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High Strength Steels for Automotive Safety Parts

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Usinor Research

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HIGH STRENGTH STEELS FOR AUTOMOTIVE SAFETY PARTS

D. CORNETTE, T. HOURMAN, O. HUDIN, J. P LAURENT, A. REYNAERT
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ABSTRACT

Energy savings are among the most important goals of steel users. Usinor proposes a wide range of very high strength steels (HSLA, DP, TRIP, etc.) for weight reduction and impact resistance. This text deals with the mechanical testing and different design solutions associated with these steel grades. Tensile and formability properties are presented first by means of basic tests (drawing, stretching, bending, etc.) in order to classify the different steels. A specific part of the text deals with a ultra high tensile strength pre-coated boron steel for hot forming. In addition to this, the crash resistance is investigated by using a dynamic axial compression test and a dynamic three point bending test on structural components with closed and open cross sections. For each steel grade, the estimated weight saving potential is compared with respect to parts manufactured in high drawability steel. Finally, two different designs are presented with steel solutions for safety parts. The first one shows the advantage of the use of TRIP steel and a hydroforming technique for a crash box instead of using a conventional forming technique. The second one deals with the design of a cross frontal sill with a complex cross section, formed using a profile rolling technique.

INTRODUCTION

In the automotive industry, significant progress has been made concerning safety, fuel economy, dent resistance and comfort. To achieve these goals, a variety of steels are being used in the vehicles. Lighter cars conform more easily to environmental regulations and to fuel economy. However, safety and comfort considerations involve supplementary equipment and can be in contradiction with the pursuit of lighter weight.
In order to contribute to these objectives and to solve these contradictions, formability and high strength requirements of steels increase continuously leading to the development of important new steel grades, and new shapes of safety parts are used.

We develop a range of high and ultra high strength steels (TRIP and Boron steels) and work on new design solutions to satisfy some of these requirements.

TRIP steels offer an attractive combination of strength and formability, and crash test results show that supplementary progress in safety improvement and lightness can be reached by the use of this high strength steel. The process used for the hot forming of Boron steel permits good formability and very good in-use properties. This ultra high strength steel enables complex parts and the advantages of the pre-coated USIBOR1500 versus the current uncoated boron steels include: no need to remove the oxide layer after hot forming, no decarburization of the steel and corrosion protection of the parts. The combination of high and ultra high strength steels with new forming technique permits improved impact resistance. An example of the use of TRIP steel and hydroforming technique versus a conventional forming technique shows the advantage of this solution in terms of safety. And, a second example gives the interest of a design solution using a profile rolling technique

TRIP STEELS

PRINCIPLES AND MANUFACTURE

Three cold rolled TRIP steels are either industrially produced or under development by continuous annealing, hot-dip galvanization and electrogalvanized process: TRIP600, TRIP800 and TRIP1000 (figure 1).

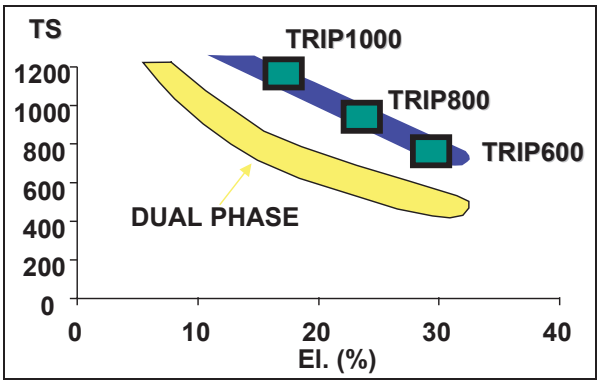

Fig. 1. Improved balance between strength and ductility compared with Dual Phase steels

TRansformation Induced Plasticity (TRIP) steels present, if compared with other steels such as HSLA and Dual

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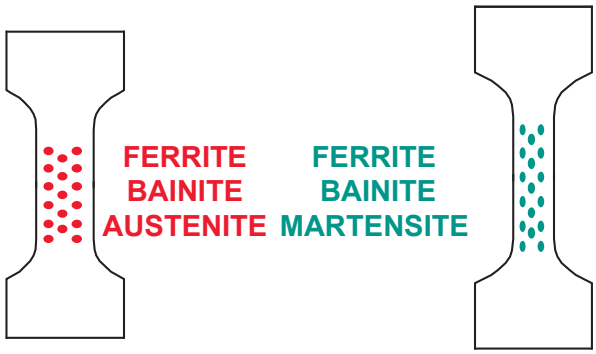
Phase, an improved balance between strength and ductility, resulting from microstructure at the end of continuous annealing (figure 1): a ductile ferritic matrix, hard bainitic phase and retained austenite. This austenite leads to martensitic transformation when stress is applied on the material, during forming for instance (figures 2 and 3). This transformation is diffusionless. It induces shape and volume phase changes giving, by the way, an improved ductility in stress direction (TRIP effect) [1]. Due to this TRIP effect, this steel family offers an excellent combination of strength and formability.



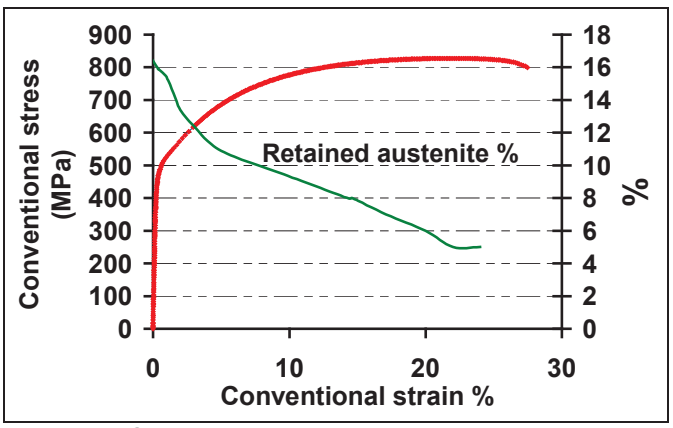


Fig. 2. Conventional stress and retained austenite fraction versus conventional strain for TRIP800

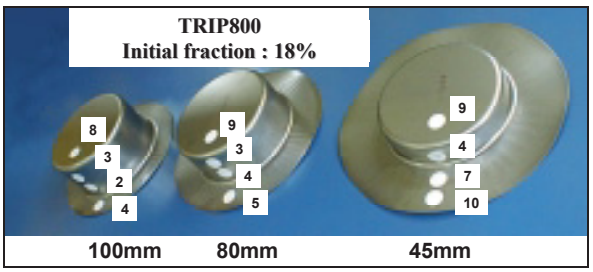


Fig. 3. Evolution of retained austenite fraction with stamping depth during press forming in drawing mode (quantified using magnetic method)

The example of TRIP800 permits to illustrate the critical annealing parameters to control microstructure of cold rolled TRIP steels and consequently to achieve mechanical properties.

Particularly, continuous annealing must be adjusted to obtain a carbon-rich retained austenite (about 1.14% for TRIP800) leading to martensite-free microstructure, by means of Ms value below room temperature [2,3] (lower than –65°C). Carbon enrichment of intercritical austenite occurs during cooling by ferrite transformation and during overaging by controlling bainitic transformation (figure 4).

Table I. Chemical composition of TRIP800 steels (10^{-3} mass %)

	C	Mn	Si
TRIP800	200	1670	1680

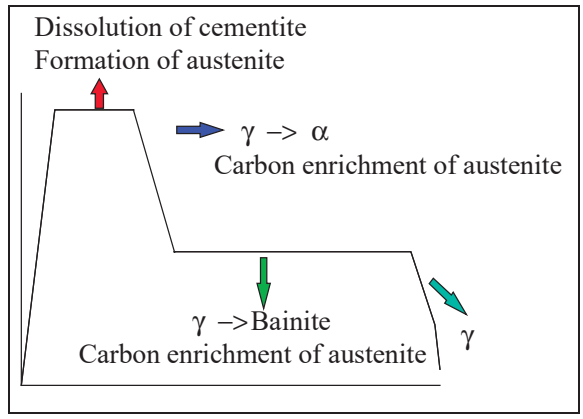


Fig. 4. Evolution of TRIP steel microstructure during annealing (α=ferrite, γ = austenite)

Microstructure evolution relating to each step of continuous annealing and induced mechanical properties at final state are the following.

Intercritical treatment

During heating and intercritical (in the ferrite austenite range) annealing, dissolution of cementite and formation of austenite occur leading to a ferritic matrix with austenite phase; the proportion of each component is determined by holding time and temperature.

Cooling

During this one, austenite transforms into ferrite. The composition is chosen, particularly Si content, to inhibit formation of cementite in ferrite and, thereby, promote the retention of austenite [4]. Cooling is stopped above martensite start temperature (Ms).

Very slow cooling rates would lead to low retained austenite fraction, by favoring ferrite and pearlite formation. High rates are not favorable to austenite transformation. Its carbon level remains low, leading to martensite in the steel, and consequently high tensile strength.

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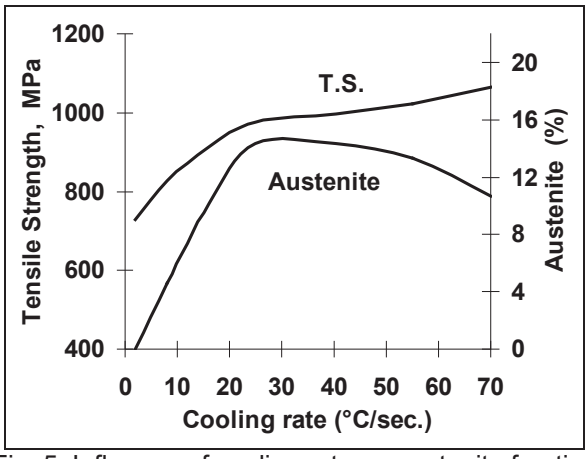

Fig. 5. Influence of cooling rate on austenite fraction and tensile strength.

Overaging

Bainitic transformation of the austenite during overaging is necessary to stabilize austenite by carbon enrichment, lowering Ms.

At 400°C (figure 6), at the beginning of holding, there is little or none bainitic transformation : carbon content in austenite is low; consequently Ms is high, providing martensite, and therefore high tensile strength and low austenite fraction.

Gradually as bainitic transformation occurs carbon content in austenite increases so that Ms decreases to below room temperature : austenite fraction increases, correlated to decrease of tensile strength. After a minimum aging time, tensile strength, elongation and austenite fraction are stabilized.

These results permit to control continuous annealing to guarantee the following TRIP properties.

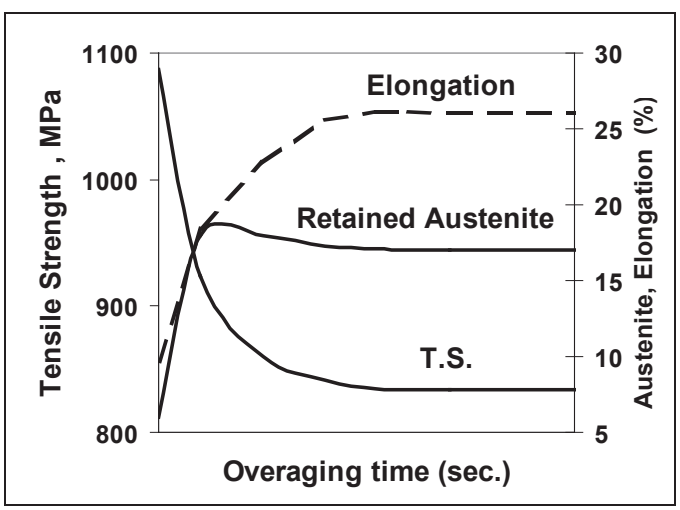

Fig. 6. Tensile strength, elongation and austenite fraction versus overaging holding time at 400°C.

MATERIALS PROPERTIES

Table II shows TRIP800 typical mechanical properties compared with soft deep-drawing quality, rephosphorized, micro-alloyed and dual phase steels.

Table II. Typical Tensile properties
(in transverse rolling direction)

Material	YS (MPa)	TS (MPa)	El. (%)	U.El. (%)	r	n	BH2
Mild DDQ steel	181	296	42.4	21.4	2.60	0.208	-
Rephos.260 (rephosphorized)	291	427	31.8	18.7	1.99	0.191	-
HSLA360 (micro-alloyed)	421	502	24.8	14.3	1.01	0.136	-
Dual Phase 450	**266**	**494**	**29.6**	**20.1**	**1.06**	**0.211**	**55**
Dual Phase 500	**285**	**599**	**26.5**	**19.3**	**0.99**	**0.198**	**49**
Dual Phase 600	**321**	**627**	**25.7**	**19.4**	**0.96**	**0.182**	**47**
HLE 460: Dual Phase 600 with 2% of Temper rolling	**471**	**667**	**23.6**	**14.5**	**0.99**	**0.138**	**-**
Dual Phase 750	**390**	**766**	**17.4**	**13.0**	**0.88**	**0.138**	**101**
TRIP800	**503**	**831**	**27.6**	**21.5**	**0.93**	**0.236**	**97**

TRIP steels present a high ductility in relation to the tensile strength as annealed. Particularly, TRIP800 steel has quite a similar uniform elongation compared with mild DDQ. Its high strain hardening capacity in spite of high strength level is described by its true strain - true stress curves (figure 7) and by the evolution of n value, when n is the instantaneous slope of the logarithmic stress-strain curve (figure 8).

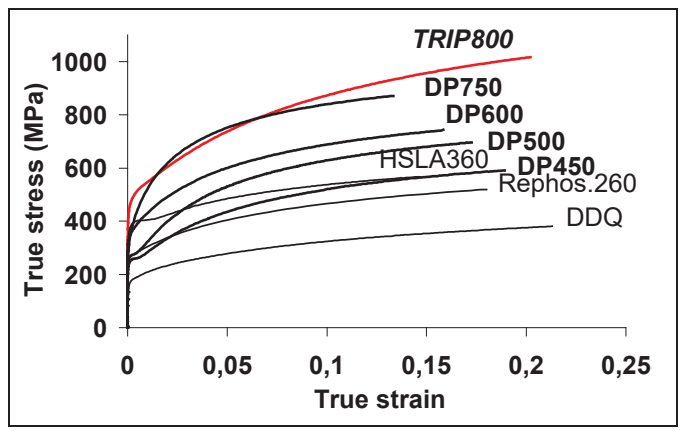

Fig. 7. True strain-true stress curves up to uniform elongation.

DP steels shows high n-value more particularly in the first stage of straining (for low elongation). Due to strain - induced transformation of retained austenite in TRIP steels, n-value is uniformly high during loading as for DDQ and rephosphorized steels. This high and uniform n-value leads to a good ability to cope with local strain

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peaks and so to a good strain distribution in the part (great security against local necking).

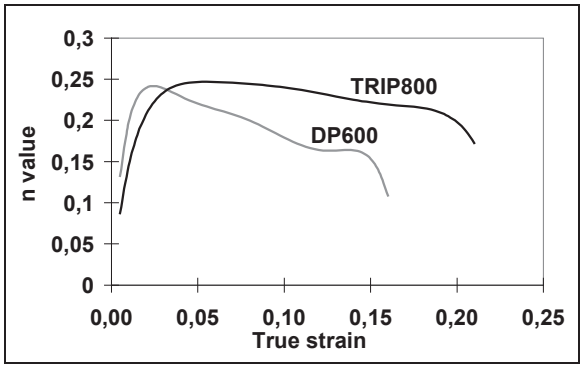

Fig. 8. n - values

Figure 9 shows the evolution of work-hardening value as a function of strain. High yield strengths on finished parts are obtained due to this high work hardening (WH2=85MPa for the TRIP800 grade).

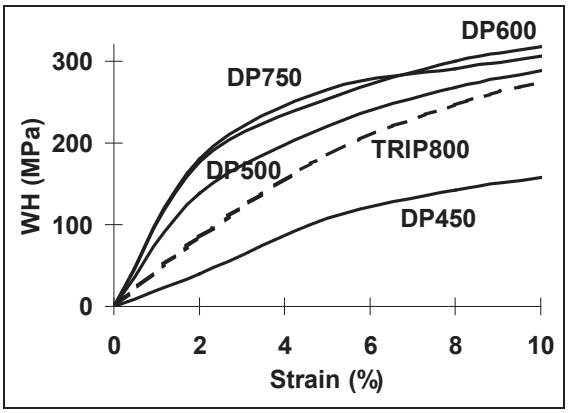

Fig. 9. Work-hardening versus strain.

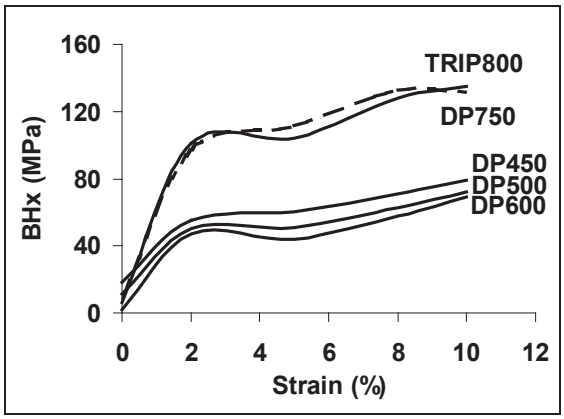

Fig. 10. Bake hardening versus strain.

Similar to dual phase steels, TRIP steels show after pre-straining a great yield strength increase during paint baking treatment (simulated by 170°C – 20min treatment) (BHO=0MPa, BH2=97MPa where 0 and 2 indicate 0% and 2% tensile prestrain prior to baking). But BHx is much higher than for DP600 and 450. Yield strengths on part can thus be substantially raised by putting to use the bake-hardening property of TRIP steels when microalloyed steels have no bake hardening effects (Table IV, figure 10) [5].

As annealed, TRIP steels are also resistant to natural ageing (simulated by 75°C – 10h treatment). Ageing appears only after pre-straining.

These ageing and Bake-Hardening properties are a consequence of dislocations-carbon atoms interaction. In Dual Phase and TRIP steels, the dislocation network is very heterogeneous; dislocations are preferentially situated in transformed grains (γ -> α) after intercritical holding, and at martensite-ferrite interfaces. Dislocation pinning by carbon atoms need a long distance diffusion, which is not allowed by ageing or paint treatment conditions. Homogeneous dislocations network is favored with pre-straining, especially after unidirectional tensile compared with temper rolling. By the way, only short distance carbon atom diffusion is necessary.

PROCESSING PROPERTIES

Press-formability

Material behavior during complex forming operations cannot only be described by uniaxial tensile test results. This paragraph presents some trial stamping results showing excellent formability of TRIP steels.

In order to determine capabilities of TRIP800 compared with others qualities, we have first conducted tests in drawing mode. The drawability characterizes the ease with which the flange material flows into the side wall during drawing and the ability of the side wall material to withstand plastic deformation in the thickness direction. A comparison of drawability expressed as the blank holder load range on 200mm diameter cup and limiting drawing ratio was conducted on TRIP800, DP750 and DDQ steel with the same 1.5mm thickness uncoated sheets. Common lubricating oil was used.

Figure 11 illustrates the large blank holder load range and large limiting drawing ratio of TRIP800, despite its small plastic strain ratio (r-value=1). TRIP800 has a large advantage in deep drawing compared with DP750, which has approximately the same tensile strength. TRIP800 also shows approximately the same limiting drawing ratio as DDQ but higher blank holder load must be applied to prevent wrinkling under the blank holder (also in unsupported areas). High press capacity must be available for TRIP800 press forming.

The surprising excellent deep drawing behavior in spite of low r-value of TRIP800 is due to the different stability of retained austenite under tension and compression stresses. As shown on figure 3, tension stresses in the wall favor a transformation to martensite and increase force transmissibility by hardening of the microstructure. In the flange, austenite is stabilized under compression so that the microstructure is relatively soft and the force

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requirement remains low. This effect can be interpreted analogously to the effect of a high r-value which leads to an improved ability for the transmission of force on the cup wall and on the transition to the bottom, and simultaneously to a lower force requirement for the deformation of the flange.

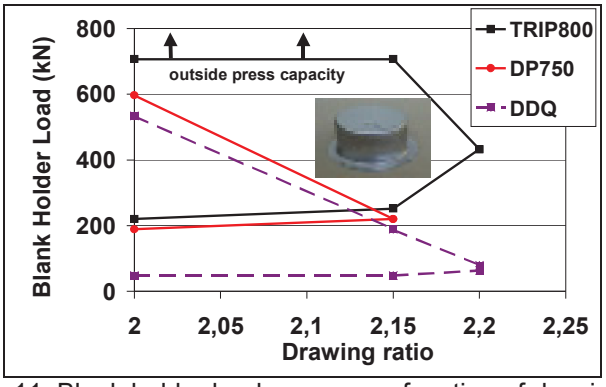

Fig. 11. Blank holder load range as a function of drawing ratio for TRIP800, DP750 and DDQ qualities.

Dome and rectangular punch stretching tests were also conducted. The heights at failure are determined in both tests. Figures 12 and 13 show the good stretch and plane strain-forming properties of TRIP800 compared with others qualities with lower tensile strength. Indeed, TRIP800 and DDQ have approximately the same height at failure. The good stretch and plane strain forming properties combined with very high tensile strength of TRIP800 can be explained by its very good strain hardening properties. This behavior prevents the occurrence of excessive local deformation by a good strain distribution during press forming. These properties make TRIP800 steel a good choice for difficult pressed parts.

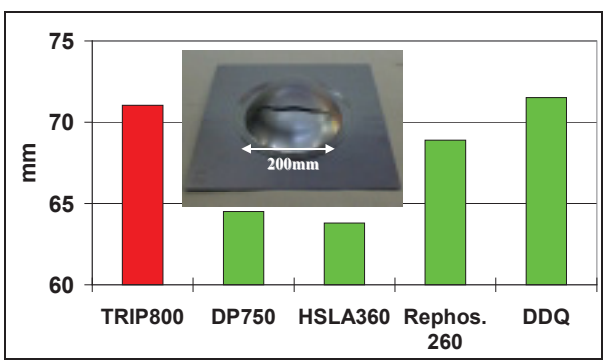

Fig. 12. Height at failure in 200mm diameter dome stretching as a function of the material

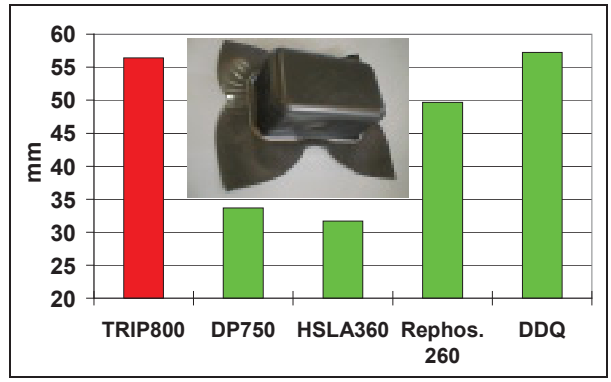

Fig. 13. Height at failure in rectangular stretching as a function of the material (150*250mm punch)

Hole flanging behavior was investigated. Figure 14 illustrates the maximal hole flanging height as a function of the material. Test was conduct with a hole flanging diameter of 25mm on punched hole. TRIP800 steel has lower flanging properties than other qualities. This is due to its very high strength. With TRIP steels as for Dual Phase, the height of hole flanging, which are met on structural parts, must be lower than with conventional steels. TRIP steels as Dual Phase are also very sensitive to edge stretching.

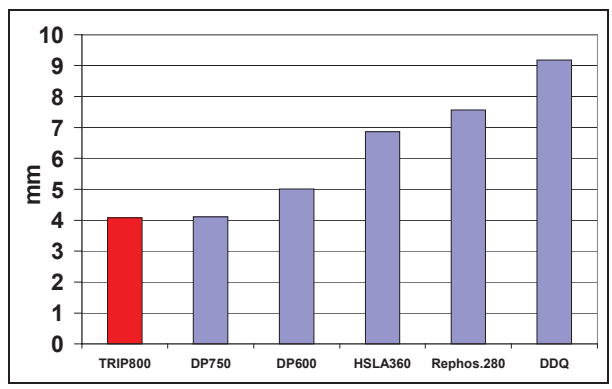

Fig. 14. Maximal hole flanging height as a function of the material

Figure 15 shows the experimental forming limit curve of TRIP800 for a 1.5mm thickness.

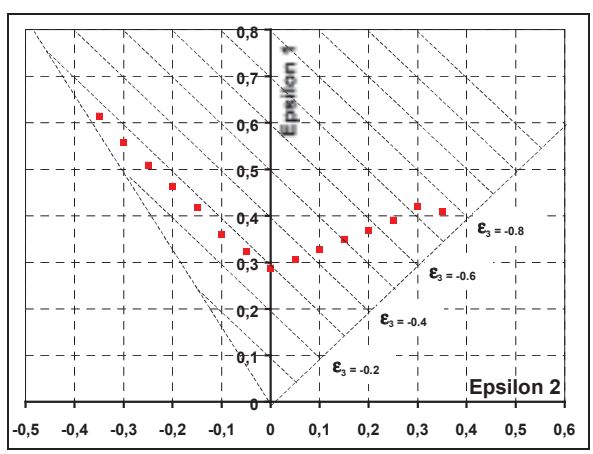

Fig. 15. TRIP800 forming limit curve

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As a conclusion of these forming tests, TRIP800 steel seems to have extremely good forming behavior compared with others qualities with lower tensile strength. TRIP800 shows the same behavior in some forming as DDQ steel but with yield and tensile strengths 300 and 500MPa, higher, respectively. TRIP800 steel grade is an interesting solution to satisfy high forming requirements. This grade offers attractive combinations of strength and formability for structural and safety autobody parts.

On the other hand, due to the higher mechanical properties offered by TRIP steels, the increases of stamping forces and wear of tool have to be taken into account. Nevertheless, the potential of lightening offered by these steels, can reduce significantly these stamping forces, and wear of tools can be reduced by the use of heat-treatment and if necessary of additional tool coating like TiN.

Also, the increase of spring back tendency due to higher strength level of TRIP steels must be considered. Well-known forming techniques can be used to control springback (small die radius and die clearance, high blank holder load in case of U-shape for example, overbending, coining radius, restriking tool,…). Stiffness increase of “open” parts using ribs in non-functional areas can also be easily conducted with TRIP800 due to its very good formability. This solution will permit use simultaneously of its high work hardening potential. As for Dual Phase steels, the high yield strengths on parts resulting from the high work hardening capacity must be taken into account during crash simulation in order to use the whole weight reduction potential of TRIP steels.

Crash performances

The following tests were conducted:
- Axial compression on spot welded closed hat shaped structure
- 3-point bending on hat shaped structure

They showed a very good crash behavior for Dual phase and TRIP qualities.

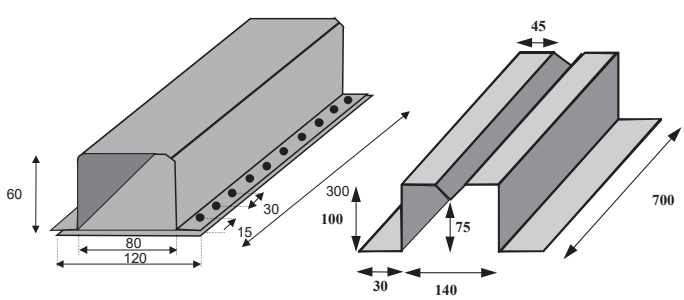

Fig. 16. Axial compression and 3 point-bending tested structures

Fig. 17. Axial compression tested structure before and after crushing at 58km/h.

Fig. 18. 3-point bending tested structures before and after crushing at 30km/h.

The following graph shows the levels of energy absorbed by TRIP800 steel during an axial crushing compared with other qualities with 1.5mm thickness.

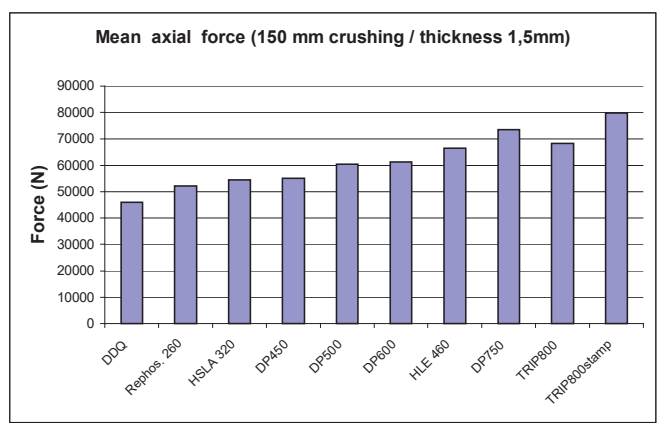

Fig. 19. Mean load for 150mm crushing

On this type of part, TRIP800 steel permits 21% weight reduction in relation to DDQ.

The following graph shows the maximum load during crushing in 3-point bending for TRIP800 compared with other qualities with 1.5mm thickness. The ultimate load is globally proportional to yield strength on part for a fixed geometry.

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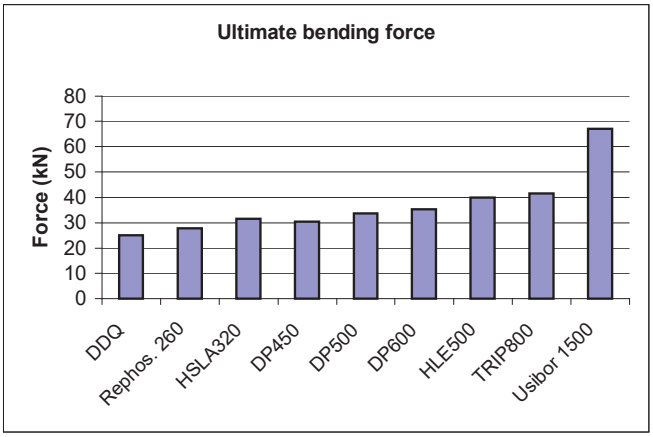

Fig. 20. Ultimate load in 3-point bending (SAE180 filter)

These results were obtained with bent specimens. Strengthening during stamping process has a very beneficial effect on the energy absorption potential of these qualities. The axial compression tests showed a gain of 10% on the absorbed energy in favor of stamped parts compared with a bent specimen. With HSLA320, strengthening compensates thinning due to stamping process and gives no gain in term of absorbed energy.

At the design stage of parts in Dual phase or TRIP steels, mechanical properties after stamping must be taken into account instead of as received sheet properties in order to benefit from the potential of these qualities.

APPLICATION

Due to their excellent combination of formability and strength, TRIP steel permit both high and low deep drawing requirement parts with high strength. They can be coated for improved corrosion resistance. Considering their high tensile strength, these steels are designed for structural parts (like seat parts,…), anti-intrusion parts, crash relevant parts with high energy absorption requirements, but also inner parts can be realized. Successful stamping and crash trials have been already obtained on A-pillar inner, B-pillar inner reinforcement inner panel, side rails and bumper reinforcement.

Supplementary progress in safety improvement and weight savings is possible with a coordination of product design and steel performance. The examples proposed illustrate how to take advantages of the potentialities of TRIP800 steel.

PRE-COATED BORON STEEL

Another way to reduce weight and improve the safety is to separate the required characteristics, i.e. good formability and very high strength. The way to realize this objective is to use steel supplied with very good formability, permitting complex shapes to be obtained. In-use properties such as high mechanical characteristics are obtained through heat treatment or hot forming. Moreover, the lengthening of anti-corrosion guarantees requires pre-protected steel supply.
In order to answer these requirements, USINOR has developed a pre-coated version of USIBOR [6] steel, which associate excellent mechanical properties of the material after the press hardening process with good corrosion protection.

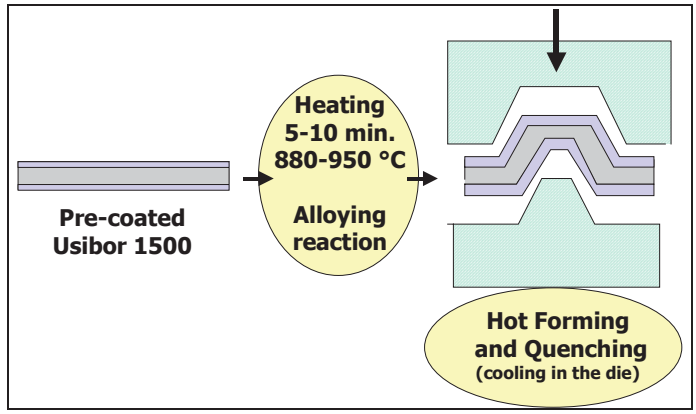

Fig. 21. Process used for the hot forming of USIBOR 1500 Pre-coated.

CHEMICAL COMPOSITION OF THE BASE MATERIAL

USIBOR 1500 is a carbon-manganese steel microalloyed with boron.

Table III. Chemical composition of pre-coated boron steel in thousandths of percent

	C	Mn	Si	S	Cr	Al	B	Ti
Min.	200	1100	150		150	20	2	20
Max.	250	1350	350	8	300	60	4	50

DESCRIPTION OF THE COATING

The coating, made of aluminum and silicon, is applied with a hot dipped process.
The average layer thickness showing the best compromise between corrosion protection and weldability is 25 µm.
Heating the pre-coated boron steel (generally 900°C, 5 minutes) creates an alloying reaction between substrate (iron) and the coating (aluminum - silicon) which leads to a hard multiphase alloy layer.
Fe-Al-Si layer is typically about 40 µm at the steel surface. The following photo shows a section view of the coating after heat treatment:

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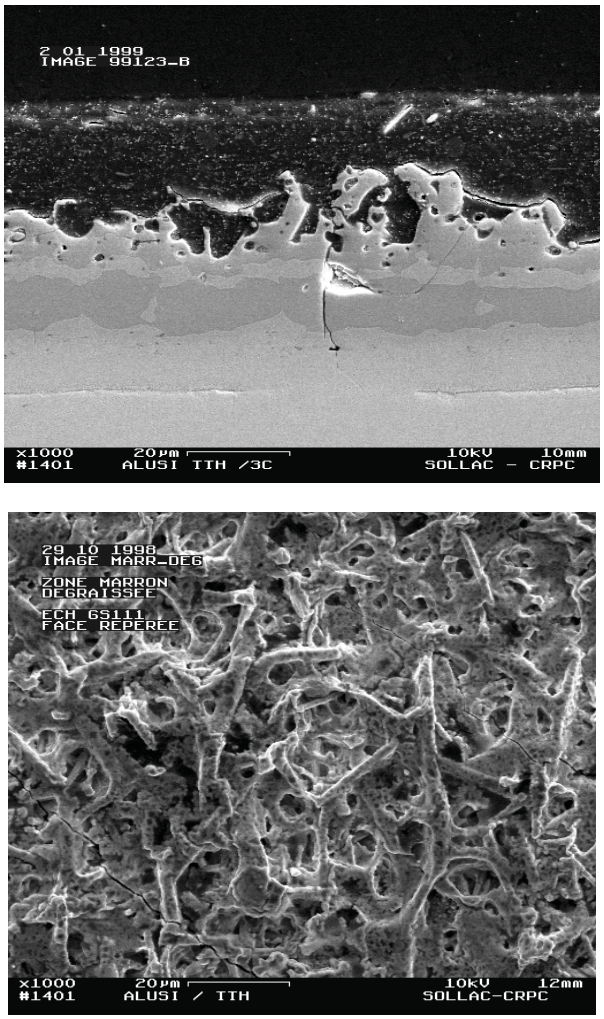

Fig. 22. Section view and coating surface after heat treatment.

MECHANICAL CHARACTERISTICS

Before heat treatment, the typical mechanical properties (measured in the transverse direction) are the following:

ISO 20x80 type	YS (MPa)	UTS (MPa)	E (%)
pre-coated boron steel	400	600	21

Mechanical properties after hot forming process are not guarantied by USINOR. Following typical values are obtained after austenitization at 900°C during 5 minutes and cooling in the die, for a material with a thickness of 1,5 mm:

ISO 20x80 type	YS (MPa)	UTS (MPa)	E (%)
pre-coated boron steel	1030	1510	5

The Al-Si coating does not significantly alter the heating process (heating speed temperature, dwell time) before forming nor the quenching speed in cooled tools.

SPOT WELDABILITY

Spot weldability tests, according to NFA 87-001, have been performed on boron steel (thickness 1,5 mm) pre-coated and quenched, welded together with DC 04 (equivalent to QS 1010, thickness 1,25 mm) zinc hot dipped coated 2 sided 10 µm.

Table IV: Welding parameters

Squeeze time	50 periods
Welding time	16 periods
Hold time	16 periods
Welding force	300 daN

Spot weldability shows good results regarding the welding range (2.1 kA). Preliminary studies on electrode life with pre-coated quenched USIBOR show results equal or better than Zinc EG-coating.

SURFACE TREATMENT

Because of high roughness values after hot forming process, pre-coated boron steel do not require any phosphatization to achieve acceptable paint adherence. Anyway, the phosphatization process does not modify the material properties.

CORROSION RESISTANCE

As quenched

Pre-coated boron steel has been tested after heat treatment and without any additional surface treatment in different corrosion conditions. Results show a good capacity for corrosion resistance. Because of the aluminum coating type, there is no galvanic protection but a good general covering effect of the coating.

Test	Results	Method/ Standard
Humid conditionned box	< 1 % of surface area covered with red rust after 10 cycles FKW	DIN 50017
Natural Exposure	No red rust after 2 months in Fos/Mer	USINOR method
Continuous salt spray	- 30 g/m² mass reduction after 500 hours - 90 g/m² mass reduction after 1000 hours	NFX 41-002

Due to the low galvanic protection brought by the coating, red rust appears very locally but does not expand with time.

Painted parts

Test	Results	Method/ Standard
Material after cataphoretic paint *	Paint delaminated	NFX 41-002

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1000 hours Salt-Spray	width ≤ 3 mm	

* PPG 742/962, 15 to 20 µm

Corrosion resistance is compatible with most car makers requirements.

CONCLUSION

Pre-coated boron steel enable to obtain complex parts, by hot stamping without spring back, with high mechanical characteristics authorizing a significant lightening.
Principal advantages of the pre-coated boron steel versus the current uncoated boron steels are the following:

- No need to remove the oxide layer after hot forming process. With uncoated material, a supplementary, and also costly, pickling operation is usually necessary.
- No decarburization of the steel during the hot forming process.
- Corrosion protection of the parts. A further hot dipped or electro-coating operation is not necessary anymore to achieve the corrosion resistance.

STEEL DESIGN SOLUTIONS

CRASH BOX

These components are designed to limit the damage that occurs on vehicles during a crash with an initial speed of 15 km/h. The cost of repair is evaluated by insurance companies and vehicles are rated into several classes of cost, with an impact on the insurance fee.
The classical design is a component made of two stamped parts that are spot-welded to give a "rectangular" profile. This component is bolted on the front member of the Body-in-white, and welded to the bumper beam. Roll formed shapes are rarely used because it is necessary to manage the exact behavior during the crush by means of triggers or by changes in the sections of the component. These crash boxes dissipate the kinetic energy during plastic deformation of the steel into successive folds.

Fig. 23. crash box with two stamped parts.

Another concept is based on the usage of concentric tubes, with a transition area between them. Instead of the compressive deformation mode, a bending and expansive mode is obtained. At first plastic deformation occurs in the bending of the transition area, and then it progress by rolling the external tube inwards. The result is a very constant crushing force along the total displacement, without any initial peak effort. The second advantage is that a very low residual length can be achieved.

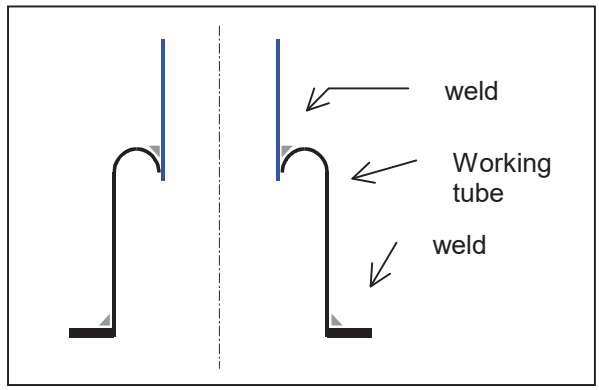

Fig. 24. crash box with two concentric tubes, initial state.

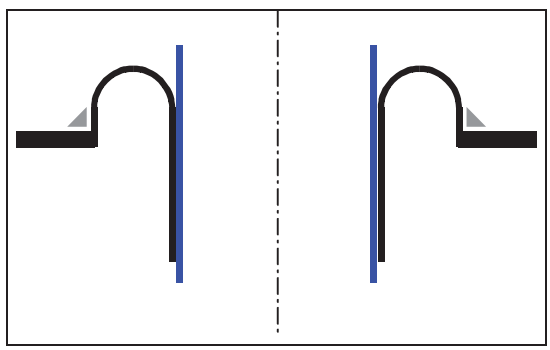

Fig. 25. crash box with two concentric tubes, final state.

As the welding of two tubes in such a design is not a robust process an industrial version is done with a stamped part and a tube. The welding is easier to do, and small defects are not dangerous because the tube pushes on the upper face. The load is not transmitted through the welding line. However this design has another limit due to the ability to produce the stamped part. It is a very deep drawn part, so mild steel is the only possibility.

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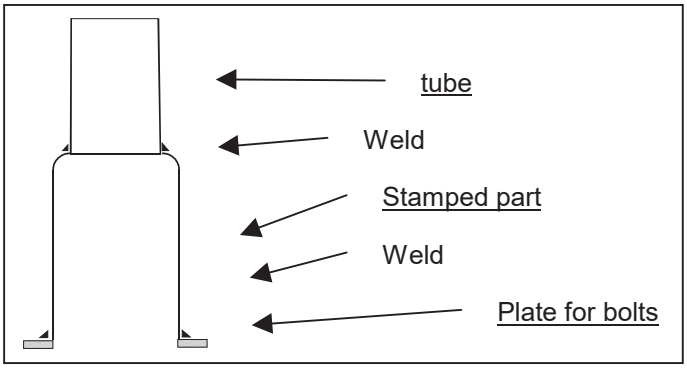

Fig. 26. crash box with stamped part and tube (section).

The hydroformed version of the crash box gives a good improvement in the concept and allows the beneficial use of high strength steel. The specific forming process allows a ratio of diameter expansion up to 30% for dual phase steel DP600 and trip steel TRIP800 with a length of the expanded area far greater than the possible depth of the stamped part. The plastic deformation during the forming process is uniform, so the hardening properties of these steels are effectively used. This hardening compensate the thinning that occurs, so the plastic deformation occurs on the right area of the part and the level of the crushing effort is far higher than with mild steel. The regularity also ensure that the material still has a capacity of deformation during the crash and that all risk of fragility is avoided, instead of the stamped parts who proved to be dependent on a very good drawing process on that matter. Another advantage is that the design office is able to integrate easily the thinning and the change in properties in the crash calculations, without complex transfer between several software.

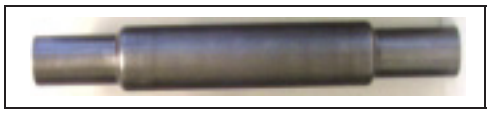
Fig. 27. hydroformed part with DP600, giving two crash boxes when cut in the middle.

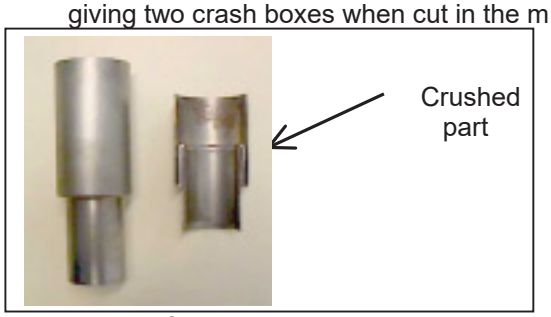

Fig. 28. hydroformed crash box, initial and crush states.

For the same mass, the crushing force and the energy absorbed given by the hydroformed part with steel TRIP800 are twice the level achieved with mild steel.

BUMPER BEAM

High strength steels are widely used for bumper beams. The requirements for the front end containing these beams are:

- No damage during crash at a speed up to 5 km/h.
- Absorption of the whole energy during crash up to 15km/h.

Various designs are used: tubular beam, profiles, stamped parts. The latter is the most flexible for the designer because it allows variable cross sections and integration of details. However the difficulty to stamp steel parts when the yield strength is over 800MPa is the main reason for the usage of roll forming to realize these beams. The other way is hot stamping and quench of boron steel.
Most of these beams have an open cross-section. This is efficient when the gauge is high. To go further in the lightening of the Body in White it is necessary to decrease the thickness and to increase the material properties. In this case the local buckling of the flanges becomes larger and closed cross section are better. However this is still not enough to avoid local flexion for a rectangle of typically hundred millimeter high and fifty millimeter width when the gage is comprised between 1 to 1.5 mm . The best cross section is composed of closed cells with smaller free areas between the edges. The development described hereafter comprises two cells in a roll formed profile.

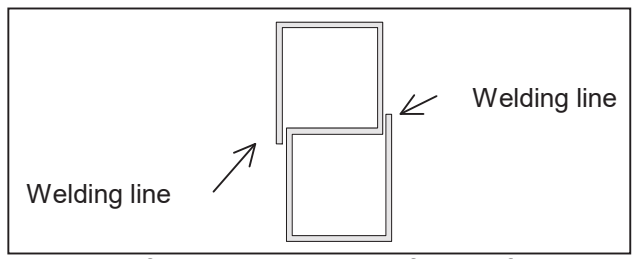

fig. 29. cross section of the profile

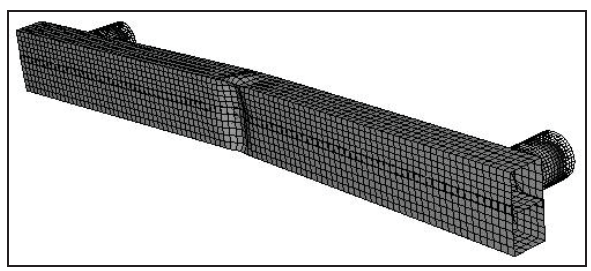
Fig. 30. front end assembly, model for crash calculations.

The steel DP1000 is now used for this bumper study (on development, not yet available for sale).
The profile can be obtained from a roll forming line equipped with a welding facility. The resulting costs are similar to tube costs. It is necessary to control precisely the spring-back resulting from the forming process to get a good weld.
The improvement in the first requirement is dramatic, compared to the previously used HSLA360. The level of load reached before plastic damage is doubled, with the same weight. The improvement in energy absorption at

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15 km/h is lower, because the shock absorber is more important than the beam in this case. The objectives are satisfied with a mass of the front end around 4,5 kg.

CONCLUSION

As a conclusion, USINOR develops new steels grades and works on new design solutions to satisfy objective of structure lightening and crash behavior improvement.

- High and ultra high strength steels

The development of TRIP steels allows considering the manufacturing of many types of complex parts by deep drawing in spite of their high mechanical properties. This steel family has a behavior very similar to the one of DDQ steels. In spite of low anisotropy coefficients, it is possible to deep draw, and some trials on tunnel or bumper reinforcements on TRIP800 steel with our customers were successful.
Today, well-know efficient forming techniques can be used to control springback and wear of tools can be reduced by the use of heat-treatment and if necessary of additional coating.
In the field of the crashworthiness, we could show that the high mechanical properties of these steels confer them excellent performances. It appears clearly that the high rates of work hardening of TRIP steels give them a high capacity of energy absorption.
The Boron steels approach is different from TRIP. The objective is to use steel supplied with very good formability, permitting complex shapes to be obtained without springback trouble, and to have very good in-use properties after hot forming. USINOR has developed a pre-coated version of Boron steel, which associate excellent mechanical properties of the material after the press hardening process with good corrosion protection.

- Steel design solutions

Two steel design solutions for safety parts are presented. The first one shows the advantage of the use of TRIP800 and a hydroforming technique for a crash box instead of using a conventional forming technique.
The second deals with the design of a cross frontal sill with a complex cross section, formed using a profile rolling technique.

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