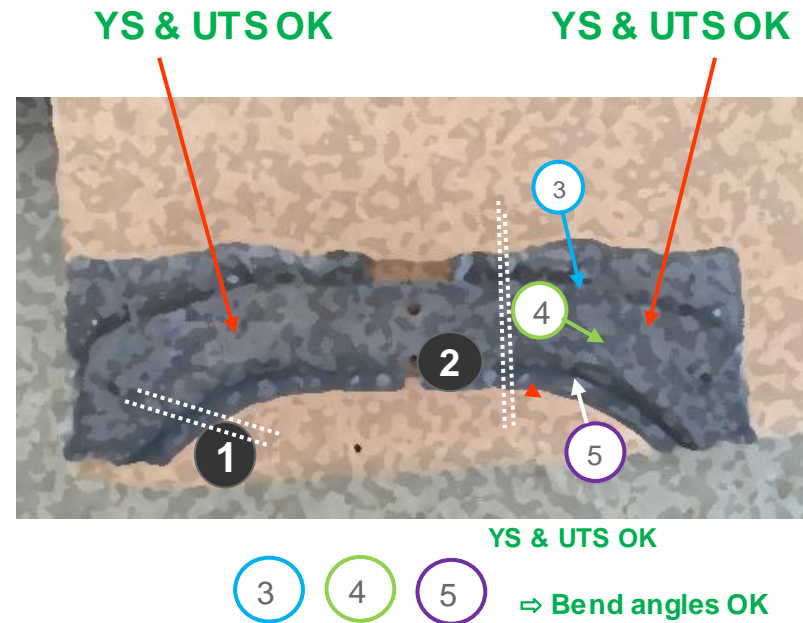
- ✓ Same Hot Stamping lines as Usibor1500+AS lines
- ✓ MP stabilities: Cooling rate @ [750-200°C]
- ✓ NO Laser Trimming needed
- ✓ No process constraint for Hydrogen embrittlement

Indicative mechanical properties after hot stamping + paint baking

Direction	YS (MPa)	TS (MPa)	Tel % A50 typical	Bending angle (Fmax)
Longitudinal	≥ 800	≥ 1000	6	≥ 80

Bending angle at Fmax following to the VDA238-100 for a thickness of 1.50 mm

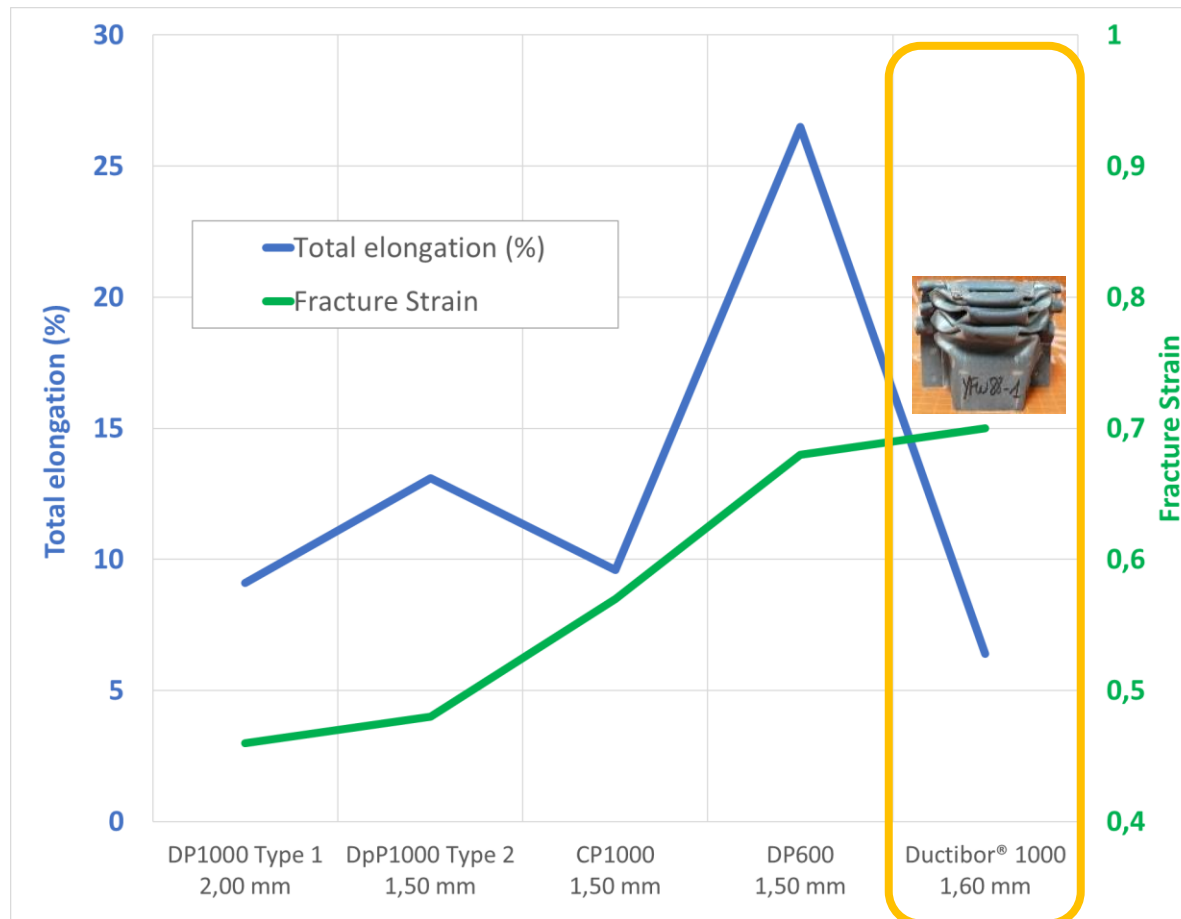
YS and TS fulfilled if the quenching speed is > 50° C/s between 750° C and 200° C (based on lab quenching tests with flat tools).



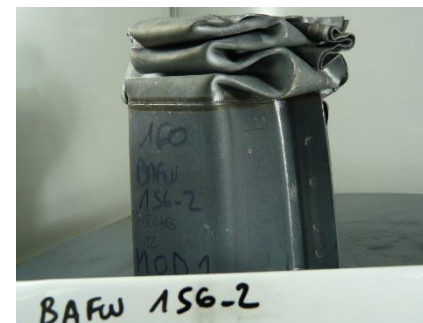
Microhardness, tensile properties and bending angle fulfill Ductibor® 1000 specification, even in “critical” areas such as walls, for transfer times of 4 and 7s

Ductibor® 1000 challenges

Crash ductility at least as good as a DP600



Laser welded blank application



Bad correlation between the total elongation and the crash ductility

Ductibor® 1000 fracture strain is even higher than the fracture strain of a DP600 ⇒ Ductibor® 1000 excellent behavior during a compression test

Usibor® 2000 and Ductibor® 1000

Weight saving potential on body-in-white applications

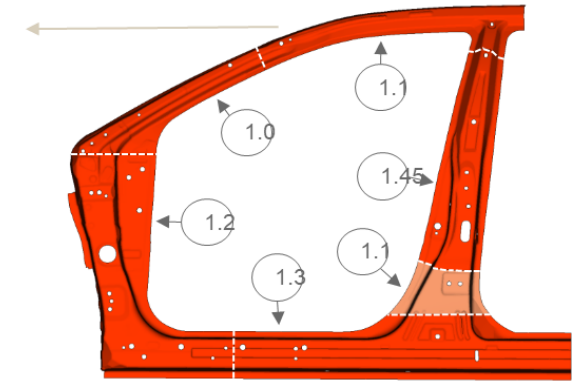
⇒ More than **30 kg or 30% mass savings** on the scope of passive safety structural parts compared to **typical AHSS solutions** on the market

⇒ At least **10% of extra mass savings** is possible for the structures intensively in **Usibor® 1500 and Ductibor® 500**

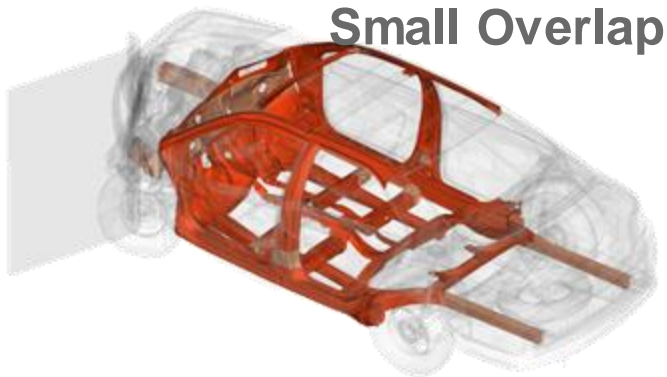
■ Usibor® 2000
■ Ductibor® 1000



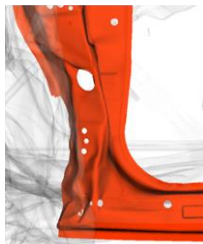
■ Usibor® 2000
■ Ductibor® 1000



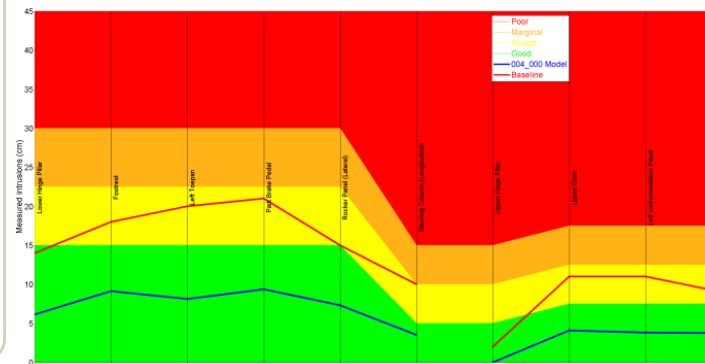
Good rating of the Usibor® 2000 solution



Lower outer A-pillar



IIHS small overlap compliance

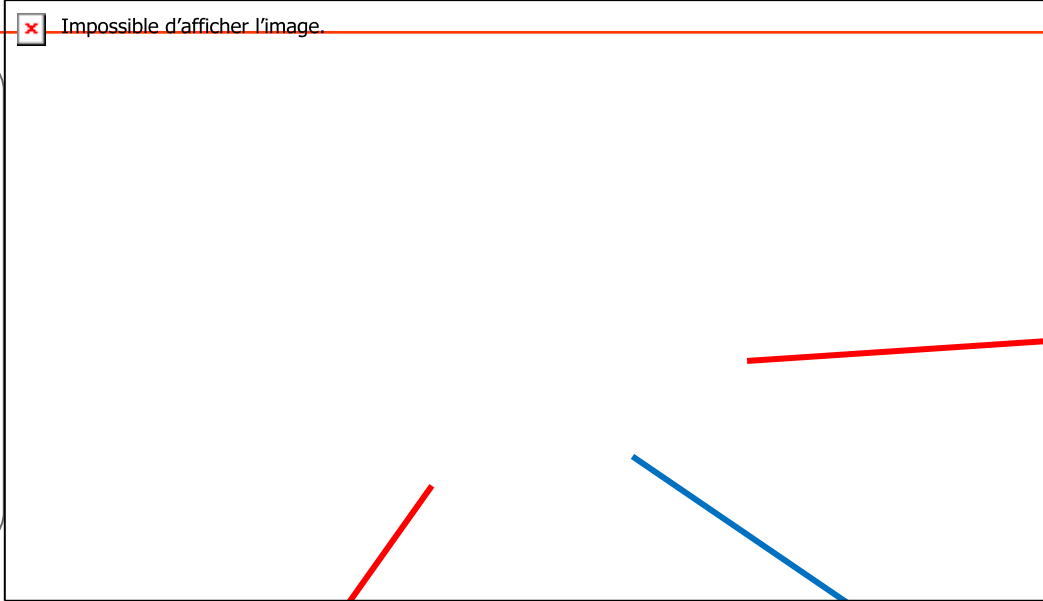


Key role of the laser welded Ductibor® 1000 / Usibor® 2000 front rails and of the Ductibor® 1000 / Usibor® 2000 door ring

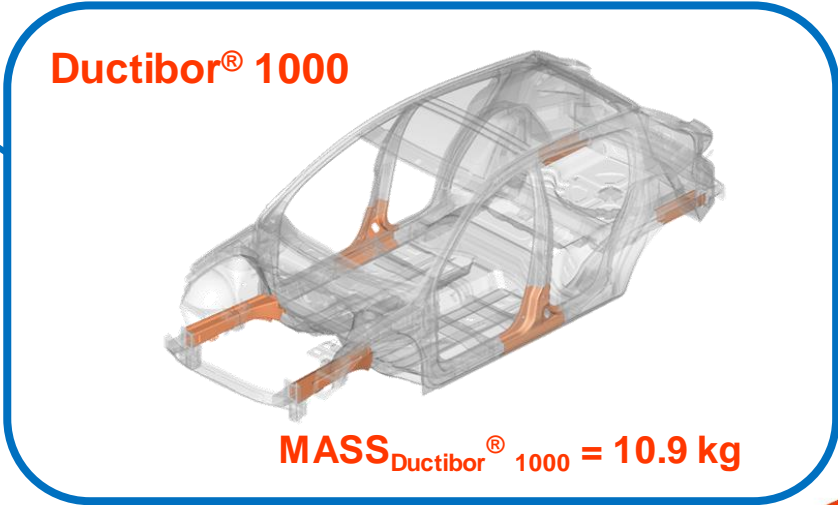
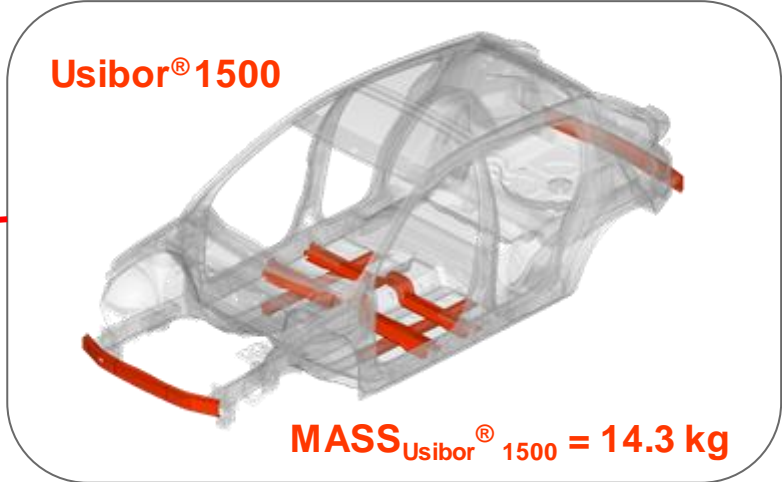
Most of the Usibor® 1500 AS applications can be considered in Usibor® 2000 AS

Key role of the laser welded Ductibor® 1000 / Usibor® 2000 front rails and of the Ductibor® 1000 / Usibor® 2000 door ring

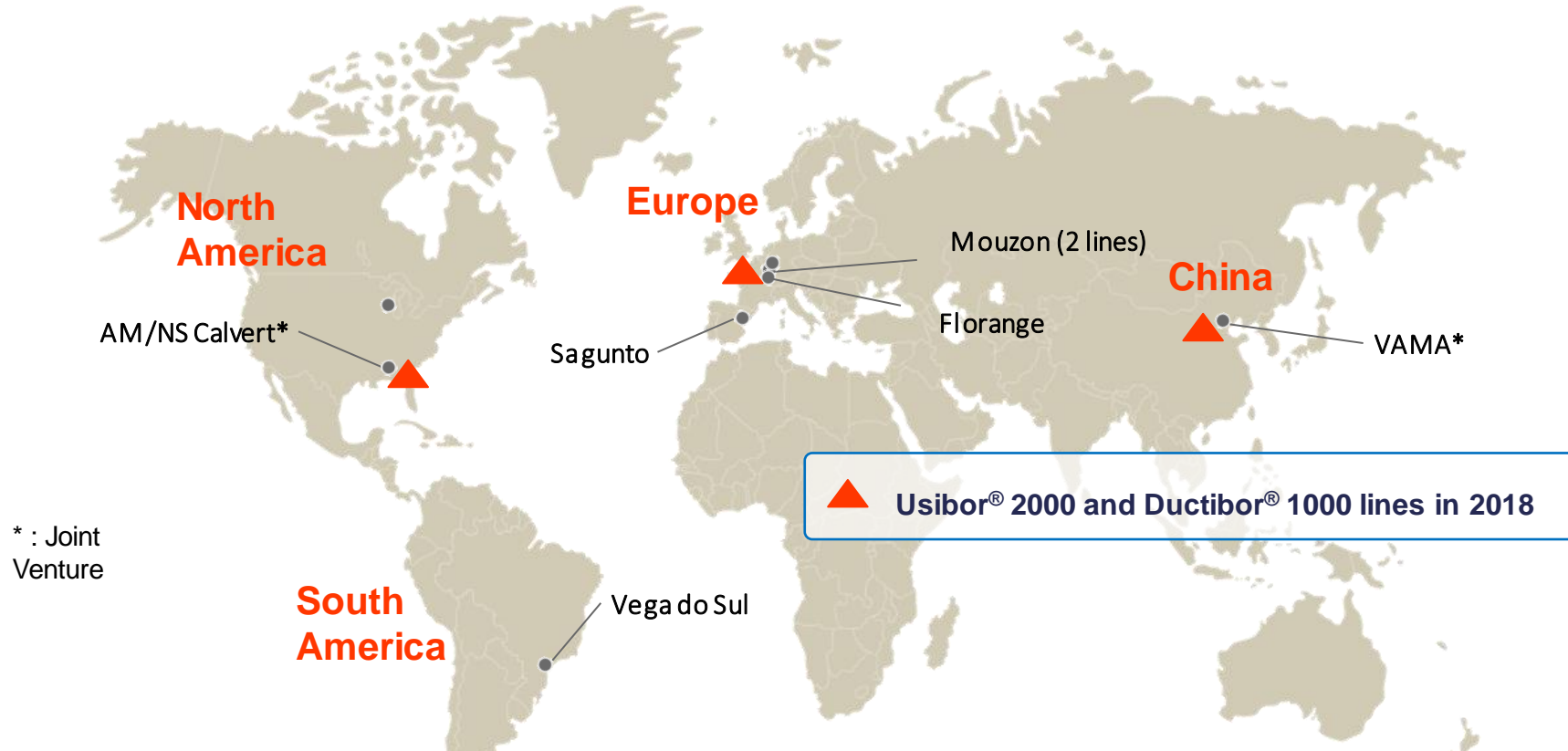
SinMotion PHEV-C: 2nd generation of AS-coated PHS



- Tensile strength values
- PHS > 1500 MPa
 - PHS > 500 MPa
 - AHSS > 1500 MPa
 - AHSS > 1180 MPa
 - AHSS > 900 MPa
 - AHSS > 780 MPa
 - AHSS > 590 MPa
 - AHSS > 450 MPa
 - HSS
 - MILD STEEL



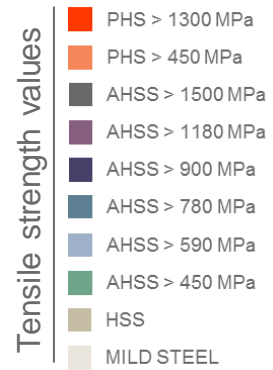
2nd generation AS-coated PHS: Global availability



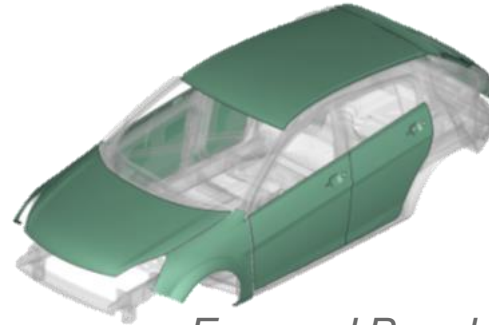
▲ Usibor® 2000 and Ductibor® 1000 lines in 2018

Grades	North America	Europe	Brazil	China
Ductibor® 1000	Ready	Ready	On going	Ready
Usibor® 2000	Ready	Ready	On going	On going

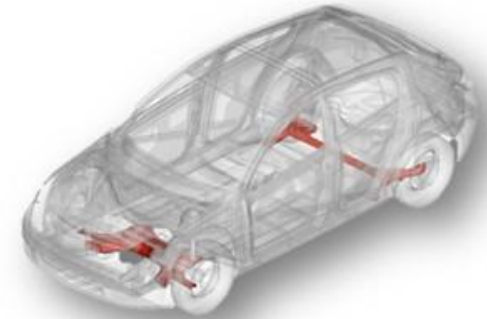
Innovative products to meet OEMs expectations for... ... BIW structure & chassis



BIW Structure



Exposed Panels

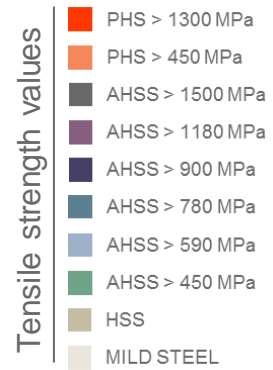


Chassis Structure

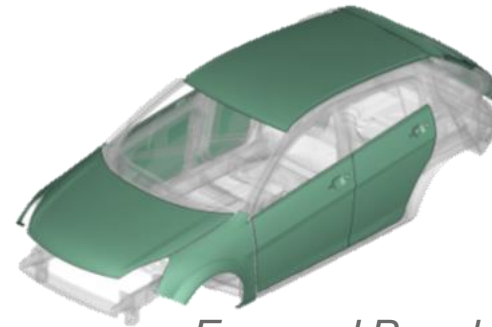
Emerging innovations: Cold stamping

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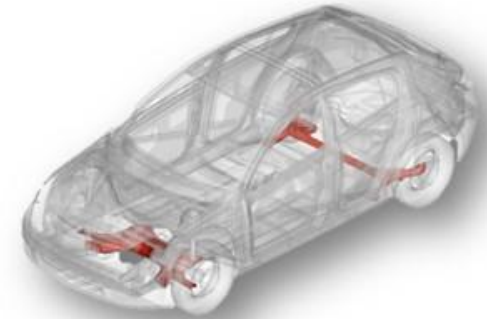
Innovative products to meet OEMs expectations for... ... **BIW structure & chassis**



BIW Structure



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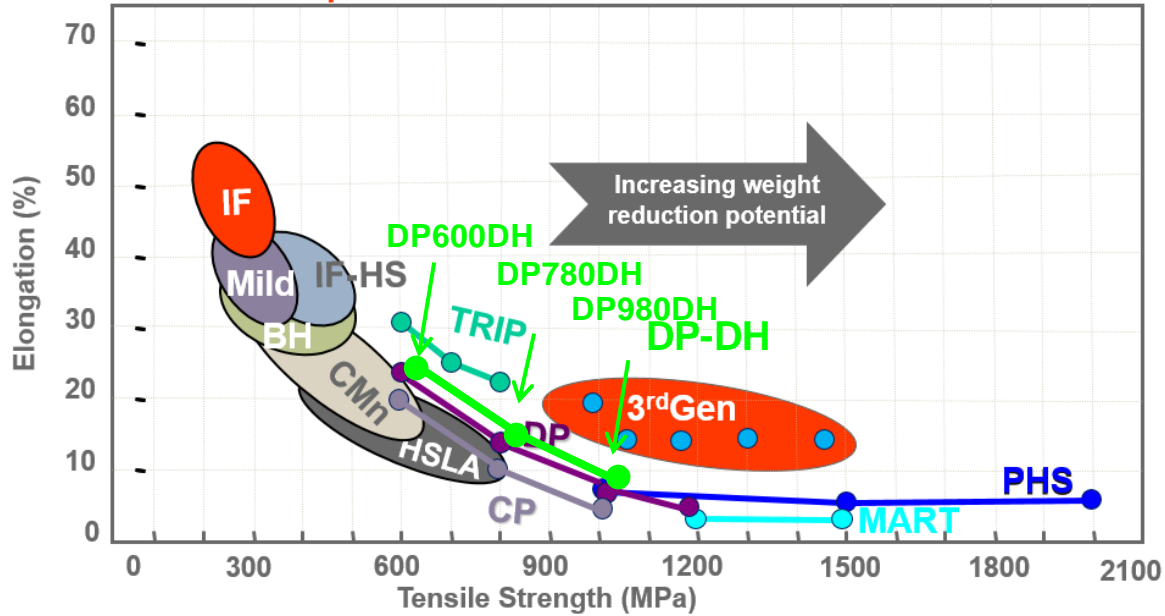


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3rd generation Advanced High Strength Steels Dual Phase with Higher Ductility



Dual Phase with Higher Ductility DP-DH series

- ✓ When substitution to DP same strength Stamping solver @ 0 Weight Reduction
- ✓ Weight reduction vs HSS/lower DP

- Commercial Unexposed only
- Customer trials
- Under development
- To be decided (possible CAPEX)

EU: Europe
 NAM: North America
 SAM: South America
 CHI: China

Jetgal®: ArcelorMittal brand coating, Jet Vapor Deposition Zn coating

TE % values are given for A_{80mm} samples

CR330Y590-DH (DP600DH)

Dir.	YS (MPa)	TS (MPa)	TE %	n ₄₋₆	n _{10-UE}	BH2 (MPa)
ISO-RD	330-430	590-700	≥26	≥0,21	≥0,16	≥30
Coating	EU	NAM	SAM	CHI		
UC	■	■	■	■		
EG	■	■	■	■		
Jetgal®	■	■	■	■		
GI	■	■	■	■		
GA	■	■	■	■		

CR440Y780-DH (DP780DH)

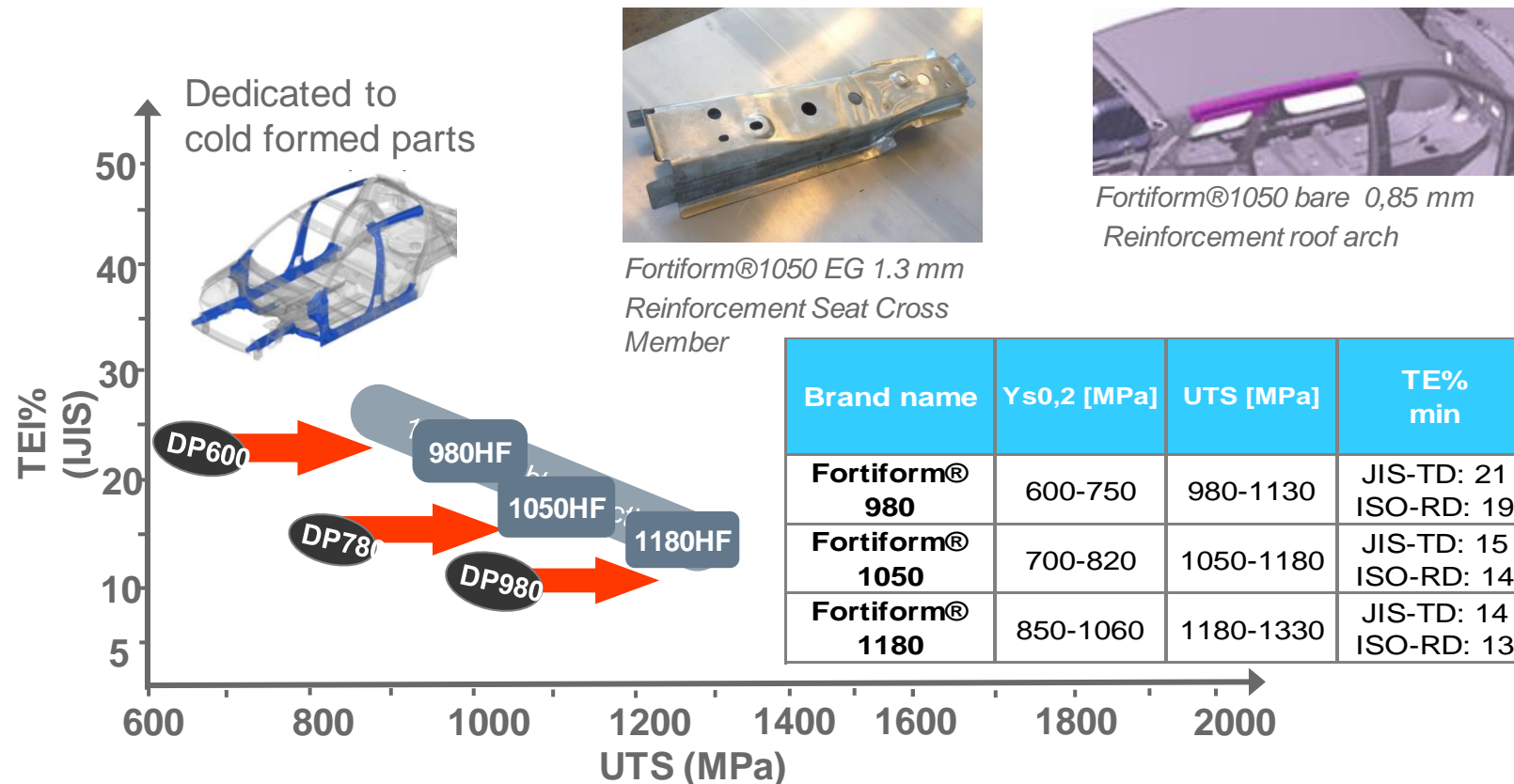
Dir.	YS (MPa)	TS (MPa)	TE %	n ₄₋₆	n _{10-UE}	BH2 (MPa)
ISO-RD	440-550	780-900	≥18	≥0,18	≥0,13	≥30
Coating	EU	NAM	SAM	CHI		
UC	■	■	■	■		
EG	■	■	■	■		
Jetgal®	■	■	■	■		
GI	■	■	■	■		
GA	■	■	■	■		

CR700Y980-DH (DP980DH)

Dir.	YS (MPa)	TS (MPa)	TE %	n ₄₋₆	n _{10-UE}	BH2 (MPa)
ISO-RD	700-850	980-1180	≥13	-	-	≥30
Coating	EU	NAM	SAM	CHI		
UC	■	■	■	■		
EG	■	■	■	■		
Jetgal®	■	■	■	■		
GI	■	■	■	■		
GA	■	■	■	■		

Fortiform® / High Formability / HF steels

- ✓ Fortiform® grades belong to the 3rd Generation UHSS family.
- ✓ They have $UTS \cdot TEI\% \approx 20000 \text{ MPa}\cdot\%$ whereas conventional steels have $UTS \cdot TEI\% \approx 10000 \text{ MPa}\cdot\%$
- ✓ Enhanced ductility is obtained via residual austenite. Other hardening phases can be carbon free bainite or/and tempered martensite.



Fortiform®1050 EG 1.3 mm
Reinforcement Seat Cross Member



Fortiform®1050 bare 0,85 mm
Reinforcement roof arch



Fortiform®1180 bare 1,2 mm
Reinforcement B-pillar trial

Fortiform® series: grade targets & global availability

Fortiform® 1180 - 1180HF

Direction	YS (MPa)	TS (MPa)	TE %	HER %
ISO-L	850-1060	1180-1330	≥ 13	≥ 30
ASTM-L	850-1060	1180-1330	≥ 13	≥ 30
JIS-T	850-1060	1180-1330	≥ 14	≥ 30

Coating	EU	NAM	SAM	CHI
UC	Commercial Unexposed only	Commercial Unexposed only	To be decided (possible CAPEX)	To be decided (possible CAPEX)
EG	Commercial Unexposed only	To be decided (possible CAPEX)	To be decided (possible CAPEX)	To be decided (possible CAPEX)
Jetgal®	Under development	To be decided (possible CAPEX)	To be decided (possible CAPEX)	To be decided (possible CAPEX)
GI	Under development	Under development	To be decided (possible CAPEX)	To be decided (possible CAPEX)
GA	To be decided (possible CAPEX)	Commercial Unexposed only	To be decided (possible CAPEX)	To be decided (possible CAPEX)



Fortiform® 980 - 980HF

Direction	YS (MPa)	TS (MPa)	TE %	HER %
ISO-L	600-750	980-1130	≥ 19	≥ 20
ASTM-L	600-750	980-1130	≥ 20	≥ 20
JIS-T	600-750	980-1130	≥ 21	≥ 20

Coating	EU	NAM	SAM	CHI
UC	Under development	Commercial Unexposed only	To be decided (possible CAPEX)	To be decided (possible CAPEX)
EG	To be decided (possible CAPEX)	To be decided (possible CAPEX)	To be decided (possible CAPEX)	To be decided (possible CAPEX)
Jetgal®	Under development	To be decided (possible CAPEX)	To be decided (possible CAPEX)	To be decided (possible CAPEX)
GI	Under development	Customer trials	To be decided (possible CAPEX)	To be decided (possible CAPEX)
GA	To be decided (possible CAPEX)	Commercial Unexposed only	To be decided (possible CAPEX)	To be decided (possible CAPEX)

Fortiform® 1050*

Direction	YS (MPa)	TS (MPa)	TE %	HER %
ISO-RD	700-850	1050-1180	≥ 14	≥ 20

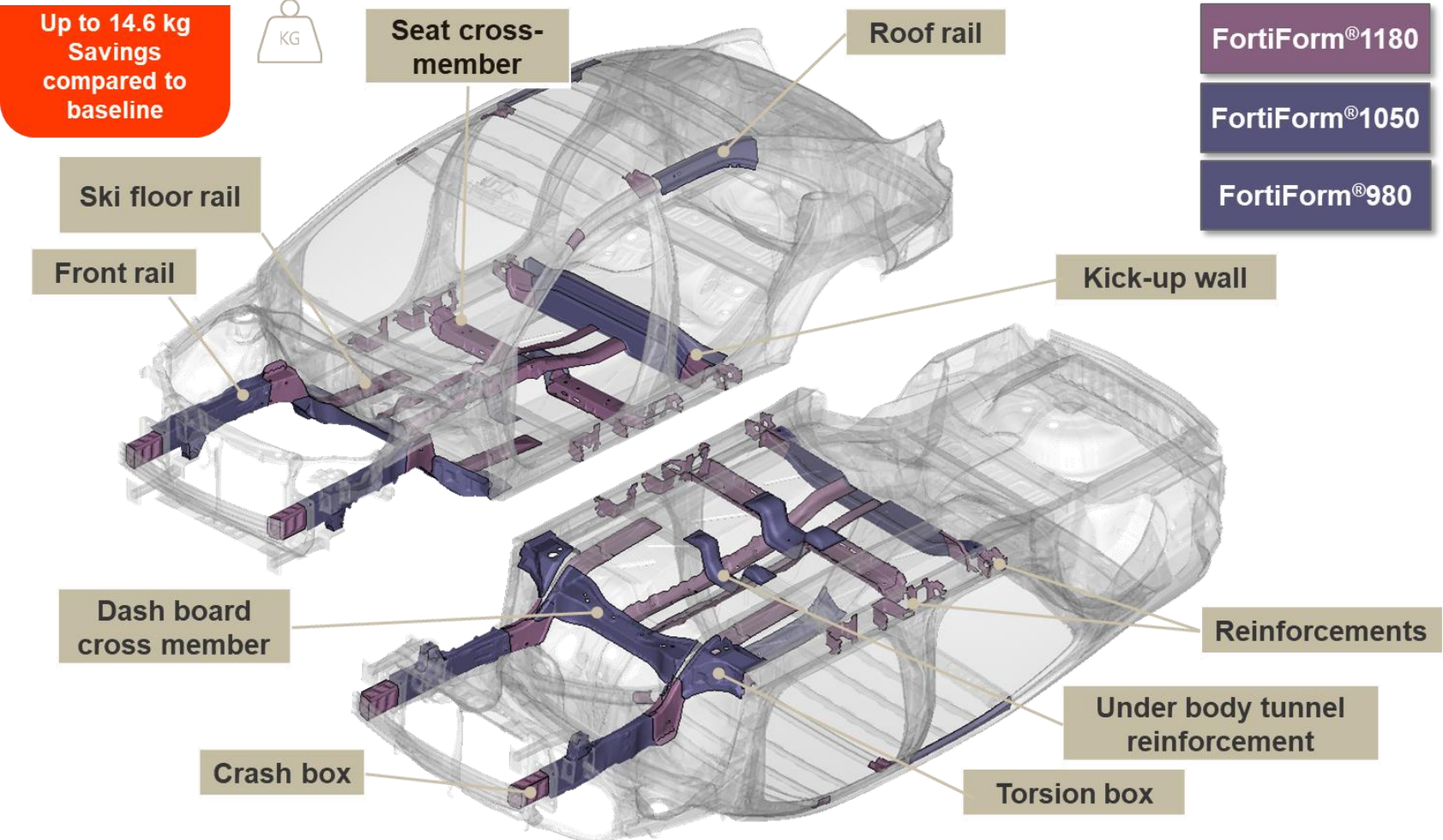
Coating	EU	NAM	SAM	CHI
UC	Commercial Unexposed only	To be decided (possible CAPEX)	To be decided (possible CAPEX)	To be decided (possible CAPEX)
EG	Commercial Unexposed only	To be decided (possible CAPEX)	To be decided (possible CAPEX)	To be decided (possible CAPEX)
Jetgal®	Customer trials	To be decided (possible CAPEX)	To be decided (possible CAPEX)	To be decided (possible CAPEX)
GI	To be decided (possible CAPEX)	To be decided (possible CAPEX)	To be decided (possible CAPEX)	To be decided (possible CAPEX)
GA	To be decided (possible CAPEX)	To be decided (possible CAPEX)	To be decided (possible CAPEX)	To be decided (possible CAPEX)

*: Compliant with the VDA239-100 CR700Y980T grade.

- Commercial Unexposed only
- Customer trials
- Under development
- To be decided (possible CAPEX)

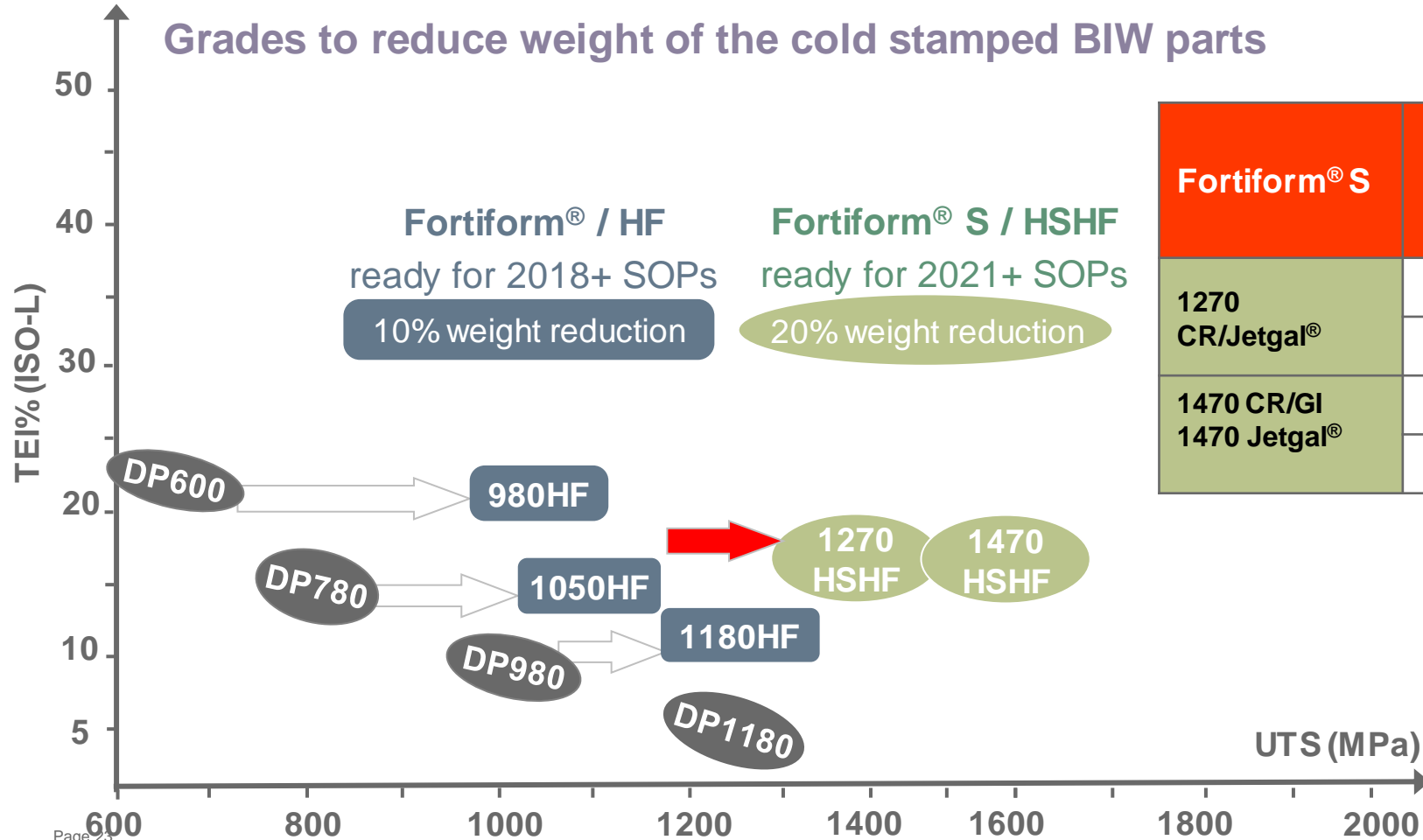
EU: Europe
NAM: North America
SAM: South America
CHI: China

Fortiform® applications S-in motion® D-segment



10 different applications were studied where strength and formability and high corrosion resistance are required

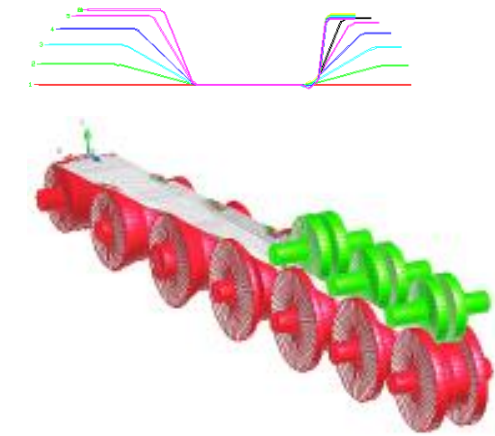
3rd generation Advanced High Strength Steels : Step further Fortiform[®] S /High Strength High Formability HSHF steels



Fortiform [®] S	Test Method	YS MPa Min.	UTS MPa Min.	TEL % Min.	HER (%) Min.
1270 CR/Jetgal [®]	JIS - T	1100	1270	15	30
	ISO-L	1100	1270	15	
1470 CR/GI 1470 Jetgal [®]	JIS - T	1000	1470	16	20
	ISO-L	1000	1470	15	

MartINsite[®] offer for roll-forming, crash forming, bending

Grades	Test Method	YS MPa Min.	UTS MPa Min.	TEL % Min.	Bare	Zinc coated	
						EG	Jetgal [®]
MartINsite [®] 1200	Iso RD & TD	950	1200	3	Green		Green
MartINsite [®] 1300	Iso RD	1030	1300	3	Yellow		Red
MartINsite [®] 1500	Iso RD & TD	1200	1500	3	Green	Green	Green
MartINsite [®] 1700	Iso RD & TD	1350	1700	3	Red		Red
MartINsite [®] 2000	Iso RD & TD	1550	2000	3	Red		Red



Roll-forming process

EG: Electrogalvanized / Jetgal[®]: Zinc deposited by Jet Vapor Deposition

- Grades already used by OEMs for roll-forming applications:
 - MartINsite[®] 1500: new product for bumpers & BIW (bare, EG & Jetgal[®])

- Commercial Unexposed only
- Customer trials
- Under development

Global availability of MartINsite® offer

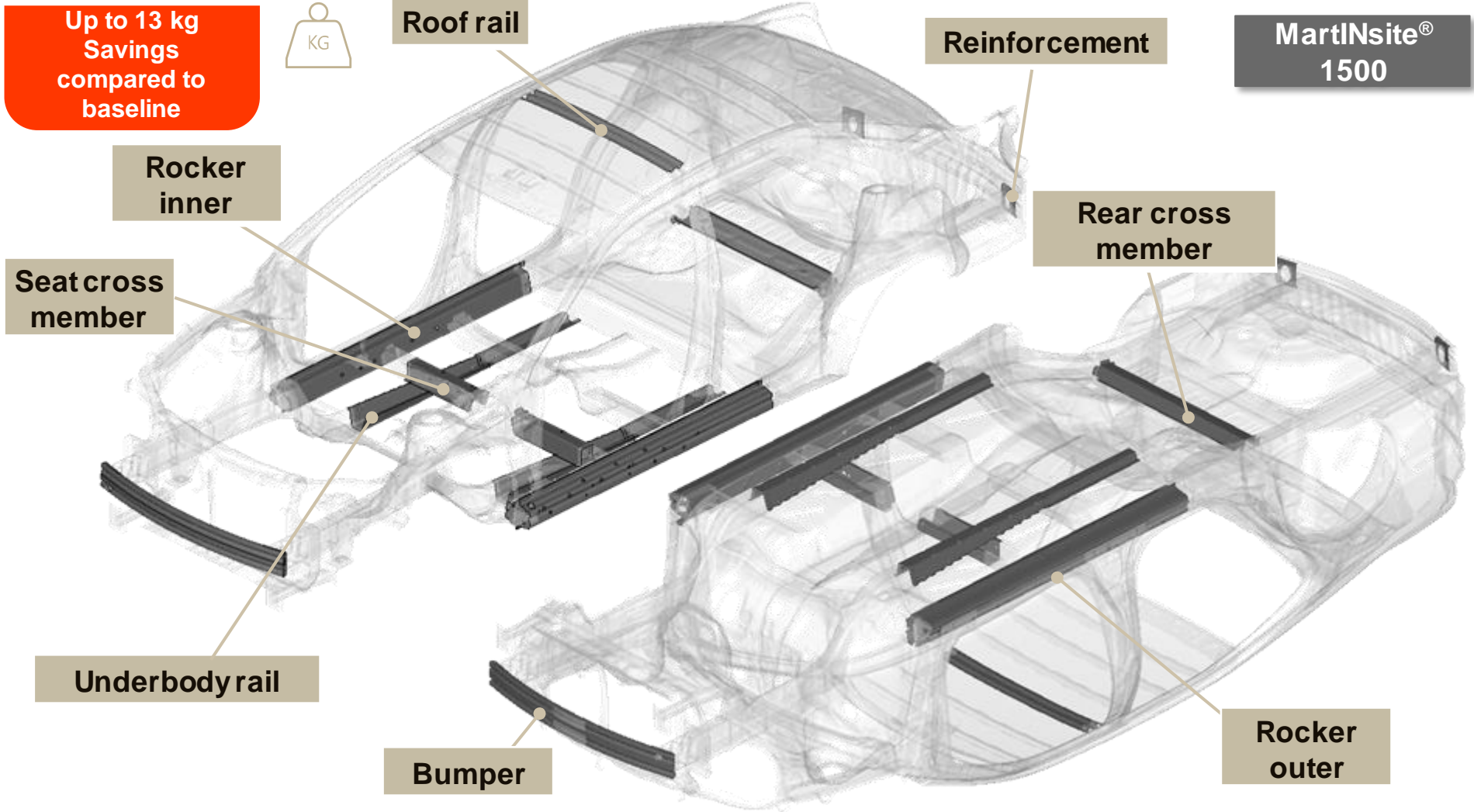


NAM	1300	1500	1700	2000
Industrial investment	✓	✓	✓	○
Grade design	✓	✓	✓	○
Industrial development	✓	✓	○	○

✓: step finished
 ○: step on going
 X: step not started

EU	1200	1300	1500	1700	2000
Industrial investment	✓	✓	✓	✓	X
Grade design	✓	✓	✓	✓	X
Industrial development	○	○	✓	○	X

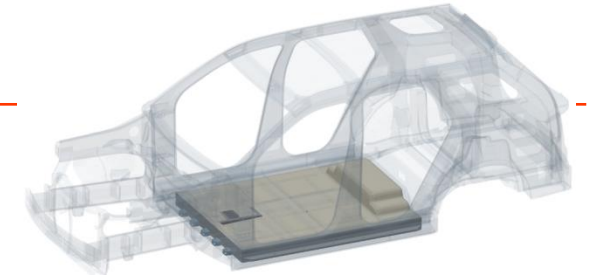
MartInsite® 1500 applications S-in motion® D-segment



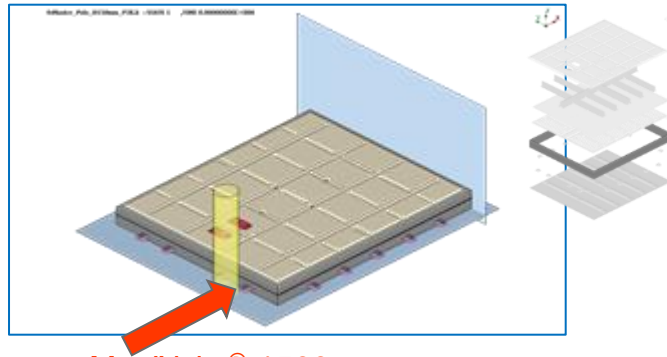
7 different applications were studied where high strength is required and design can be adapted to cope with material forming ability

S-in motion[®] battery pack: MartInsite1500 for high performances

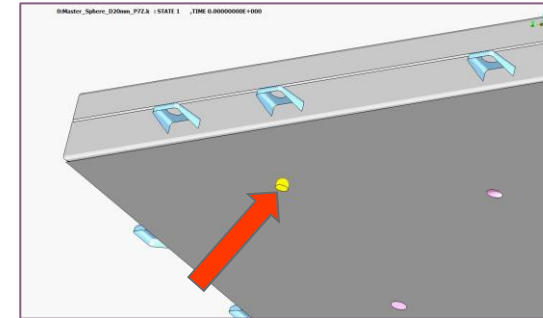
- A set of loadcases are respected (from Norms, good practices and accidental feedbacks)
- 3 main AHSS sub-modules solicited



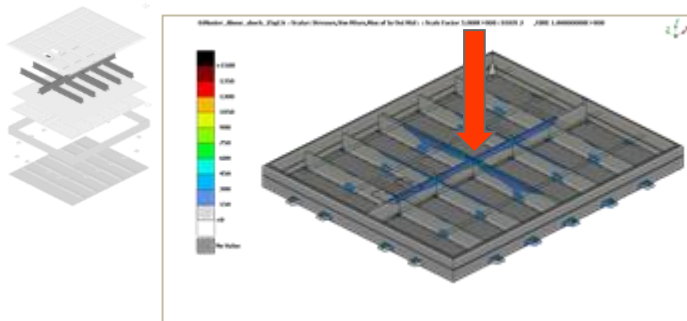
Frame - MartInsite[®] 1500 for crush / pole



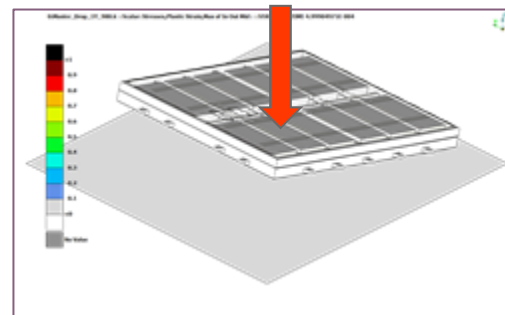
Lower shield and reinforcements - MartInsite[®] 1500 + DP780 for intrusions from underneath



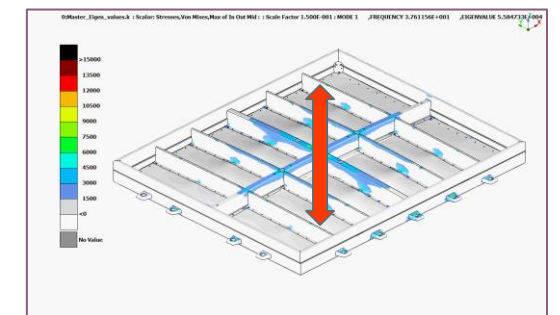
Cross-members – MartInsite[®] 1500 for strong accelerations



Cross-members – MartInsite[®] 1500 for drop



Cross-members & assemblies for first frequency & vibratory fatigue



Conclusions

- Innovations for Hot Stamping
 - GEN2 PHS
 - Further innovations on PHS to come
- Innovations for Cold Forming
 - DH grades (acc to VDA239-100rev1)
 - Fortiform® 980,1180, later Fortiform®S 1270, 1470
 - MartInsite grades 1200 to 1700
- Global offer to follow OEM's on all locations
- Data for Product application
- Evaluated applications for Weight Reduction in conventional and electrified vehicles
- Follow closely OEM's needs in their new challenges

Questions session

- <https://automotive.arcelormittal.com/>
- <https://automotive.arcelormittal.com/products>
- https://automotive.arcelormittal.com/s-in_motion_solutions/battery_pack

