Hot Stamping Steel solutions to answer CO_2 & Crash regulations evolution

ArcelorMittal

12th July 2019

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- AM Product Apps on smart phone

The world’s leading steel and mining company

- ArcelorMittal is the world's leading steel and mining company, with a presence in more than 60 countries and steelmaking operations in over 20 countries on four continents.
- Guided by a philosophy to produce safe, sustainable steel, we are the leading supplier of quality steel in the major global steel markets including automotive, construction, household appliances and packaging, with world-class research and development and outstanding distribution networks.
- Through our core values of sustainability, quality and leadership, we operate responsibly with respect to the health, safety and wellbeing of our employees, contractors and the communities in which we operate.
- For us, steel is the fabric of life, as it is at the heart of the modern world from railways to cars and washing machines. We are actively researching and producing steel-based technologies and solutions that make many of the products and components we use in our everyday lives more energy-efficient.

Underpinning all our operations is a philosophy to produce safe, sustainable steel

Evolution of requirements due to crash test and fuel economy regulations

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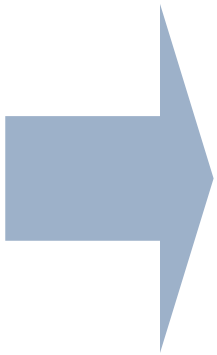
Key automotive industry requirements

- **Global platforms:** Carmakers demand that the same products be delivered to their production facilities worldwide, to support global platforms that are designed centrally. The percentage of vehicles built on global platforms will increase from 46% in 2014 to 63% in 2020
- **Regulation:** Shift in product needs to meet regulatory targets for fuel economy as well as passenger safety during crash events

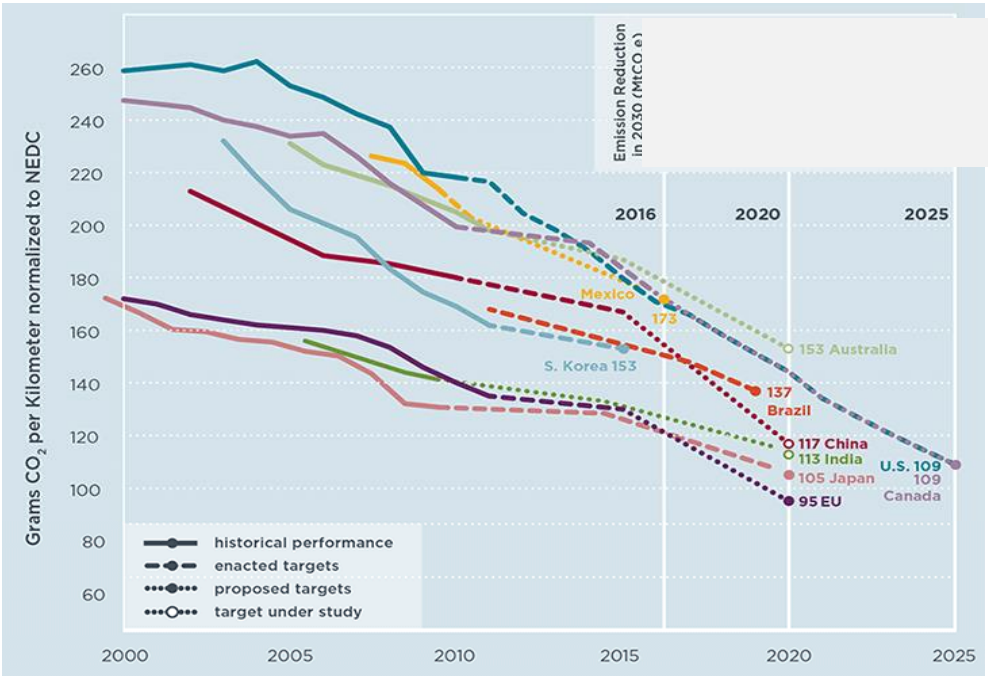


- ArcelorMittal offers the specific solutions to address these challenges
- ArcelorMittal maintains both its geographical and its technological leadership in the automotive market

ArcelorMittal well positioned to meet automotive industry requirements

Rigorous fuel economy standards…

Global CO_2 (or equivalent) regulation trends



Country or Region	Target Year	Standard Type	Unadjusted Fleet Target/Measure	Structure	Test Cycle
EU	2015 2021	CO_2	130 gCO_2/km 95 gCO_2/km	Weight-based corporate average	NEDC
China	2015 2020 (proposed)	Fuel consumption	6.9 L/100km 5 L/100km	Weight-class based per vehicle and corporate average	NEDC
U.S.	2016 2025	Fuel economy/ GHG	36.2 mpg[i] or 225 gCO_2/mi 56.2 mpg[ii] or 143 gCO_2/mi	FP-based corporate avg.	U.S. combined
Canada	2016 2025 (proposed)	GHG	217 gCO_2/mi[iii] N/A[iv]	FP-based corporate avg.	U.S. combined
Japan	2015 2020	Fuel economy	16.8 km/L 20.3 km/L	Weight-class based corporate average	JC08
Brazil	2017	Fuel economy	1.82 MJ/km	Weight-based corporate average	U.S. combined
India	2016 2021	CO_2	130 g/km 113 g/km	Weight-based corporate average	NEDC for low-powered vehicle
South Korea	2015	Fuel economy/GHG	17 km/L or 140 gCO_2/km	Weight-based corporate average	U.S. combined
Mexico	2016	Fuel economy/GHG	39.3 mpg or 140 g/km	FP-based corporate avg.	U.S. combined

- Targets and methodology could be different across the regions, but trend of sharp decrease
- India: 113 g/CO_2 target expected
- Similar trend for passenger safety in a crash event

Fuel economy targets to be achieved whilst improving crash performance standards

* CAFE refers to Corporate Average Fuel Economy

And new crash regulations in India

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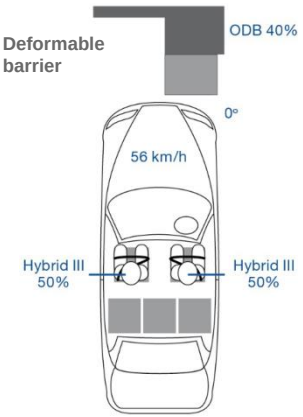
FRONTAL CRASH

AIS 098



BNVSAP
- Mandatory
Implementation for new platforms by Oct,2017 and for all old platforms by Oct,2019 for M1 vehicle catagory with GVW<2.5T

AIS 098
- Test Speed 56 -0/+1 km/h
- The vehicle shall overlap the barrier face by 40% ± 20 mm
- Upper & Lower foot impact test

PEDESTRIAN PROTECTION

BNVSAP
- Several impactor tests (upper/lower legform, Flex PLI, adult/child headform)

AIS 100
Test Speed 40 km/h

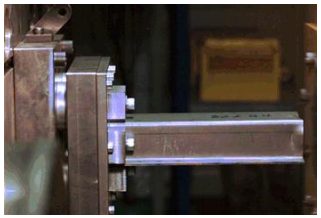
LATERAL COLLUSION

AIS 099

BNVSAP
- Mandatory implementation for new platforms by Oct,2017 and for all old platforms by Oct,2018 for M1 vehicle catagory with GVW<2.5T.

AIS 099
- Test Speed - 50 - 0/+1 km/h
- Upper & Lower foot impact test

Cars will gradually have to meet more stringent norms such as Rear impact test, whiplash injuries and child restrain systems standards and requirements



Crash Standards

Legal Crash Regulations

Future Update

New (Future)

Passenger Vehicles Emission Norms in India

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Current: Average Fleet CO2 is 137 gram/ Km

2016 to 2021: Average Fleet CO2 Target - 130 g/km

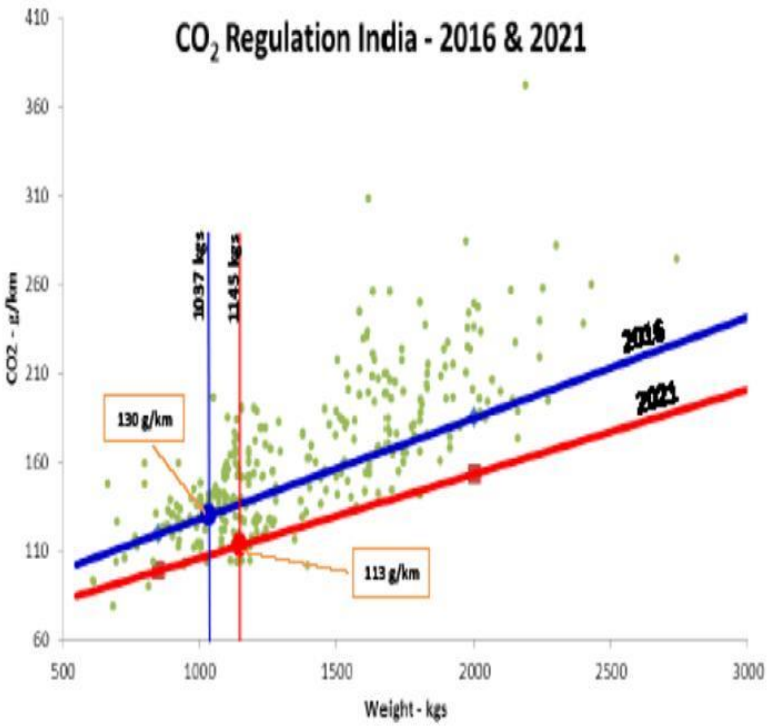
C = 0.06 X W +76

From 2022 / 2023: Average Fleet CO2 Target - 113 g/km

C = 0.055 X W + 66

C = Corporated Average CO2 production in g/km
W = Corporated Average Sales Kerb weight (in kg)

Fuel Efficiency Regulation for Passenger Cars in India



Light weighting solutions to meet CO_2 target of 113 gram/km

Passenger Vehicles Fuel Efficiency Norms in India

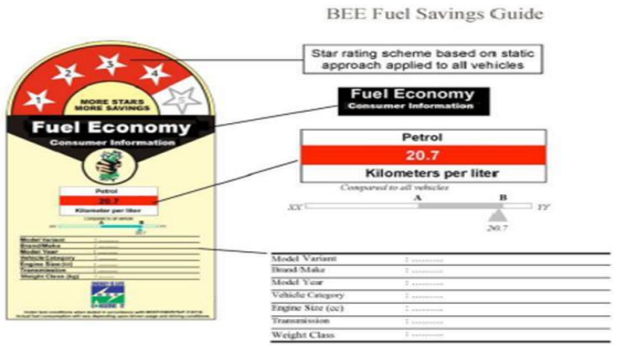
- Average Fleet Fuel Efficiency from 2016 to 2020:
  18.2 km/liter
  Base Average weight of 1037 kg
- Average Fleet Fuel Efficiency from 2021:
  21 km/liter
  Base Average weight of 1145 kg
- Fuel Efficiency Labelling

(for fiscal years 2016-17 to 2020-21)

a	0.0024
b	1037
c	5.4922
Average Fuel Consumption Standard for Manufacturer	= 0.0024 x (W – 1037) + 5.4922

(fiscal year 2021-22 onwards)

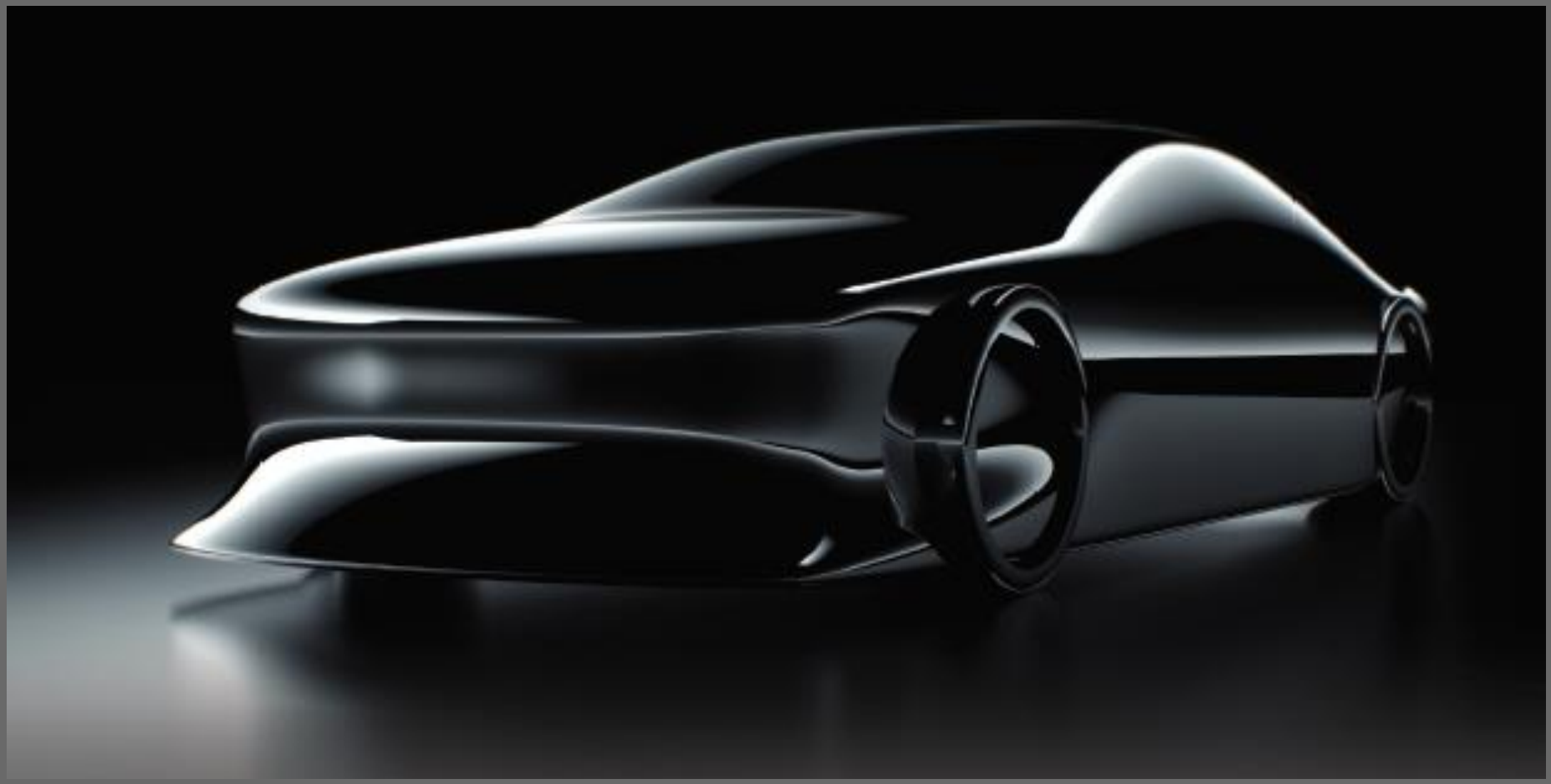
a	0.002
b	1145
c	4.7694
Average Fuel Consumption Standard for Manufacturer	= 0.002 x (W – 1145) + 4.7694



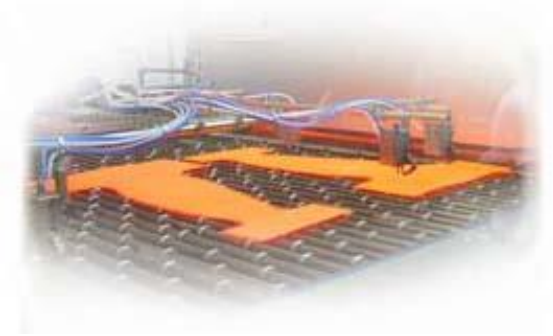
Proposed Mandatory Fuel Efficiency Start Rating Label

Light weighting solutions & powertrain improvement to meet the targets

Forces of AS coated hot stamping steels
ArcelorMittal product offer



Main forces of the hot stamping

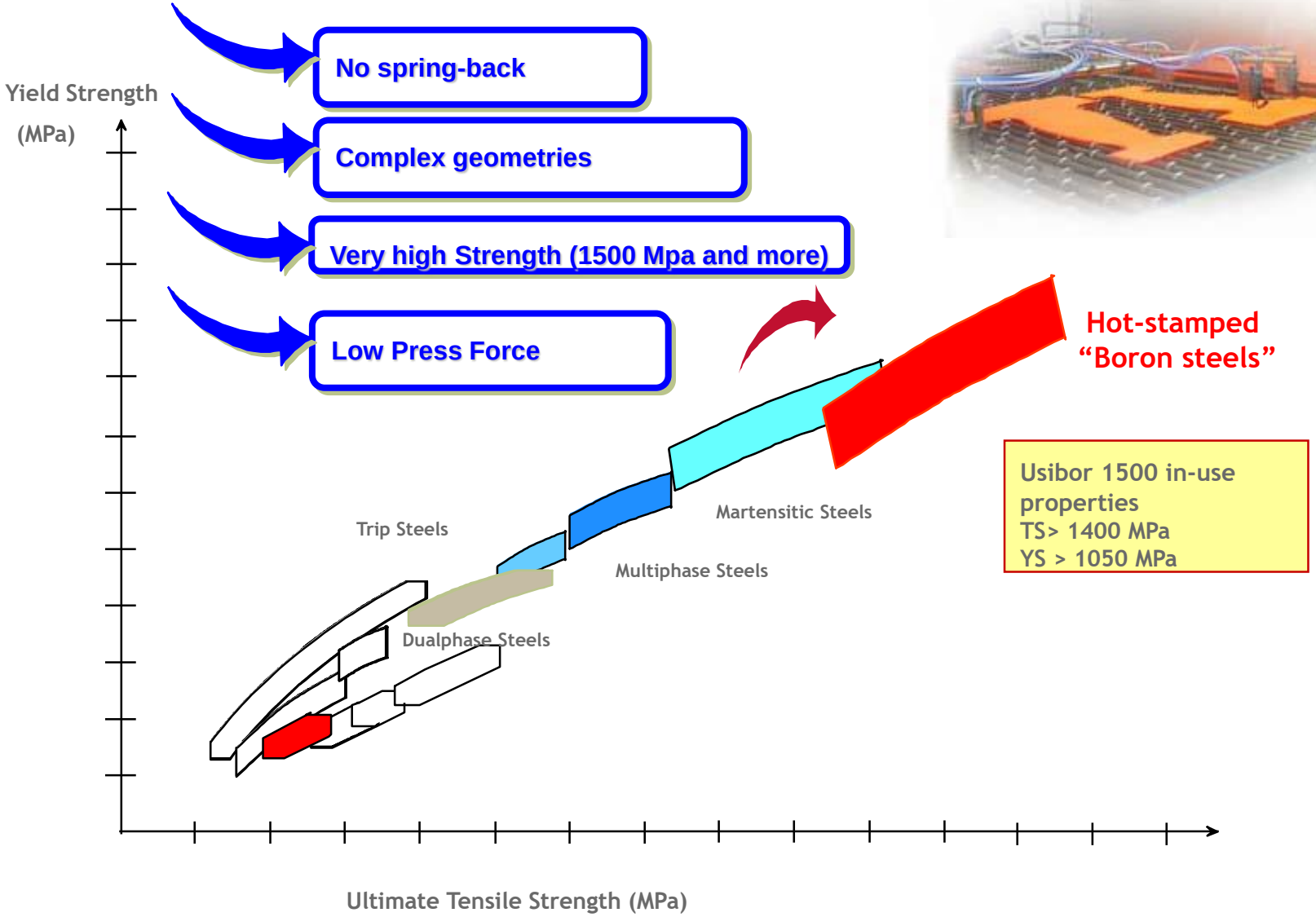


No spring-back

Complex geometries

Very high Strength (1500 Mpa and more)

Low Press Force

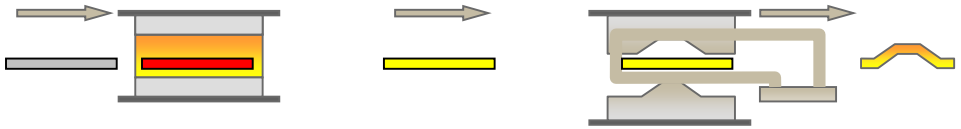


Usibor 1500 in-use properties
TS> 1400 MPa
YS > 1050 MPa

Summary of PHS range

PHS for automotive: a mainstream solution for weight saving

- Lighter and stronger vehicles can be designed thanks to our coated hot stamping boron steels, or PHS (press hardenable steels)
- Advantages of PHS in general
  - Very high strength (up to 2000 MPa tensile strength)
  - No springback, enabling complex parts
  - Huge weight saving potential for anti-intrusion parts (up to 30%)
- Advantages of ArcelorMittal AS coated PHS
  - Excellent corrosion resistance
  - Tailored properties thanks to Laser Welded Blanks (LWBs), combining Usibor® with Ductibor®
  - Very fast global growth
  - Simple direct hot stamping process



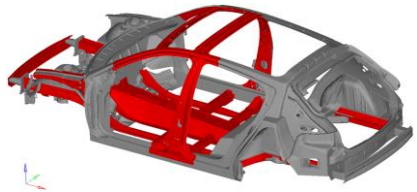
Heating
880-930° C
3 – 10 min

Transfer
approx. 7 sec

Stamping (600-800° C)
+ Hardening (>> 50 K/s)

Heated blanks before hot stamping

Potential use of hot stamping solutions in a body-in-white
(S-in motion® concept)



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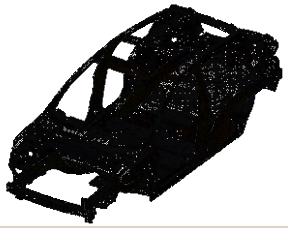

(R)evolution of steel grades
The roadmap of steel products:
Focus on the second generation of Usibor® - Ductibor®

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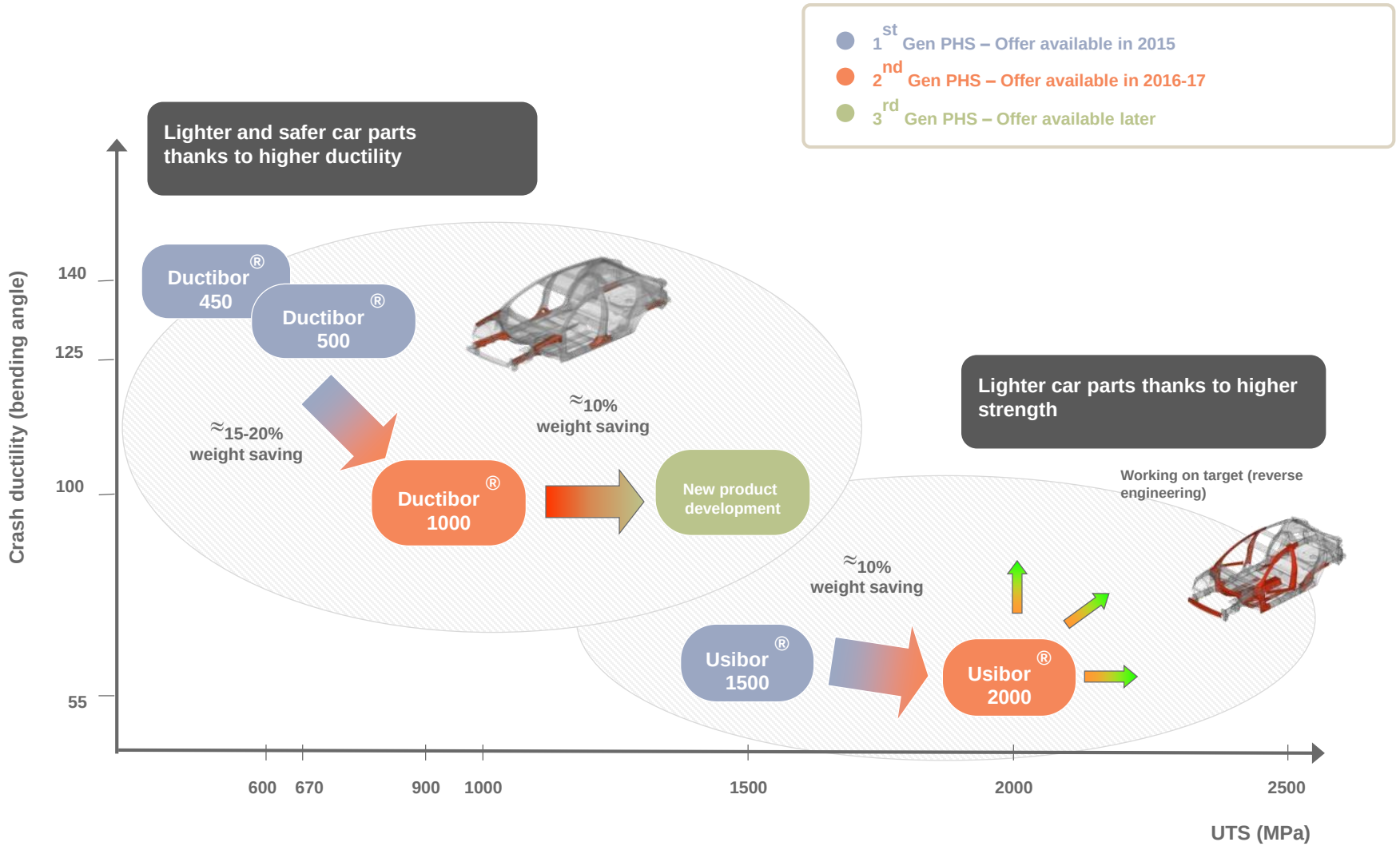
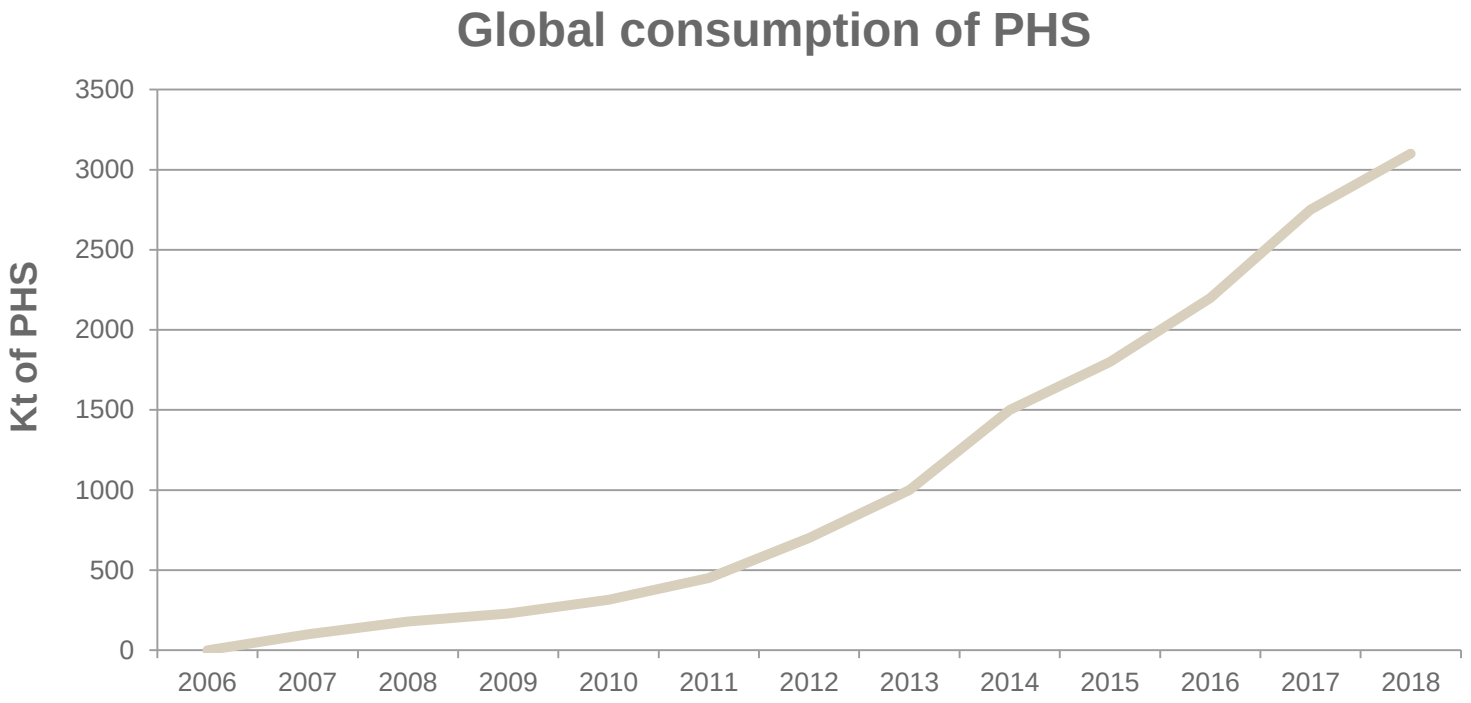


Increasing consumption of PHS
Demand to grow from 1 Mt in 2013 to 3 Mt in 2018

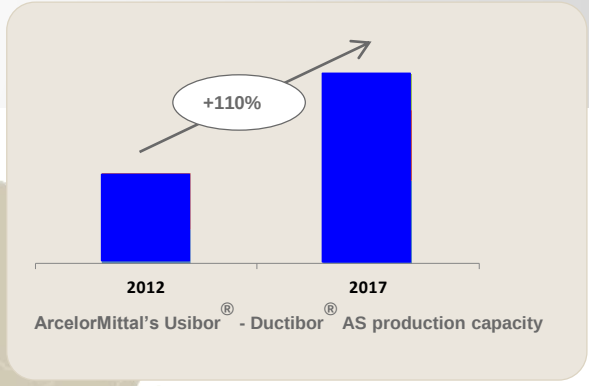


- **2006-2011: Low ramp-up: from 0 to 500 Kt, mainly Europe and US**
- **2012-2018: Globalisation with booming demand in China: 3 Mt**
- **> 2018: Globalisation continues (Brazil, India, etc.)**
  + robust demand in matures regions (Europe, NAFTA)

ArcelorMittal's current global capacity Usibor® - Ductibor® AS produced on 10 steel lines in 2017

+110% capacity increase since 2012

The number of hot stamping lines should more than double from 2014 to 2019



ArcelorMittal's Usibor® - Ductibor® AS production capacity

● ArcelorMittal aluminized lines producing Usibor® and Ductibor® range of products

* Joint Venture
** Idle but capable

Global availability of Usibor® 1500 and Ductibor® 500 – and soon Usibor® 2000 and Ductibor® 1000 too – as well as our dedicated laser welding technology

2nd Gen PHS
Launching Usibor® 2000 and Ductibor® 1000

Popular Usibor® and Ductibor®
PHS automotive offer set to expand

- ArcelorMittal will soon extend its global industrial portfolio of advanced high strength steels (AHSS) for automotive with two new products: **Usibor® 2000 and Ductibor® 1000**.
- These highly advanced grades will enhance ArcelorMittal's hot stamping steel offer and will open the door to new lightweight opportunities through new laser welded blank (LWB) combinations.
- The new steels have the potential to reduce vehicle weight significantly: up to 26% for the body-in-white (BIW) compared to the weight achievable with current grades, as demonstrated in our recent S-in motion® projects.

We might not know what the cars of the future will look like. But we do know they will be made with Usibor®!

Stronger, thinner and lighter car parts thanks to hot stamping solutions

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10 to 15 percent additional weight savings

- ArcelorMittal's current coated hot stamping products (Usibor® 1500 and Ductibor® 500) account for at least 20 percent of most vehicle bodies-in-white manufactured in the world today.
- This can be increased to 40 percent, as Volvo have demonstrated with their recently released XC90.
- Usibor® 2000 has been under development by ArcelorMittal for some time and is compatible with standard press hardening technologies and processes.
- It is an aluminum-silicon coated advanced high strength steel which is even stronger than its popular predecessor Usibor® 1500.
- Usibor® 2000 can be used for monolithic parts or as LWBs in combination with Ductibor® 1000.

"Usibor® 2000 could typically bring 10 to 15 percent weight savings when compared to existing hot stamping solutions."
Jean-Luc Thirion, head of ArcelorMittal Global R&D for automotive

Usibor® 2000 as part of a laser welded blank or for monolithic parts

Opportunities for both monolithical parts and laser welded blanks (LWBs)

- The properties of Ductibor® 1000 complement those of Usibor® 2000 when the two steels are combined into a single LWB to ensure the right steel is put in the right place.
- LWBs created from this combination offer several significant advantages including weight savings, improved crash behavior, and cost savings through material and manufacturing optimization.
- A global footprint thanks to Tailored Blanks production sites in Europe and NAFTA; Gonvvama (JV ArcelorMittal-Gonvarri) in China, ANTB (JV ArcelorMittal-JBM) in India.

Typical applications for Usibor® 2000 and Ductibor® 1000 include body-in-white safety parts such as rails and pillars.

ArcelorMittal offers a full range of PHS under the Usibor® and Ductibor® brands

Substrate	Indicative tensile-properties of the substrate without the coating after press hardening + paint baking and a thickness > 1,20 mm				Coating			
	YS [3] min. (MPa)	UTS [3] min. (MPa)	A50 typical (%)	Bending angle min. (º)	AS80	AS150	GI	GA
Ductibor® 450 [1]	340	440	15	90				
Ductibor® 500 [1]	400	550	15	90				
Usibor® 1500	1050	1400	5	50 [2]				
Ductibor® 1000	800 [4]	1000 [4]	6	80 [2]				
Usibor® 2000	1400 [5]	1800 [5]	5	45 [2]				

[1] Properties obtained with material thicker than 1,20 mm and hot stamped under lab conditions on flat specimens.
[2] Bending angle following to the VDA238-100, referring to 1.50 mm thickness.
[3] YS and UTS of the steel calculated based on the steel section without the coating.
[4] YS and UTS min reached if the quenching speed is > 75ºC/s, between forming start temperature and 750ºC, extraction temperature < 200C.
[5] YS and UTS min reached if the quenching speed is > 40ºC/s, between 400ºC and 200ºC, extraction temperature < 200C.

Available
Under industrialization

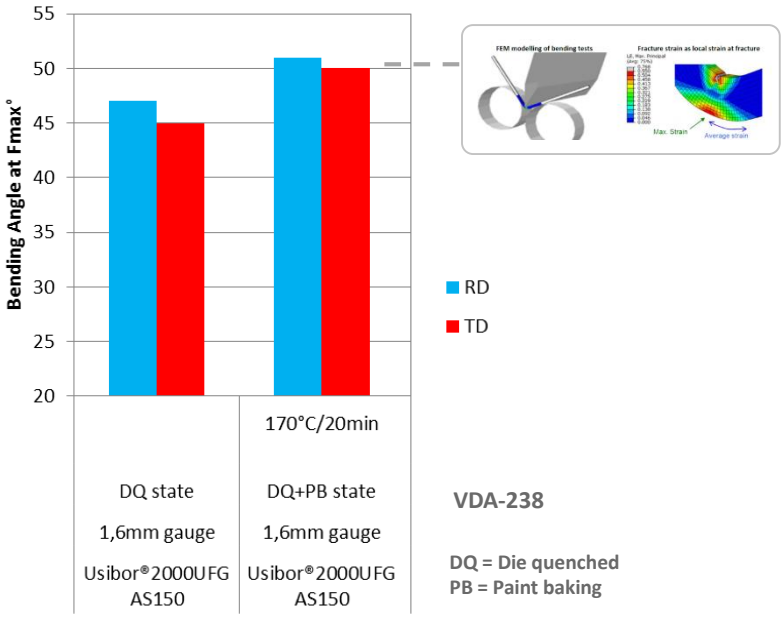
ArcelorMittal is the only global steelmaker to offer the full range of PHS products : the full range of strength is available with the AS coating. From a global point of view, the use of Zn coated PHS remains very limited.

Usibor® 2000 challenges

Crash ductility and resistance against delayed fracture

Crash ductility

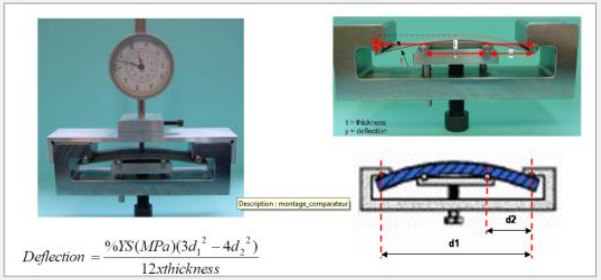
- Bending test – evaluation of the fracture strain in plane strain

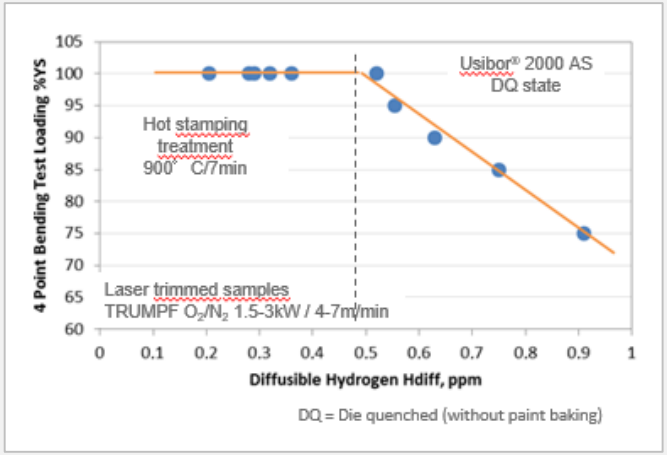


The fracture strain target is reached after paint baking and should be compatible with most of the anti-intrusion BIW applications.

Resistance against delayed fracture

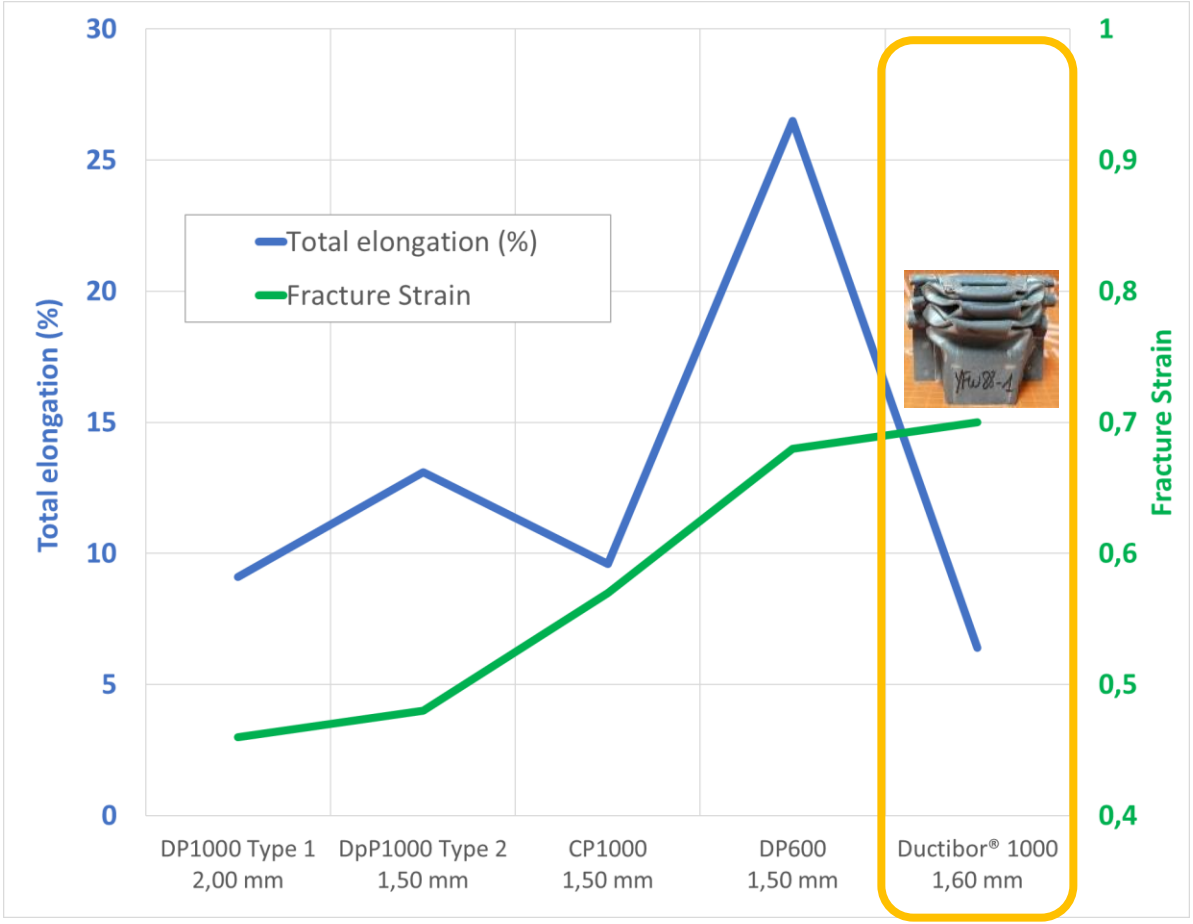
- The 4 points bending test



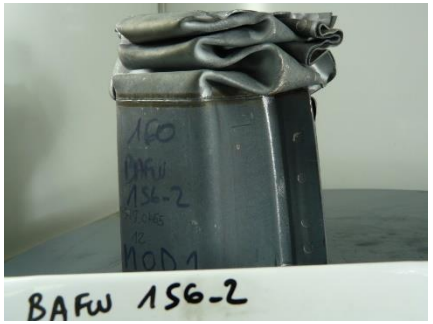


Usibor® 2000 is safe for an applied stress of 100% YS without post degassing heat treatment if the dew point remains < -5° C.

Ductibor® 1000 challenges
Crash ductility at least as good as a DP600



Laser welded blank application

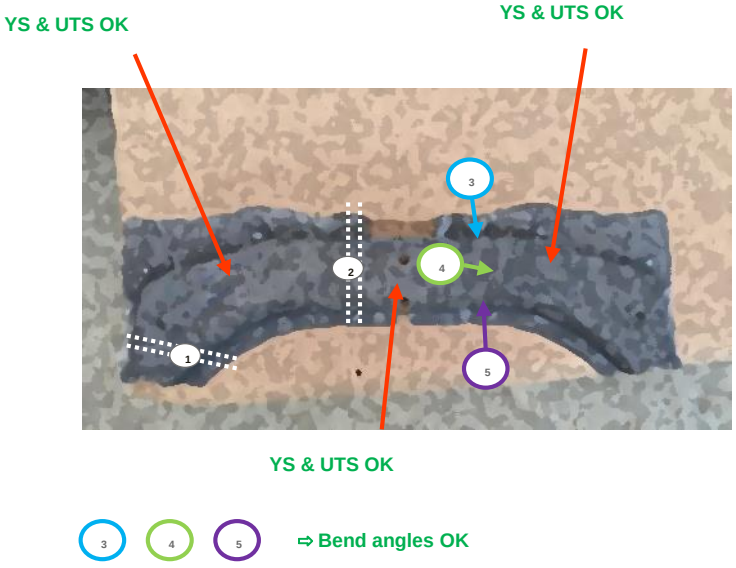


Bad correlation between the total elongation and the crash ductility. Ductibor® 1000 fracture strain is even higher than the fracture strain of a DP600 ⇨ Ductibor® 1000 excellent behavior during a compression test.

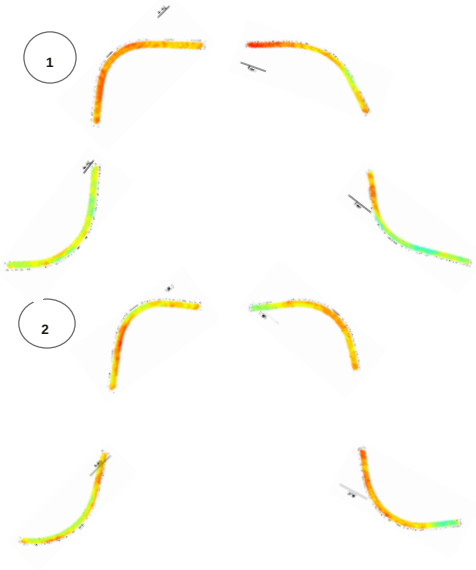
Ductibor® 1000 challenges

Robustness of the mechanical properties on real parts

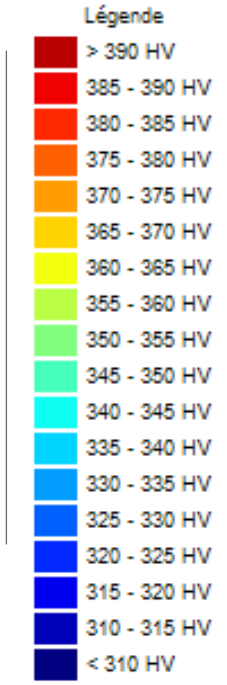
Example 2: monolithic part



⇨ Bend angles OK



⇨ MicrohardnessOK



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 fullfilled 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.

Usibor® 2000 and Ductibor® 1000

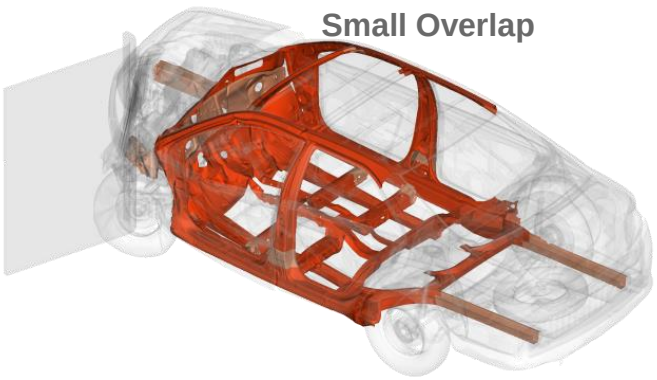
Weight saving potential on body-in-white applications

- ⇨ 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

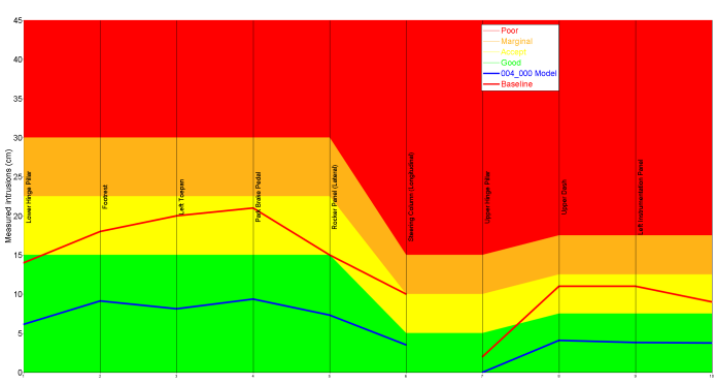
Good rating of the Usibor® 2000 solution

Small Overlap



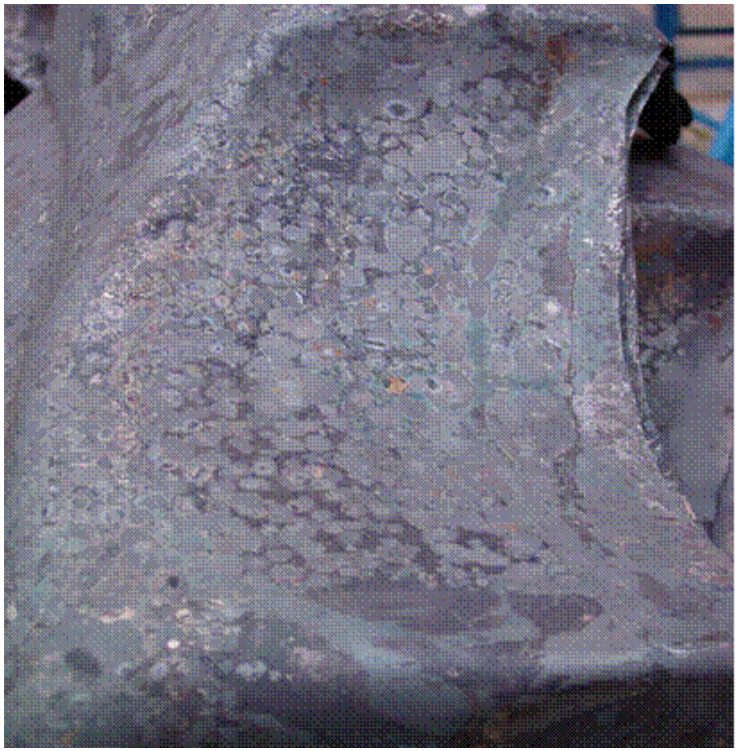
Lower outer A-pillar

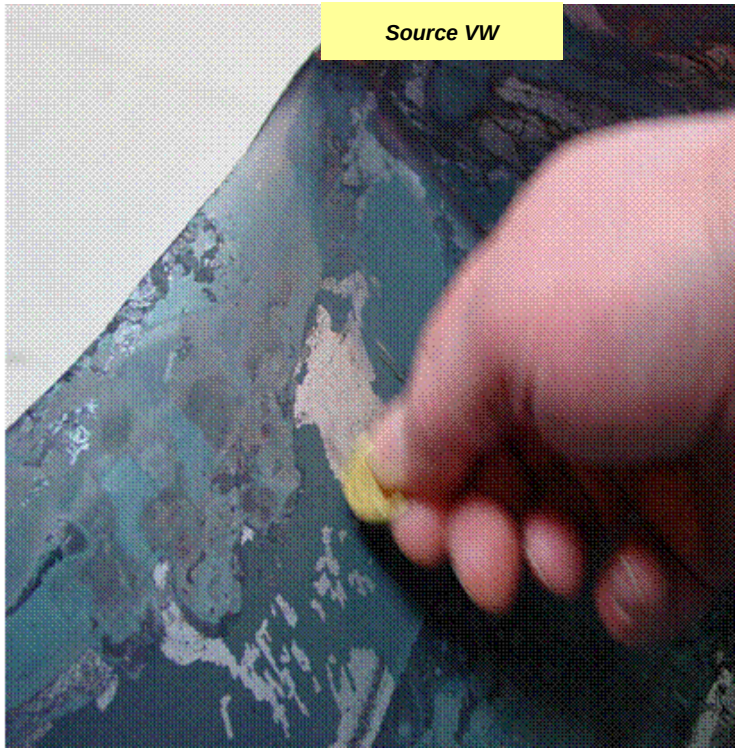
IIHS small overlap compliance



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 considered in Usibor 2000 AS.

Advantage of Pre coated Steel PHS





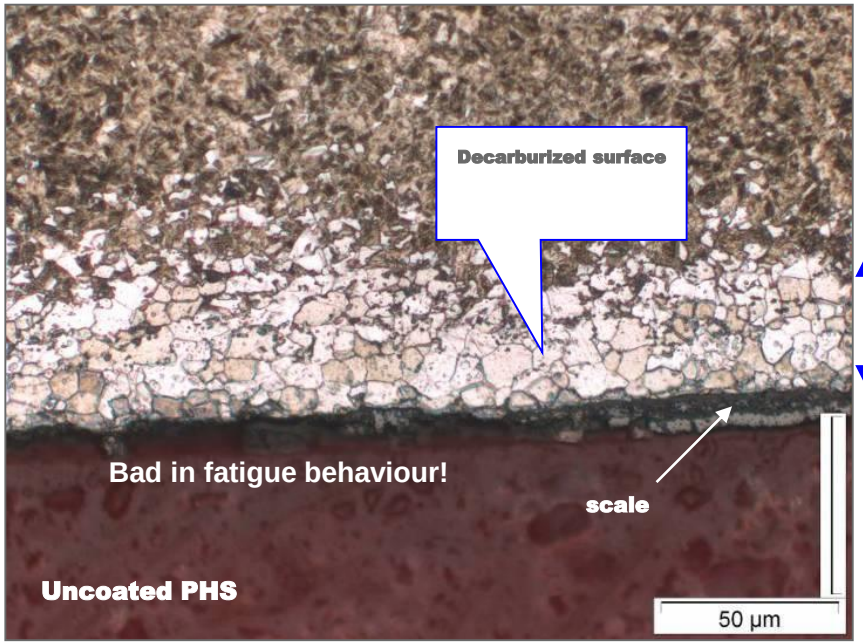
The avoidance and management of scale formation is the major know how of stampers who offer "uncoated" material today. The hot stamping of uncoated Boron steel is much more complicated than the hot stamping of USIBOR® 1500 + AS.

Advantages of pre-coated PHS

- With a coating, it is not necessary to do the austenitization under inert atmosphere.
- No scale growth : less tool wear, no need to remove the oxide layer after HT (shot blasting).
- The AS coating avoids also the steel decarburization (which can decrease the fatigue properties).
- No necessary temporary protection such as oil.
- No necessary post-protection of the parts against corrosion (hot dipping or electro-coating).
- Increased geometry tolerances (no deformation by shot-blasting), especially for thin parts.

Example of fatigue limit at 2.10^6 cycles

Stress ratio	Coated	Uncoated/ decarburized
0.1	727MPa	617MPa
-1	475MPa	305MPa



Surface of an UNCOATED boron steel after hot-stamping and shot-blasting : decarburization and residual scale (even with inert atmosphere in the furnaces)

AS coating excellent protection against perforating corrosion
Corrosion tests on a hot stamped not painted omega shape

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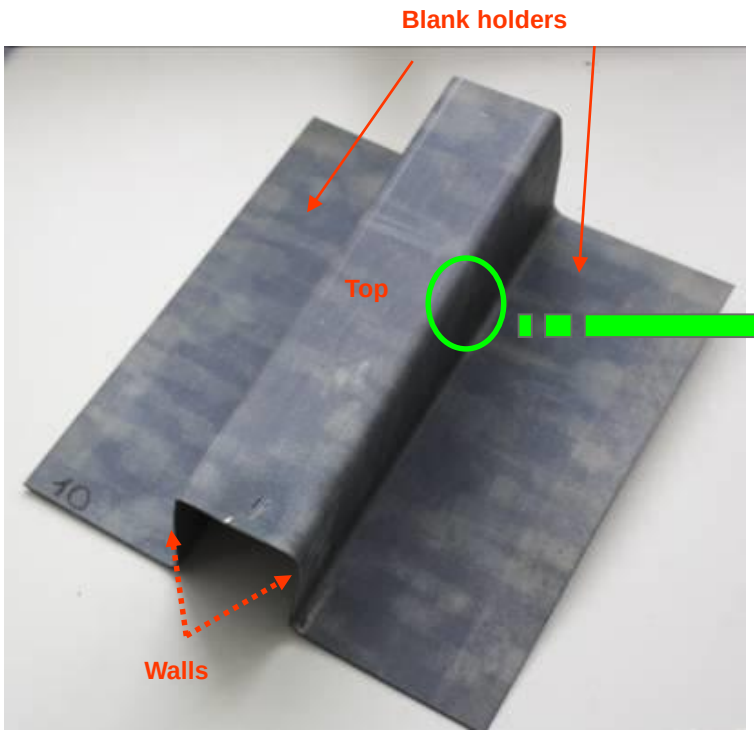
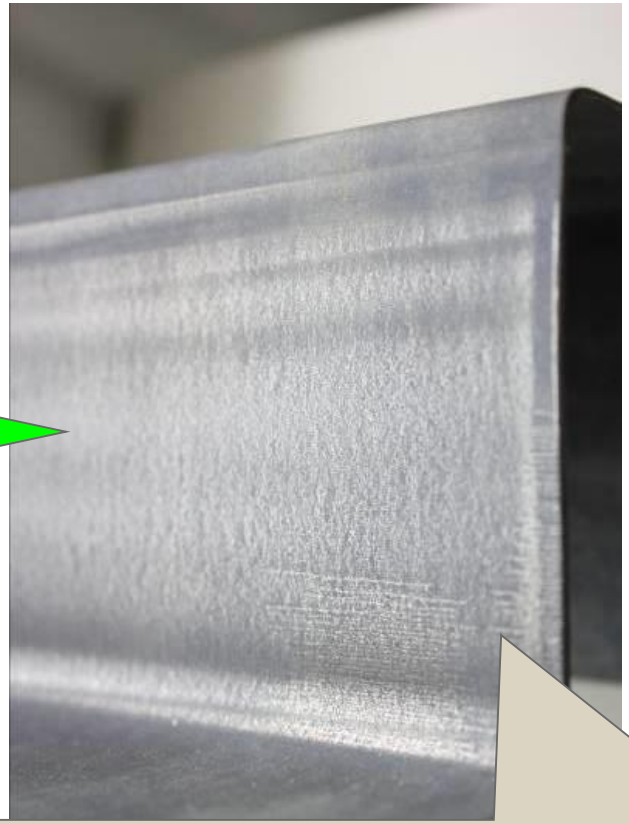
⇨ **Perforating corrosion tested on non painted Omega walls**

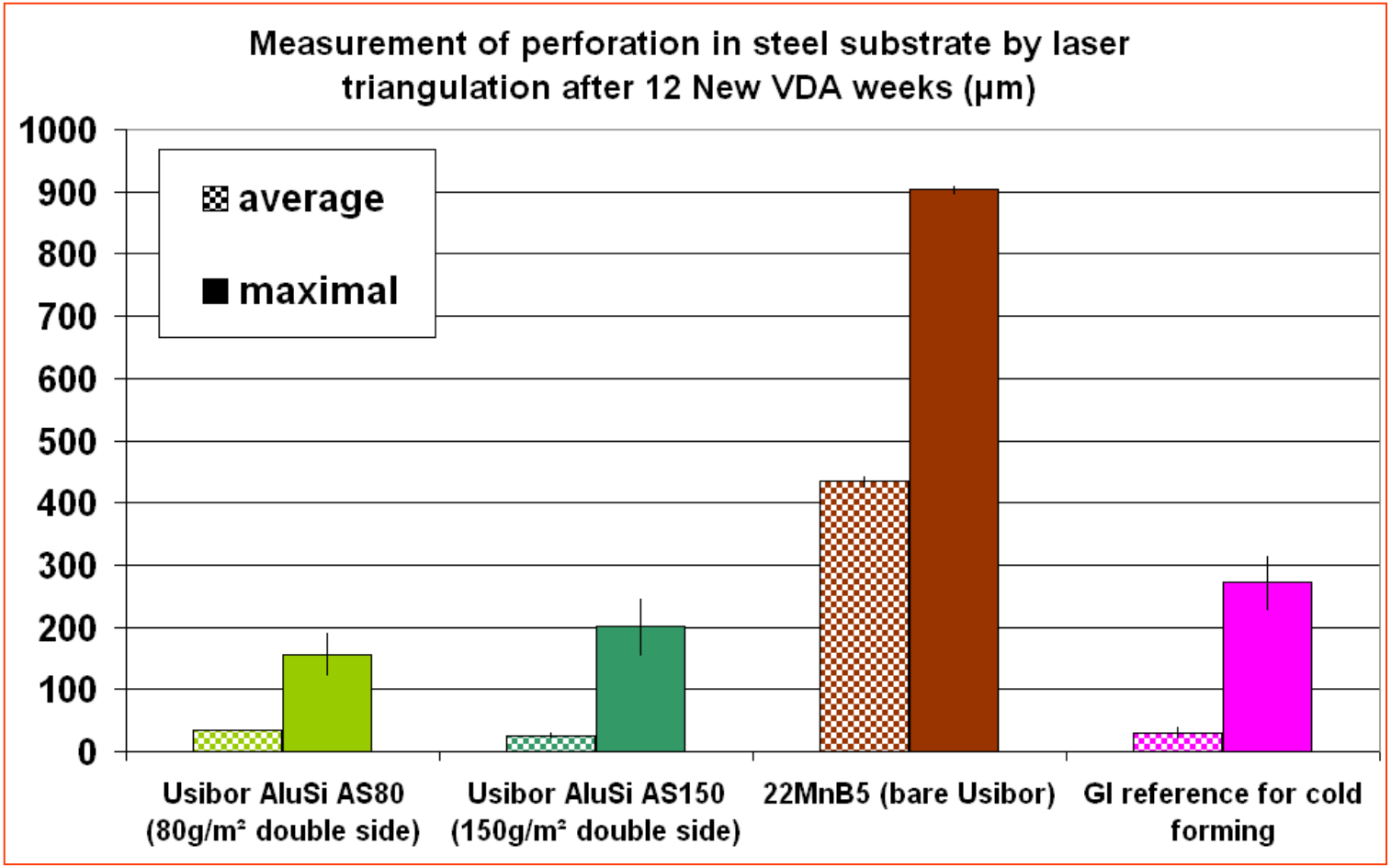




omega wall:
tool friction (vertically)
and Al-Si-Fe coating cracking (horizontally)

AS coating excellent protection against perforating corrosion

Corrosion tests on a hot stamped not painted omega shape



Excellent perforating corrosion resistance of Usibor® AS150 and AS80 while high risk of perforating corrosion with uncoated 22MnB5.

Growth in hot stamping is accompanied by a corresponding increase in hot stamping lines

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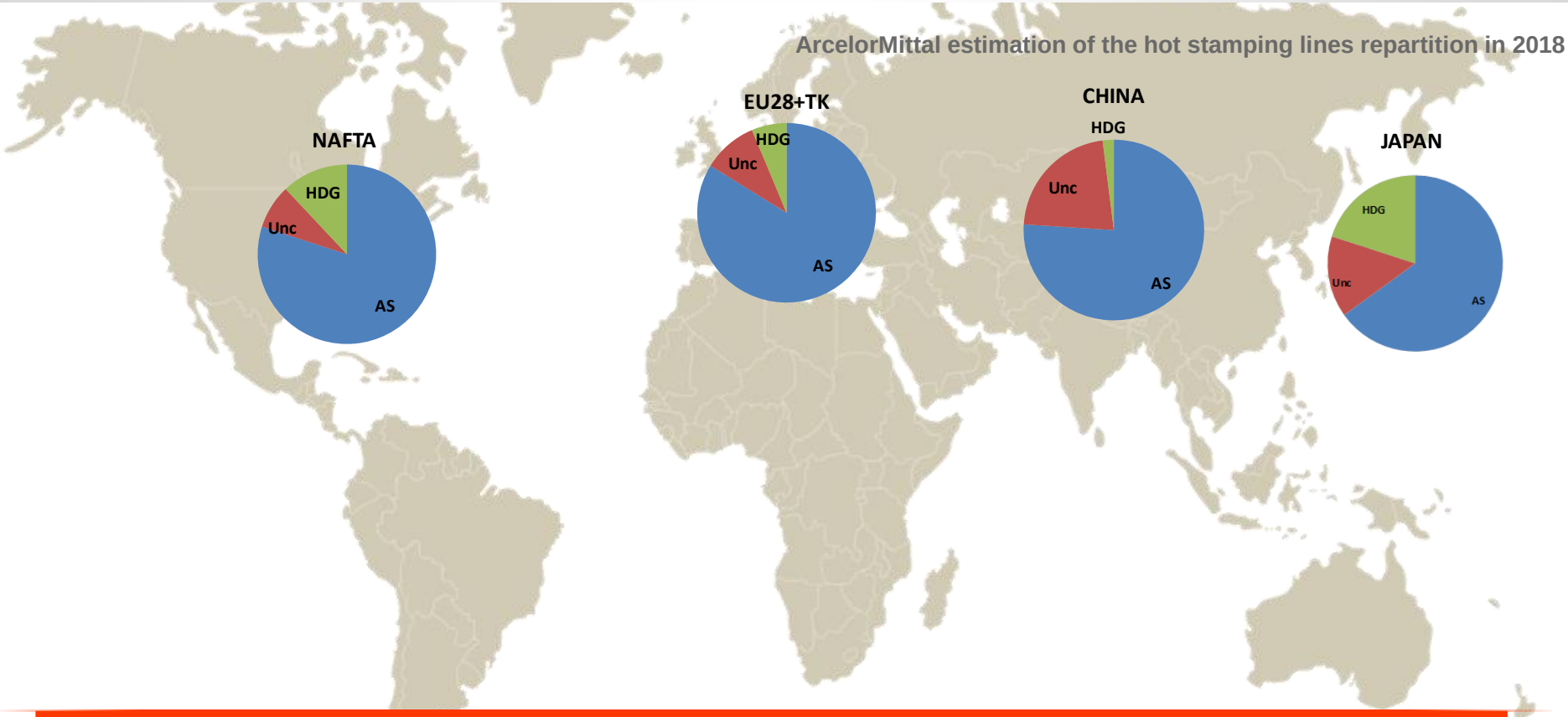
Alusi (AS), HDG (Zn-coated), and uncoated (Unc) shares by region in 2018

ArcelorMittal estimation of the hot stamping lines repartition in 2018



In Europe, NAFTA, China, more than 75% of ArcelorMittal's hot stamping lines are dedicated to Usibor®1500 AS.
Usibor®1500 AS is the most globally used coated hot stamping steel.

AS coated hot stamping steels

Trends

ArcelorMittal

- ✓ Hot stamping process costs and easiness
  - ✓ The hot stamping of AS coated steels remains the simplest and cheapest way to take benefit of the best in class lightweight potential for hot stamped solutions
  - ✓ Uncoated and Zn coated solutions remain more complex and more expensive in most of the cases : AS coatings process windows are bigger
- ✓ Performance
  - ✓ AS coatings protection against perforating corrosion is the best-in-class solution for hot stamping steel
  - ✓ AS coatings allow wide process windows
- ✓ Availability
  - ✓ As coated hot stamping steels are available worldwide
  - ✓ Most of the hot stampers are able to hot stamp AS coated steels
  - ✓ ArcelorMittal 2nd generation of hot stamping steels will be available wordlwide with the AS coating

Automotive Europe product offer:
Available online and as a smart phone app

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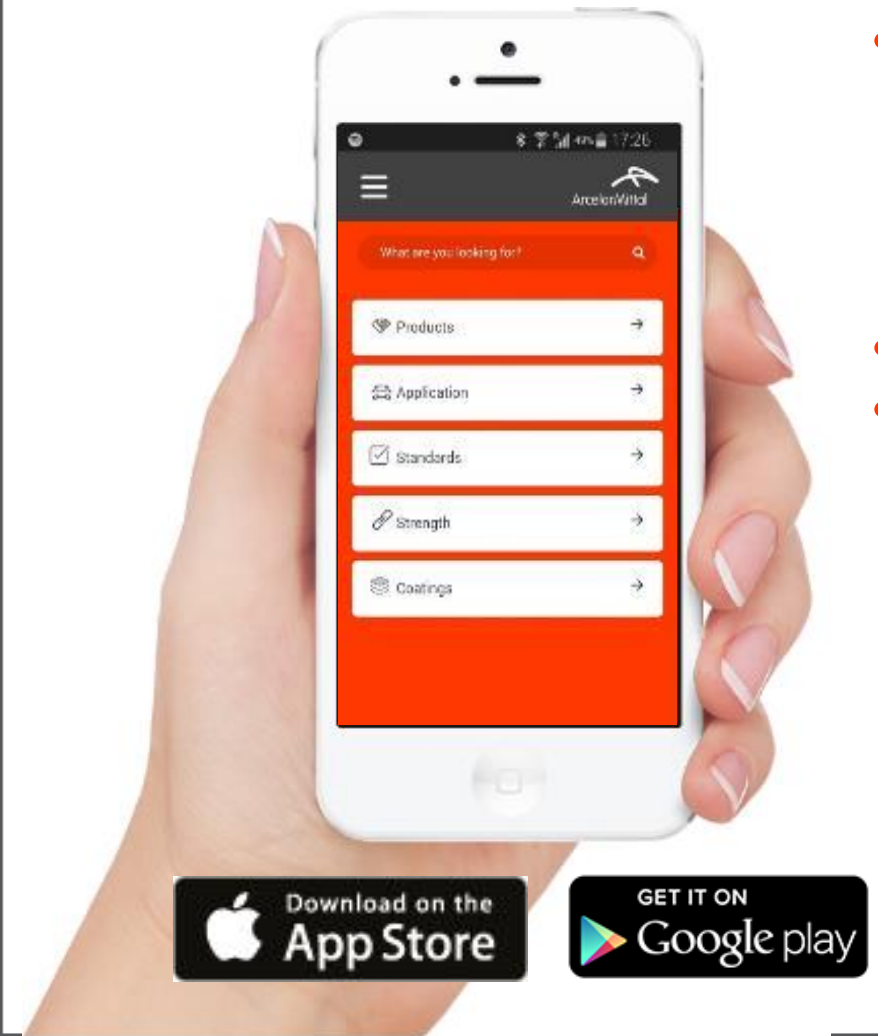

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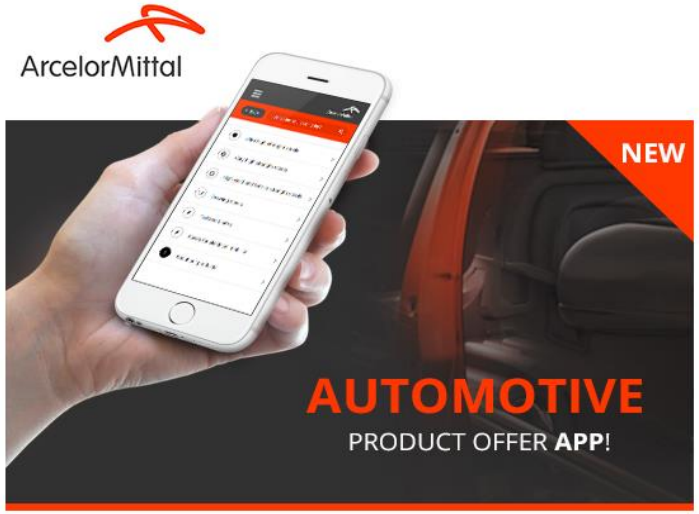

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