

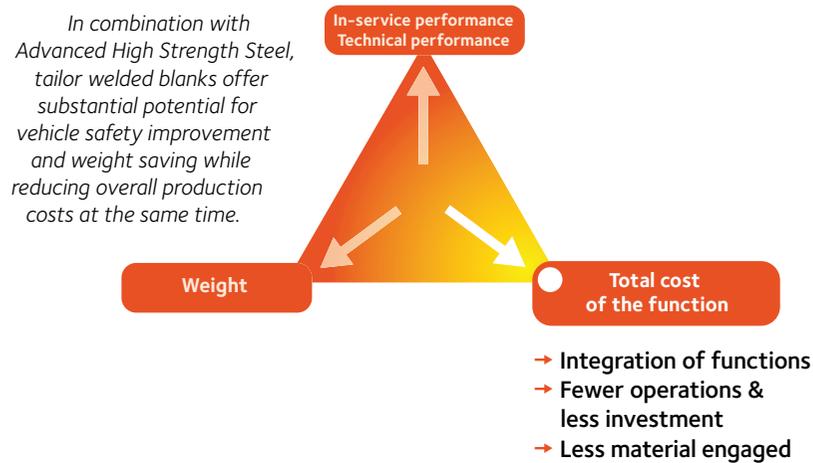
I – Tailored Blanks value proposal

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1. Introduction

Tailor welded blanks together with the Advanced High Strength Steels (AHSS) offer a great potential to increase safety and/or decrease the weight of cars while at the same time reducing their cost. However, cost reduction can also be the main priority itself.

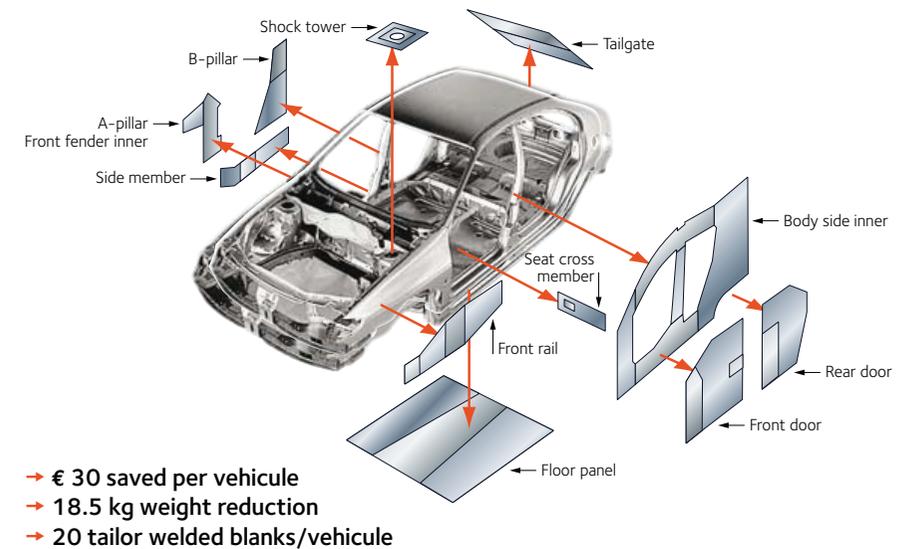
FIG. 1 - The strategy for applying tailor welded blanks will depend on the targets of a given vehicle project



Tailored Blanks has developed a product catalogue of generic parts based on real parts of production vehicles, which gives an estimation of the gains of the different tailor welded blanks applications both from a weight saving and cost saving perspective.

Generally the studies aim at comparing the tailor welded blanks solution with a conventional monolithic post-assembled solution at equal technical performance.

FIG. 2 - Cost reduction package on generic vehicle



Once the strategic priorities of the vehicle are identified, Tailored Blanks can put together a solution package of tailor welded blanks and present a first estimation of achievable gains.

The example above shows a case where cost reduction is the priority. Some more tailor welded blanks could well be introduced to reduce the weight, even at a very reasonable extra cost of about 1€/kg saved, but as we have focused on cost reduction, these solutions have been left out in this case. The performance of these solutions is either better or comparable to the monolithic references.

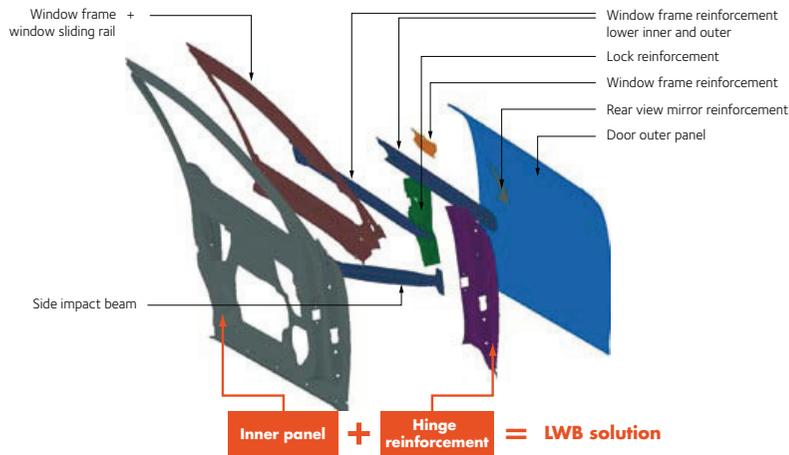
This type of example can serve as a state of the art study in order to discuss ideas at the concept stage of the vehicle. A detailed analysis will then be conducted to confirm the estimations presented.

2. Economical drivers

In order to determine, together with the design departments of the customers, whether a part is suitable as a tailor welded blank or not, Tailored Blanks proposes support for design and cost estimation of the final part. By this approach Tailored Blanks makes sure that the tailor welded blanks meet not only the technical requirements of the customer but also present an economical interest. Therefore ArcelorMittal has developed a model to support decisions in the design phase of the car to determine the final part cost with different solutions. This model is explained more in detail in chapter II - Customer service.

It is important to well define the scope of the study by determining the reinforcements that can be integrated with the tailor welded blanks. In the example that we will follow throughout this chapter, the aim was to integrate the hinge reinforcements of a front door. Normally tailor welded blanks are proposed instead of a post-assembled solution of several stamped parts. As the aim is mostly to obtain the same performance of the tailor welded blank, we can allow ourselves to make a comparative study which enables us to get good results using generic load cases and compare the performance of the two different solutions. In the case of the door we are applying loads on different locations in the upper window frame. The door stiffness is measured through displacements in critical points such as the upper rear corner of the window frame. It is important to limit the deformations in this point in order to prevent wind noise and door sagging.

FIG. 3 - Exploded view of door with illustration of reinforcements



In this example, by integrating the hinge reinforcements with the door, the customer saves one stamping and one assembly operation. This will have positive secondary effects as there will be less tolerance deviations and no overlap for spot welding which would improve corrosion resistance. Furthermore there will be fewer parts to handle which will give cost advantages both from a stock capacity and

a logistical point of view. Fewer parts to stamp means also reduction of stamping tool investments and less space and fewer robots needed for the assembly operations.

The continuous laser weld gives a better stiffness to the overall part as a perfect interaction between the door sheet and the reinforcement is created, compared to the conventional case with the reinforcement being spot-welded to the door panel inner. This enables us to reduce not only the total thickness of the reinforcement area but normally also the door inner panel itself by some 0.05 mm. This is the key to lightweight doors with tailor welded blanks as hinge reinforcement is normally bigger in terms of surface area than the post-assembled solution. A typical mass reduction with doors in tailor welded blank amounts to around 1-2 kg/vehicle.

FIG. 4 - Tailor welded blanks generate less scrap during blanking for a front door inner

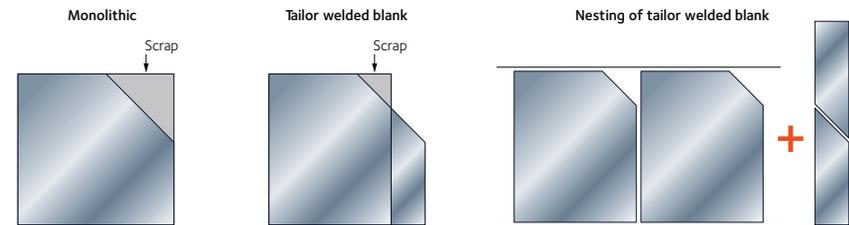
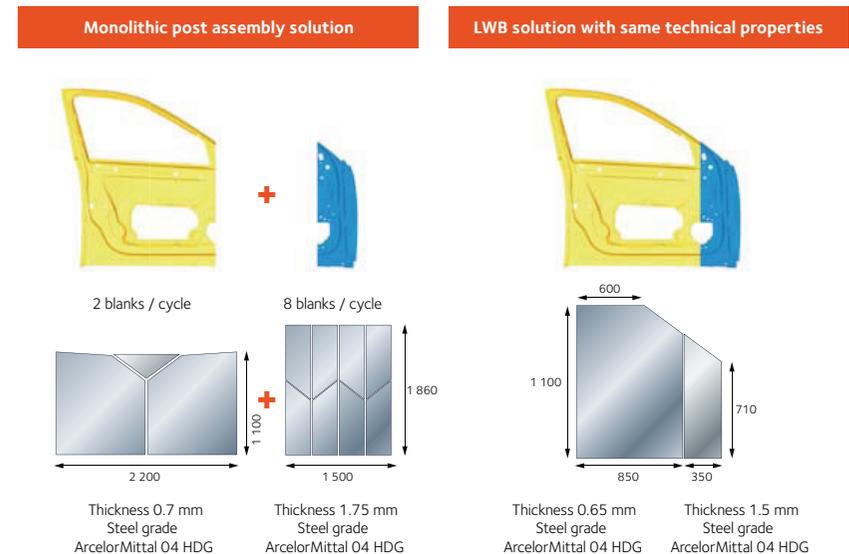
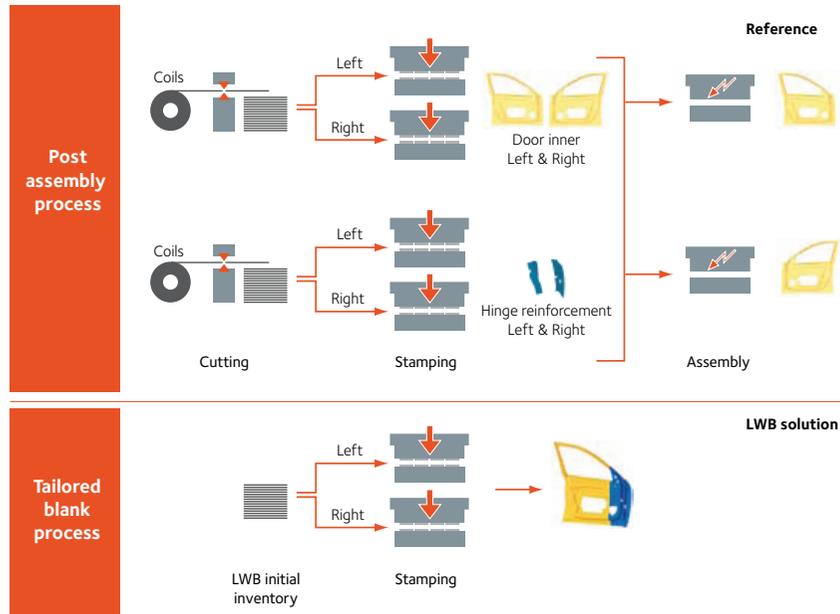


FIG. 5 - Illustration of generic door used in the study and corresponding tailor welded blank geometry



At equal service specifications, the tailor welded blank concept also allows an even bigger saving in material consumption as the nesting can be improved by the fact that the door panel is cut in two. The reinforcement part can be very well nested when two pieces are cut per tool stroke. Similarly, removing the front corner will generate less scrap at the time it is cut from the coil (see Fig. 4)

FIG. 6 - Reduction in the process steps using tailor welded blanks



In the case of a door, the cost of the tailor welded blank itself can be up to 30% more expensive than the cost of the coil material used for a conventional door.

As one blanking operation is avoided, the press operations and the coil stocks for the parts can be completely eliminated. This is estimated to give a gain of about 5-10% of the total cost of the complete part.

The stamping operations which can be avoided account for an additional 10-15% reduction. The big gain is obtained by the fact that the number of assembly operations is reduced. This gives a total reduction of the part price of approximately 20-25%. All in all, the total saving of the finished door will be between 5 and 20% or 1 to 4€/vehicle.

In the example of a front door inner the tailor welded blank allows us to stamp only one part instead of stamping the door panel inner and the reinforcement separately. Two stamping operations and two assembly operations are thus eliminated which has a considerable impact on the total cost of the part, as can be seen in the figure above.

The blanking operations are performed by Tailored Blanks. This reduces the total process time for the customer and shortens the time between cash out and cash in. The working capital needed for the part is thus reduced.

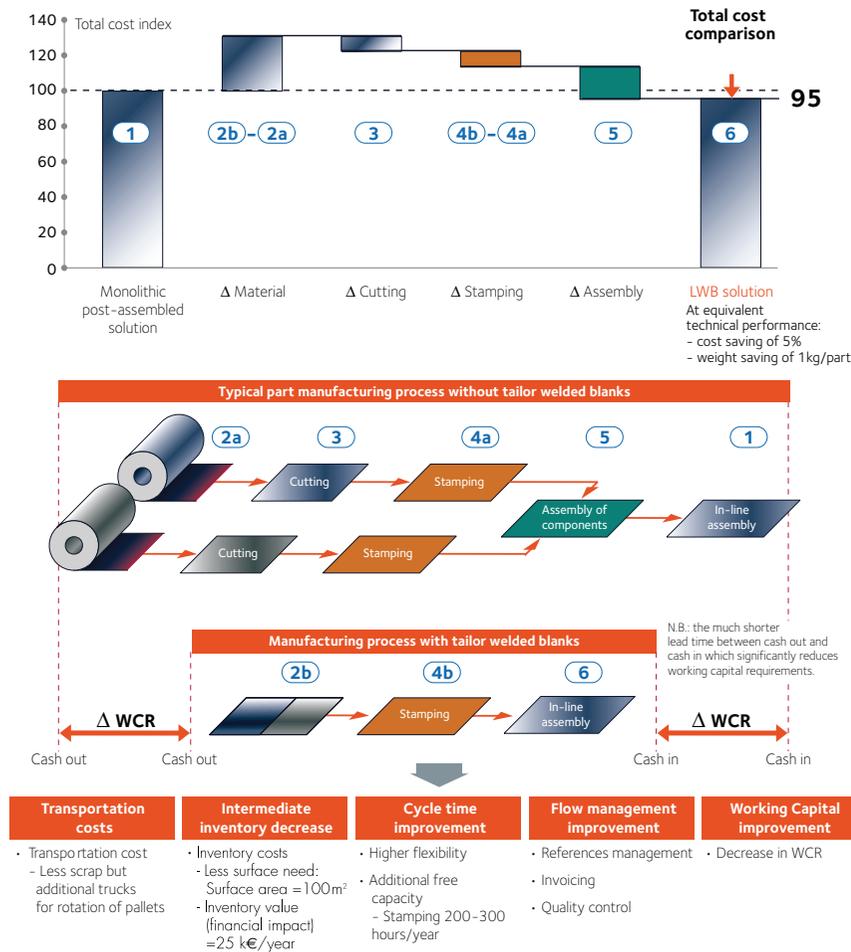
From a logistical point of view the customer will have less parts to handle in his internal logistics. There will be less scrap generated by his processing as the parts are already cut to shape before stamping. Normally the final dimensions are cut to shape after the stamping but in some cases the customer demands the tailor welded blank in the final net shape. In this case, this results in one less stamping operation and thus in reduced investments.

Spot-welded, post-assembled parts subject to corrosion will require a sealing joint to prevent corrosion in the gap between the sheets. The tailored welded blanks solutions do not require this sealing as they are continuously butt-welded. The cost impact of this corrosion protection can be considerable for parts with a large circumference to be sealed (1€ for two front doors).

As there are fewer parts to assemble when using tailor welded blanks, there will also be less deviation in dimensional tolerances. This means reduced finishing costs for re-working.

Furthermore, fewer parts to be handled in the information systems will reduce administrative costs.

FIG. 7 - Total cost comparison between conventional monolithic post-assembled blanks and the tailor welded blank solution



The figure shows the logistical gains and the reduction in working capital required by the tailor welded blank concept as compared to a conventional post-assembled structure of monolithic parts. In this example, the tailor welded blank solution results in a cost saving of 5%.

3. Technical drivers

3.1. Weight reduction

Over the past decades, fuel efficiency and safety as well as environmental concerns have driven the automotive industry to continuously reduce the weight of the body in white of vehicles. The main tasks are to improve fuel efficiency and reduce emissions while improving the overall structure of vehicles for passenger comfort and safety. In order to take the necessary steps to help reduce weight and costs, technical alternatives in materials have been proposed and used for parts in the car body, but none have shown the versatility of steel.

Various grades of steel, such as high strength steels, coated steels and drawing quality grades, continue to offer a greater spectrum of solutions to automotive requirements than any competing material.

The weight of steel versus alternative materials, however, remains an area of concern for product engineering.

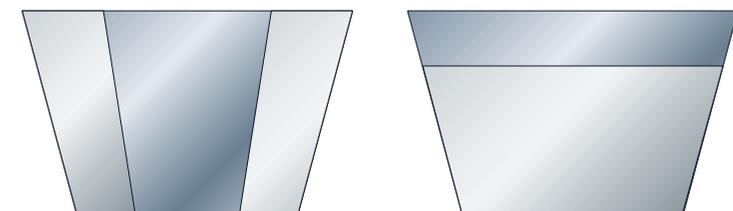
This is why the tailor welded blanks concept, which consists of two or more separate blanks combining the best properties offered by different steel grades, has proven to be an efficient design solution to reduce the weight of the vehicle.

It allows the engineers to “tailor” the blank so that each of the steel’s best attributes – such as thickness, strength, coating, etc. – is located precisely where it is needed within the part. This process not only reduces the weight of the finished part, but it can also be used for part integration, eliminating many reinforcements and stiffeners.

Example of weight reduction in the case of a floor panel:

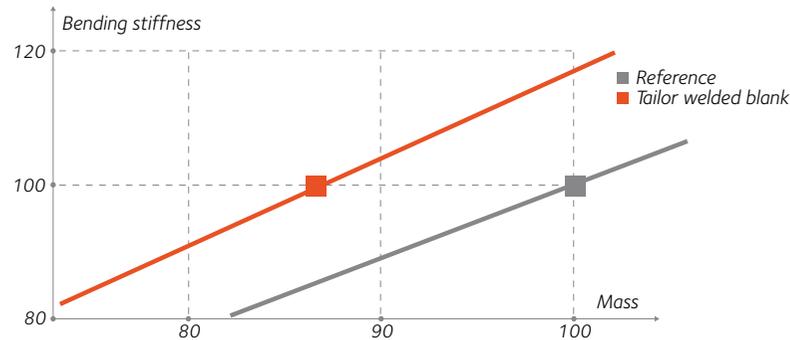
Floor panels in cars are made of tailor welded blanks mainly in order to reduce weight, but also to allow significant cost reduction. Two concepts usually exist depending on the position of the gearbox for rear or front wheel drive. Either the reinforcements are integrated with the tunnel area by means of two longitudinal weld seams in the case of the central panel or they overlap the area of the closing plates for cross members in a rear floor panel by means of one or two transversal weld seams. In another design, the dash panel function can be integrated with a tailor welded blanks solution by using two sub-blanks with a transversal welded seam.

FIG. 8 - Two floor panels in tailor welded blanks of different configurations



The weight saving is not only due to the reduced thickness of the base blank plus the reinforcement, but also to the global thickness reduction of both blanks resulting from the stiffness contribution of the continuous weld. The concept of a tailored welded blank can usually achieve a thickness reduction up to 13% compared to a monolithic post-assembled structure with overlap. In the case of a tailored welded blanks solution for a tunnel with two longitudinal weld seams, the weight reduction on the blank can reach about 17% for the blank and 15% on the finished part. In total, this gives a weight reduction of more than 3 kg/vehicle.

FIG. 9 - Comparison of weight and stiffness of a ULSAB BIW between tailor welded blanks and a conventional monolithic solution

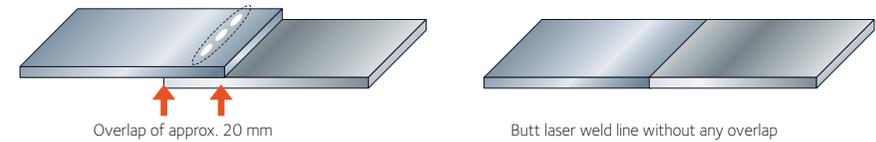


Compared with the reference (basis 100 in weight and bending stiffness), the use of tailor welded blanks results in:

- > 13% weight saving for the same stiffness.
- > 17% increase in bending stiffness for the same weight.

A second contribution of the continuous weld is the fact that the overlap between the blanks, which is needed for spot welding, is not necessary. This offers an additional weight advantage for the laser weld line of about 0.235 kg per weld line (thickness 1.0 mm, overlap 20 mm, weld line 1500 mm) (see Fig. 10).

FIG. 10 - Laser tailored blanks avoid overlapping weld seams



There are still a lot of other parts in the body in white where weight reductions are possible, as for example the body side inner. Studies within ArcelorMittal show an overall weight reduction potential of about 35 kg. However, the weight reduction achieved depends ultimately on the level of function integration and thus early co-engineering.

FIG. 11 - Shock tower



Example of weight reduction in the case of the shock tower: Shock towers in cars are mainly used with a very high thickness or an additional reinforcement on the top of the tower. This area of the part needs to be thick in order to support the high loads induced by the front suspension. Using a patchwork solution for this part not only offers better in-service behavior due to reduced play between the two main parts, but also offers a considerable weight reduction potential of up to 25% (depending on the design of the part). This can result in a weight reduction of about 1.5 kg/vehicle.

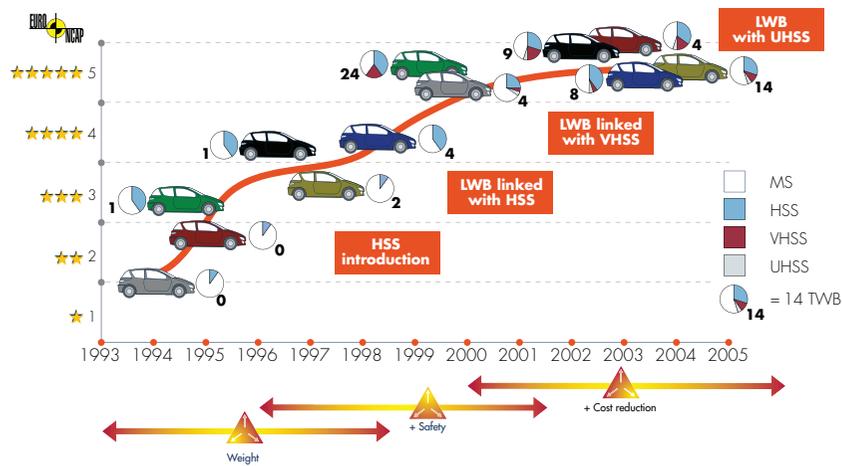
3.2. Safety improvement

Over the last ten years, passive vehicle safety has been an increasingly important criterion and consumer tests are now more demanding than regulatory requirements (EuroNCAP). The tailor welded blank technology and the new Advanced High Strength Steels (AHSS) that have been introduced on the market have enabled automakers to improve passive safety without increasing the mass of the body in white.

A study covering six different vehicles in two successive generations shows that automakers have taken these technologies on board.

A 1997 model vehicle using two tailor welded blanks and some 5% AHSS only received a three-star rating. Its successor, with 14 tailored welded blanks and 45% AHSS, obtained five stars when it was introduced to the market in 2004.

FIG. 12 - Increasing number of laser welded blanks and increasing proportion of AHSS steels plotted against increasing passive safety requirements



Tailored Blanks now offers tailor welded blanks made of Ultra High Strength Steels (UHSS), further increasing the potential for improving safety while reducing vehicle mass. More UHSS steels can be employed when tailor welded blanks are used instead of monolithic post-assembled solutions in the following cases:

- > UHSS steels used in areas where formability requirements are not too stringent and more formable steels can be used in more complex areas such as the underbody assembly of a B-pillar, which requires high formability.
- > UHSS grades and optimized thicknesses in parts subjected to different local loads (longitudinal beam at the bottom of the underbody, subjected to high loading only in the front part).
- > UHSS steels welded to HSS or stamping quality steels to manage crash energy (front and rear longitudinal beam).

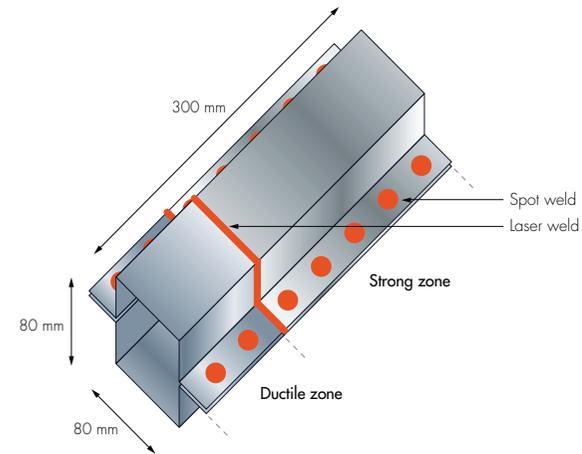
3.2.1. Crash resistance of longitudinal beams made of tailor welded blanks

To assess the advantages of using tailor welded blanks in structural parts, crash tests were carried out on double omega type spot-welded samples taken as representative of longitudinal-beam type safety parts (Fig. 13). The length of the samples was set at 300 mm in all cases. Tests carried out at average speed (24 kph) were performed by means of a drop hammer, while tests at high speed (56 kph) were carried out by means of a pneumatic catapult.

A variety of assemblies were tested; materials were selected in such a way as to assess the relative effects of thicknesses and mechanical properties.

The longitudinal beams tested were assemblies of two materials. A definition of the “ductile zone” concept will facilitate understanding of the test descriptions given below: the ductile zone is that part of the longitudinal beam which is made of the material with either the lowest thickness or - at equivalent thickness - the lowest mechanical strength, with the rest of the beam making up the “strong zone”.

FIG. 13 - Double omega longitudinal beam



3.2.2. Crash test analysis

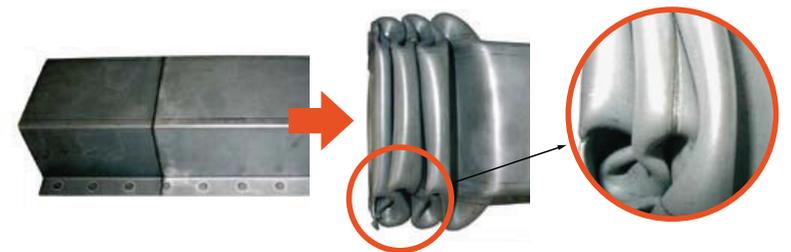
In this type of test, the focus is on three criteria:

- > **Overall buckling resistance:** the regularity of fold pattern ensures that the risk of global buckling is considerably reduced.
- > **Energy absorption:** this is the main purpose of these parts. Consequently, average force - which is multiplied by crushing strain to compute the theoretical energy absorbed - is a key finding. The initial peak force, taken as the maximum force to which the structure is subjected, is a crucial variable in structural part design.
- > **Mechanical strength of joints:** joint failure and metal tearing can lead to overall buckling of the structure.

3.2.3. Welded longitudinal beam crushing process

In butt-welded structures, the crushing process is perfectly sequential (see Fig. 14).

FIG. 14 - Crushing of butt-welded longitudinal beams



The ductile zone is the zone that is crushed first. A fold forms and it is then crushed until a second fold forms, and so on. Only when the entire ductile zone has been crushed does the strong zone begin in turn to absorb the remaining energy.

3.2.4. Overall buckling resistance

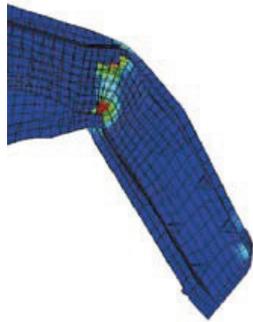
Since the welded beam behaves like two independent beams that are separately subjected to impact, the buckling length of the part is reduced when tailor welded blanks are used. Consequently, reducing part buckling length considerably reduces the risk of plastification nodes.

In fact, butt-welded longitudinal beams exhibit very stable crushing behavior, thus limiting the overall buckling phenomenon. This is a major advantage of the technology.

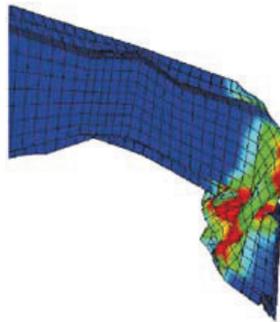
The purpose of the tailor welded blank is to avoid overall buckling. This means that the mechanical characteristics and, more importantly, the thicknesses of the longitudinal beam can be optimized, which in turn optimizes energy absorption.

FIG. 15

Conventional monolithic post-assembled longitudinal beam: overall buckling



Tailor welded blank beam: crushing is limited and stable in the ductile zone, thus reducing overall buckling



3.2.5. Mechanical strength of welds in extreme conditions

To assess the strength of the laser weld under extreme conditions, tests were carried out on a variety of cold rolled steel assemblies at 56 kph. Whatever the configuration, there is no failure of the weld or even cracks in the base metal in the vicinity of the weld, especially within the folds that undergo severe expansion deformation.

These tests demonstrate that the presence of a laser weld within a safety structure does not entail any particular risk of tearing under current crash test standards.

3.2.6. Specific roles of the laser weld

To determine the influence of the laser weld, we crash-tested welded longitudinal beams with the same material on both sides of the weld. We compared the results with those obtained in tests of monolithic beams made of the same material.

Two points should be noted:

- > **The presence of the weld** stiffens the beam and thus increases its resistance to elastic buckling. This gives it better stability and thus enables it to form more folds and absorb a larger amount of energy.
- > **The position of the weld** does not modify the average crushing force because the differences noted in peak force entail a very small difference in energy absorbed. Conversely, if the weld is in the fold, there is a local increase in force in the order of 10%.

3.2.7. Key ideas to be noted

- > Passive safety applications are particularly suitable for tailor welded blanks.
- > Tailor welded blanks make it possible to reduce the risk of overall buckling of structures and to achieve optimum energy absorption. Figure 15 illustrates this aspect.
- > It is thereby possible to eliminate certain stiffeners and to substantially reduce structure weight.
- > To obtain the “tailor welded blank” benefit, it is essential that the assemblies are made up of materials of sufficiently differentiated grades and thicknesses.
- > When this is the case, welded structures behave as independent parts.
- > No problem of laser weld strength in extreme conditions was detected.

In the chapter on applications a detailed example is given of a rail that shows a 17% potential for light weighting by using tailor welded blanks and AHSS steels with the same intrusion values as the monolithic steel reference part.

The tailor welded blank technology, when used in conjunction with steels of even higher mechanical strength, holds out major prospects for achieving optimum trade-offs between a high degree of passive safety and mass savings.

4. Innovative tailored blanks solutions

4.1. Advanced High Strength Steels (AHSS)

To improve the crash resistance even further and reduce the weight, ArcelorMittal today offers tailor welded blanks in combination with the full range of Advanced High Strength Steels (AHSS).

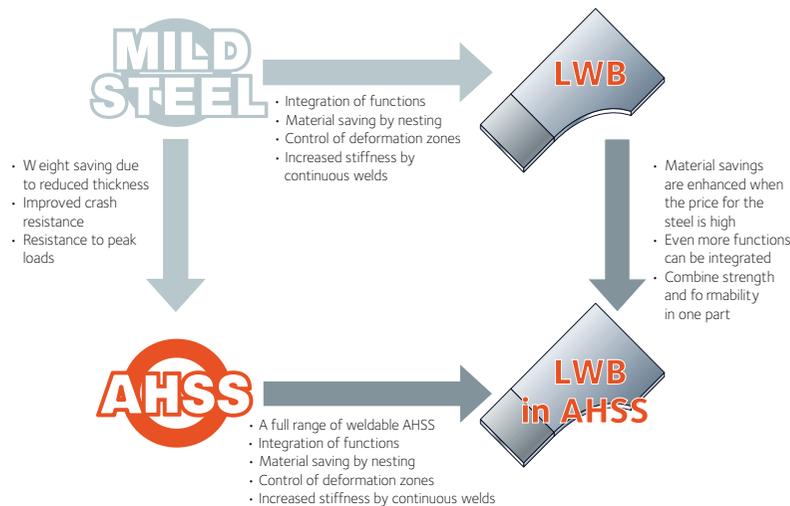
With an increased competition on the automotive market, new solutions must be provided at no or very limited extra cost.

Tailor welded blanks present in most cases an economical advantage as they allow integration of local reinforcements. Thus the number of parts to be stamped and later on assembled is reduced, which leads to lower overall costs and fewer dimensional tolerance deviations. In parts with complex geometry such as body sides or wheel houses, the scrap optimization alone often justifies the use of tailor welded blanks. In safety parts such as rails or pillars the use of tailor welded blanks allows to localize deformations in case of crash to predefined zones where the intrusion presents the lowest danger to the passengers.

The same arguments that are used for tailor welded blanks as compared to conventional solutions for mild steels are valid for AHSS. In fact, the more expensive the steel, the more advantageous it is to find an efficient nesting solution that reduces the material engaged to produce the part or the more important it is to use the high strength grades only where it is necessary. A tailor welded blank with AHSS and drawing steels allows for instance to combine the strength necessary in the middle with the formability requirements in the upper and lower parts of a B-pillar.

The tailor welded blanks solution even offers a third advantage of reducing cost because of lower engaged material and function integration.

FIG. 16 - Potential optimization for parts by using the tailor welded blank concept



The most recent evolution in car body design is combining both levers and making tailor welded blanks in AHSS (see Fig.16).

- > (see 4-field matrix clockwise) The cost advantages of tailor welded blanks become even more advantageous by using AHSS. Material nesting becomes more important with increasing material prices and AHSS allows more function integration.
- > (see 4-field matrix counter clockwise) ArcelorMittal offers today a wide range of AHSS. The same advantages known for tailor welded blanks in mild steel can be enhanced by using AHSS.

ArcelorMittal has developed a range of AHSS that can be laser welded without any additional heat treatments. This is important as it allows an efficient production of tailor welded blanks without significant increase in cycle times that have a direct influence on the production cost. The aim has in the first place been to provide weldable grades at each strength level of product families of Dual phase, TRIP and Multiphase.

Ericksen, longitudinal tensile and U-bending tests have been performed to confirm the weldability of these grades. The characteristics of the tests are described more in detail in the feasibility studies in chapter II.

The figure below shows the actual weldability of different grade combinations.

FIG. 17 - Weldability of AHSS grade combinations (Industrially available)

DDQ / HSS <450MPa	Level	Multiphase			Dualphase			TRIP		Ductibor	Usibor	
		<450	450	600	800/1000	450	600	800/1000	700	800	500	1500
Multi phase	< 450	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	450	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	600	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Dual phase	800/1000	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	450	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	600	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
TRIP	800/1000	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	450	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Ductibor*	600	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	700	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Usibor*	800	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	500	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Usibor*	1500	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
	1500	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green

■ Fulfill all conventional technical requirements
■ Dedicated ArcelorMittal Tailored Blanks process required

4.2. Usibor® 1500P and Ductibor® 500P – Innovative Hot-Stamped Laser Welded Blank Solutions for weight savings and improved crashworthiness

Usibor®1 500P based laser-welded blanks (LWB) appear as an innovative optimal solution for crash management, as it combines the advantages of both hot-stamped steels and tailored-blanks technology. Today, in combination with Usibor®1 500P, a brand new steel called Ductibor® 500P has been designed for the most demanding energy absorption areas. It is then possible to tremendously widen the number of applications for hot-stamped LWB parts.

The combination of press hardened steel (PHS) and LWB technology is a great opportunity to develop numerous parts taking benefits from both concepts:

- > On one hand, Usibor® 1500P as a press hardened steel fulfils two main functionalities: weight saving and safety improvement. Thanks to its outstanding mechanical properties after hot stamping, weight reduction up to 50% can be reached when compared with an High Strength Steel
- > On the other hand, LWB technology offers another substantial potential for weight saving, vehicle safety improvement while reducing overall productions costs at the same time, thanks to: parts integration, blanking, stamping and post-assembling operations reduction and better material consumption with improved sub-blanks cutting lay-outs

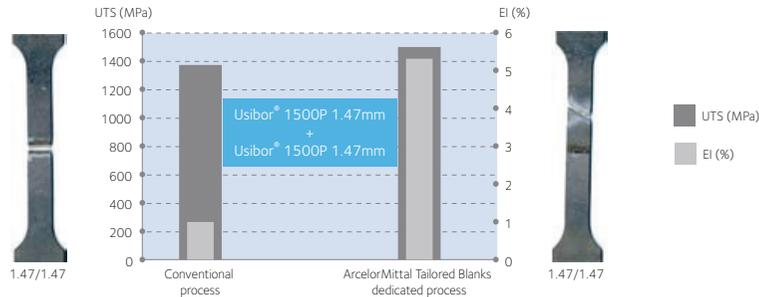
4.2.1. A dedicated welding process

Laser welding of Usibor® 1500P and Ductibor® 500P – which are both aluminium-silicon (AlSi) coated products – requires specific care to reach optimum performances. Indeed, with a standard welding process, AlSi coating dilution occurs in molten zone leading to creation of intermetallic phases and modification of cooling diagrams in that area: the in-use properties of the LWB can be strongly degraded.

In this context, a dedicated process has been developed to allow a full and safe use of coated PHS-based LWB for crash applications: then after hot-forming the part is fully functional (fulfilling all customer specifications such as minimum strength and elongation in the various areas), with high energy absorption capabilities and no failure in the weld.

As the Laser seam never appears to be the weakest point, design can be carried out the same way as for the regular cold stamped LWB. This dedicated process has also been designed to keep long term properties like corrosion behavior close to the weld line at an optimal level.

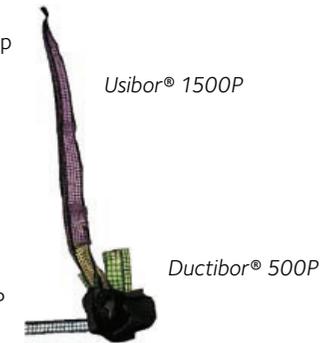
FIG. 18 – Comparison between conventional and Noble dedicated welding process for Usibor® 1500P based LWB



Objectives of both technological and product developments in the field of hot-stamped LaserWelded Blanks jointly carried out by ArcelorMittal and Tailored Blanks was to be able to deliver innovative, fully functional and reliable solutions that will especially fulfil their strong expectations in terms of weight savings for BIW structural applications, without cost penalty.

4.2.2. Ductibor® 500P: a complementary material for a complete PHS-based LWB tool kit

In order to increase the number of applications for PHS-based LWB there was a need to develop a new steel grade, for the most demanding energy absorption areas. The principal development targets for this PHS were to offer a relatively high level of maximum elongation and mechanical characteristics on the parts, while guarantying the necessary robustness of mechanical properties obtained after hot-stamping.

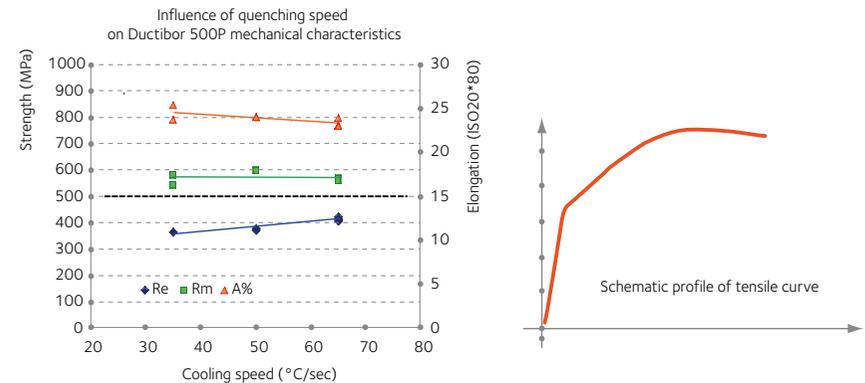


The successful development of Ductibor® 500P allows designers to consider all types of crash related parts, even the most demanding ones in terms of energy absorption capabilities such as front or rear rails.

The illustration on the right side presents the behavior of a B-pillar reinforcement made out of Usibor® 1500P and Ductibor® 500P, during a side impact. The lower area made out of Ductibor® 500P will deform in a fully controlled manner ensuring the right crash management and the necessary energy absorption.

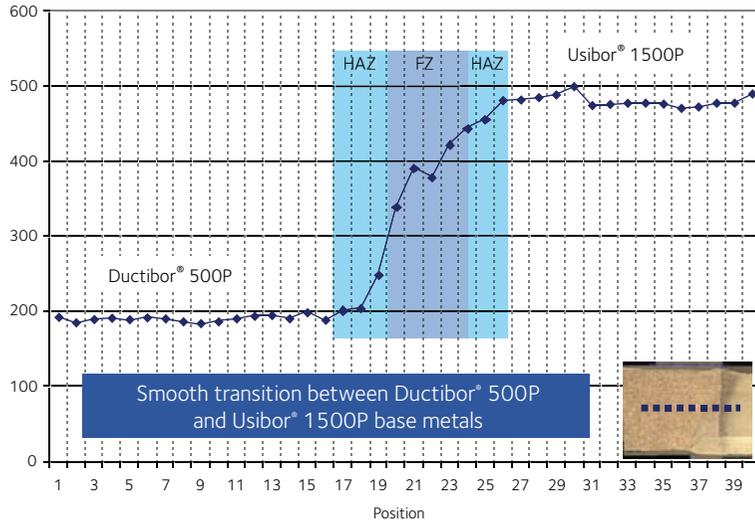
The principal development targets for this PHS were to offer a relatively high level of maximum elongation and mechanical characteristics on the parts, while guarantying the necessary robustness of mechanical properties obtained after hot-stamping as seen on figure below (flow curve is also presented):

FIG. 19 – Influence of quenching speed on Ductibor® 500P mechanical characteristics obtained after hot stamping



Thanks to lower carbon content of Ductibor® 500P, dilution occurs in molten zone during welding: this area ensures a smooth transition zone between the two blanks as shown on the figure below.

FIG. 20- Hardness profile for Usibor®1500P / Ductibor® 500P LWB

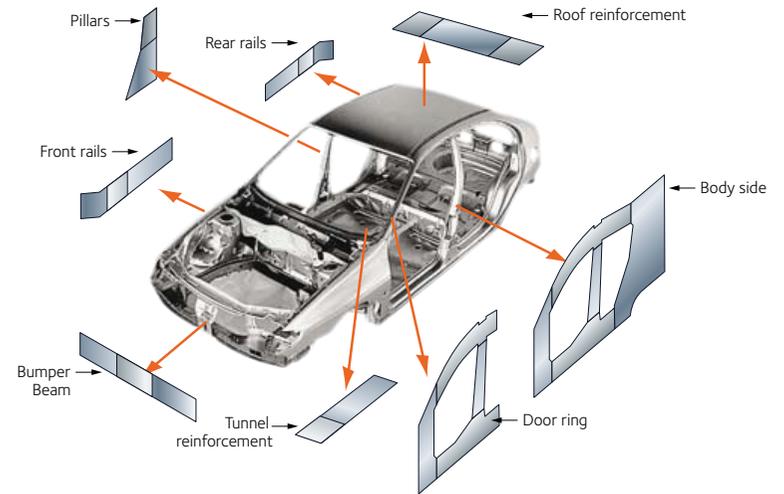


Ductibor® 500P offers the same robustness regarding hot-stamping process parameters as the one already known for Usibor® 1500P.

Analyzing a body in white (BIW), various parts appear to be good candidates to get benefits from PHS-based LWB solutions. Potential applications are composed of some typical PHS monolithic parts as B-pillars and new parts, especially front and rear rails that have never been hot stamped.

For those parts, energy absorption by plastic deformation in limited area requirement – already existing in the lower area of B-pillar – is even more a critical issue. This is now possible thanks to the new PHS Ductibor® 500P and its elongation capabilities. The combination of this material with Usibor® 1500P in a LWB concept allows an enlargement of hot-stamped applications.

FIG. 21 - Potential Laser Welded Blank applications made out of Usibor® 1500P and Ductibor® 500P



Rear rail case study

For this proposal the objective is weight reduction. The most part of the rail is made-out of coated-PHS with a rear area made-out of Ductibor® 500P for energy absorption during the crash

FIG. 22 - Comparison between conventional and innovative Usibor® 1500P / Ductibor® 500P LWB solutions for a rear rail

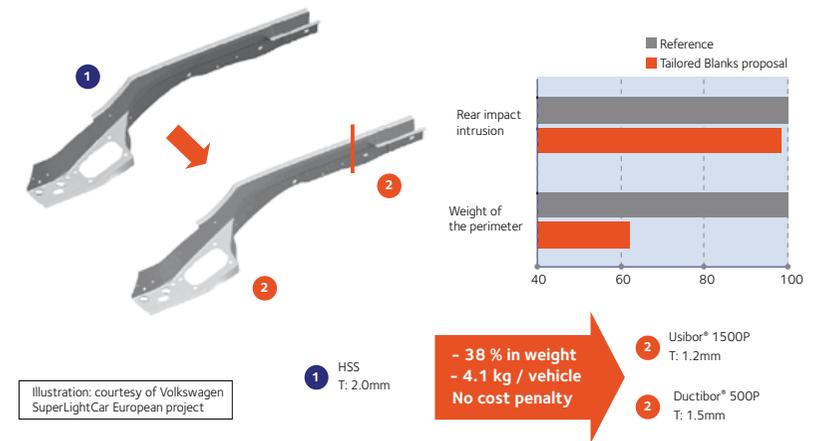


Illustration: courtesy of Volkswagen SuperLightCar European project

4.2.3. Crash resistance of Usibor® 1500P / Ductibor® 500P LWB solutions

Usibor® 1500P / Ductibor® 500P based innovative LWB solutions have been fully characterised in order to validate their functional behavior, and make available towards our customers all necessary information for them to be able to consider implementation either in a pre-project or car project phase.

FIG. 23 - Characterisation of crash resistance of Usibor® 1500P / Ductibor® 500P LWB solutions either in flexion (left hand side) or in compression (right hand side)



Crash tests on various shapes for Usibor® 1500P / Ductibor® 500P LWB showed:

- >No failure in the weld during crush @16m/s
- >Good stability of the structure
- >Ductibor® 500P deforms: energy absorption
- >Usibor® 1500P does not deform: anti-intrusion
- >Ductibor® 500P exhibit energy absorption performances similar to a DualPhase 600

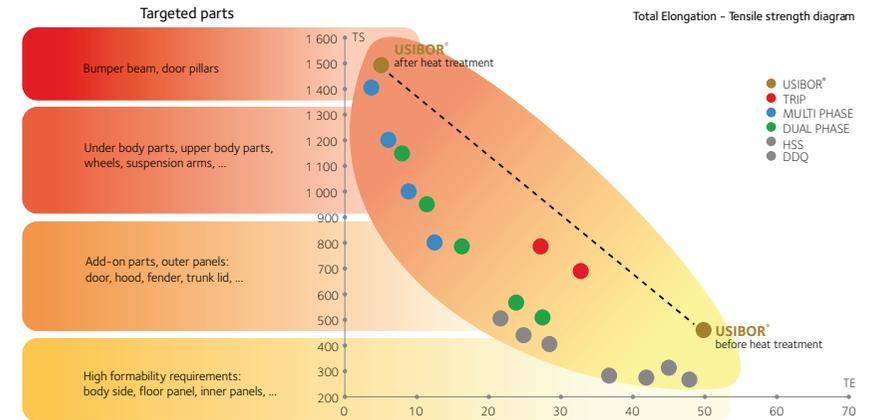
In addition, all kind of mechanical characterisations (such as high-speed tensile tests, Hopkinson bars...) have been carried out on Ductibor® 500P so that complete datasheet and material card are available for designers, to especially implement them into Crash code for numerical simulation

The Usibor® 1500P / Ductibor® 500P LWB is an advanced and robust concept for both pillar and rail applications, fully functional, with all necessary data available. It is a powerful tool for BIW optimisation in terms of weight, performance and cost all together.

5. Steel grades for applications

ArcelorMittal has a wide range of steel grades that allow the design engineer to choose the steel grade with the most appropriate strength and formability properties to meet the requirements of the application. The tailor welded blanks give further freedom to the design engineer who will be able to fine tune the properties not only on the part level but also between different zones in the same part.

FIG. 24 - Product range of ArcelorMittal Auto and proposals for applications



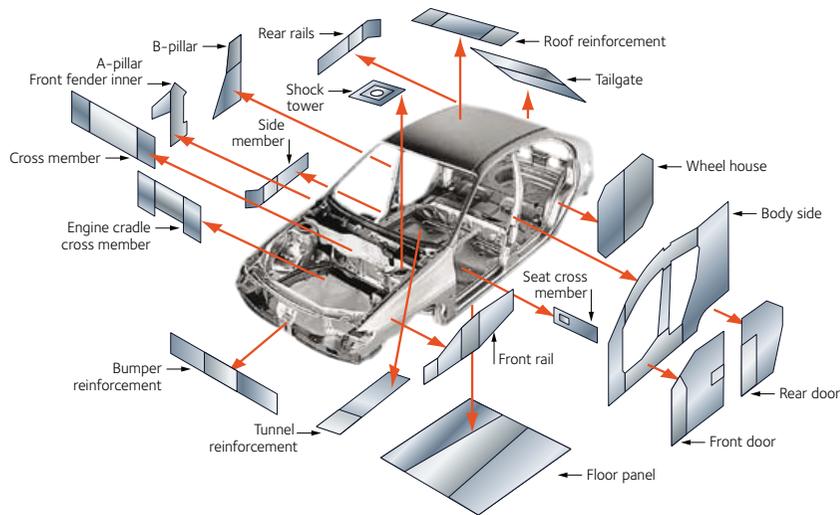
6. Applications

Tailor welded blanks are used in a multitude of applications in the automotive industry. The most common are mentioned in Figure 25 and will be described in this chapter. Many of the applications, for example B-pillars, can be used both as reinforcements or as closing plates.

The descriptions aim at giving the design engineers ideas that can be further discussed with the development engineers of Tailored Blanks.

Tailored Blanks has developed business cases for all these applications in order to demonstrate the economical benefit.

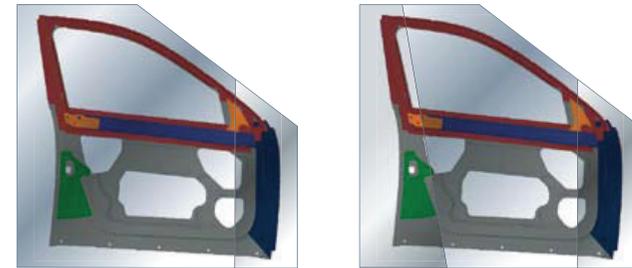
FIG. 25 - The most common applications for tailor welded blanks



6.1. Doors

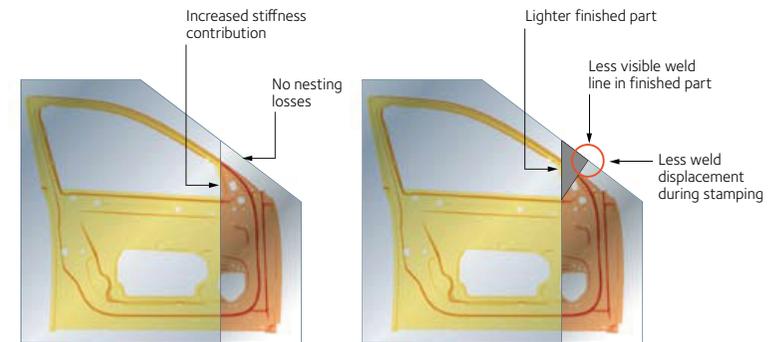
The main driver for using tailor welded blanks in doors is cost saving even though some weight reduction is often possible as well. By integrating the hinges reinforcement a considerable cost saving is possible. Sometimes it is also possible to integrate reinforcements for mirror, lock, anti intrusion beams and window frame stiffeners.

FIG. 26 - Two different tailor welded blanks configurations to integrate various reinforcement of the door inner



Tailor welded blanks are used for front as well as rear doors. For front doors both linear and non-linear tailor welded blanks are common.

FIG. 27 - Left: front door inner with linear weld, right: front door inner with non-linear weld



Advantages with a linear weld:	Advantages with a non-linear weld:
<ul style="list-style-type: none"> > Lower cost of the tailor welded blanks. > Stiffness contribution to the upper window frame. 	<ul style="list-style-type: none"> > Weld line less visible. > Less weight of the finished part. > Water tightness. > Stamping feasibility as the weld line is perpendicular to the edge of the tailor welded blank and thus aligned with the material flow during stamping.

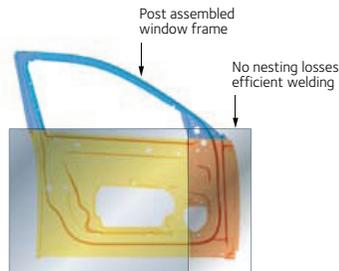
For rear doors it is common to use non-linear welds as the reinforcement can be limited to the lower area of the door where the hinges are located. The rear door is also much higher in the area of the hinges than a front door and the cost impact of an extended reinforcement is therefore more important. There is also less potential to integrate other reinforcements.

FIG. 28 - Typical rear door blank



Sash doors are made by linear tailor welded blanks and are often stamped in pairs. This is a cost efficient solution from the tailor welded blanks point of view as the nesting is simple and the weld cycle is often easy to optimize.

FIG. 29 - Sash door blank



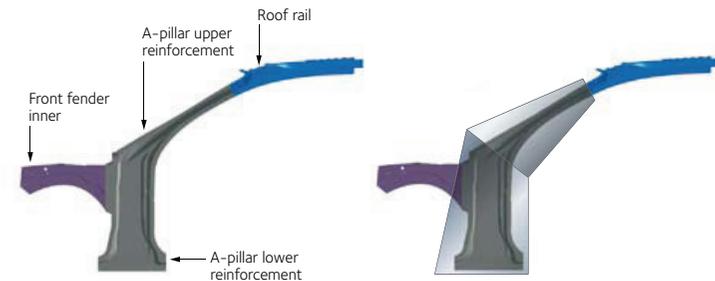
The most common solution is one weld door but in some cases a tailor welded blank composed of three blanks is used in order to stiffen also the rear area of the door (see Fig. 25). This is the case when reinforcements are needed along the rear side of the door. Another way is to integrate only the lock reinforcement by means of a local patchwork which is spot-welded on the laser welded blank. This is a weight and cost efficient solution as another stamped part is removed.

The weight of the door can be reduced despite the bigger reinforced area than in the monolithic post-assembled case. This is possible as there is a continuous weld between the reinforcement and the door sheet. This weld gives a stiffness contribution as the interaction between the two parts becomes perfect and the door sheet thickness can thus be reduced.

6.2. Pillars

Both A- and B-pillar can be made of tailor welded blanks. In the case of A-pillars, the main driver is the cost, as tailor welded blanks allow the combination of efficient nestings on one hand and few stamping operations on the other. In order to stamp as few parts as possible, the A-pillar lower can be welded to either the A-pillar upper or to the front fender. Such a part as a monolithic blank is expensive as material yield would be far too low (see also front fender application in Fig. 32).

FIG. 30 - A-pillar lower and upper



Tailor welded blanks for B-pillars are a cost efficient way to obtain a good crash management. Crash management means localizing deformations to areas where they do not put the drivers or the passengers in danger as well as reducing the deformation speed. Deformations are necessary to absorb energy and in the case of a B-pillar the idea is to create a deformation node in the bottom of the pillar where the intrusion will not have lethal consequences. In this case the idea is to reduce the overall intrusion depth to avoid severe injuries. The maximum intrusion should be localized below the pelvic zone and at a minimum speed (see Fig. 31).

FIG. 31 - Monolithic and tailor welded blank deformation zones of a B-pillar



Strains are localized at the bottom part of B-pillar, in the Ductibor® 500P area.

The crash management is achieved through a reinforcement in the case of monolithic post-assembled solution. The most cost efficient tailor welded blank solutions are those where both the material thickness and the grades are varied and it can be managed to avoid an additional reinforcement.

The central part of the B-pillar is made of a thick plate with very high strength to provide a stiff part with limited deformations. The upper and lower part will be subjected to difficult stamping requirements. Hence, for these parts a softer grade that meets these requirements is chosen.

Current car generations have B-pillars made of hot-stamped parts. This is perfectly compatible with the recent evolution of tailor welded blanks technology. The stiff central part is in this case made of Usibor® 1500P, an aluminized boron steel with a tensile strength of 1500 MPa, and the lower part is made of the softer Ductibor® 500P material that allows the creation of a plastic hinge in case of crash. The Ductibor® 500P material is a microalloyed steel that preserves well its properties after the hotstamping. The Ductibor® 500P material is of course aluminized in order to avoid shot blasting of the finished part which is both costly and detrimental for the dimensional tolerances.

The tailor welded blanks shape will depend on the number of parts to be produced. For low volume cars (< 50 kv/yr) it is important to keep the investments low. In this case it is favourable to make simple shapes like rectangular or trapezoidal blanks. This will generate some more scrap than optimized cut-to-shape blanks but as the volume is low, the higher material consumption will be less costly than the tool investment. For big runners on the other hand, the tool cost per part is low and we need to make the most efficient nesting as possible in order to minimize the material consumption (see also the chapter on nesting).

The elimination of the overlap for spot welding eliminates a moisture trap and also reduces the weight of the part. A differentiation of the coating is possible as the corrosion resistance requirements are more severe in the lower area.

6.3. Front fender inner

Tailor welded blanks for front fenders allow weight saving as the thickness of the part can be differentiated. If the part participates in the crash management, which is especially advantageous for small vehicles where the space for front module is limited, it may be useful to vary the grades as well. In this case, the front part will be used as a deformation zone exactly as in the case of the rails, and will probably be in a thicker sheet to provide stiffness in the anti-intrusion area of the front structure.

Furthermore, the front fender can also be combined with the A-pillar. This is particularly interesting for small vehicles where the parts can be combined in one tailor welded blank without penalizing the cost due to unefficient nestings that would be the case without tailor welded blanks.

FIG. 32 - Front fender inner (example of design)



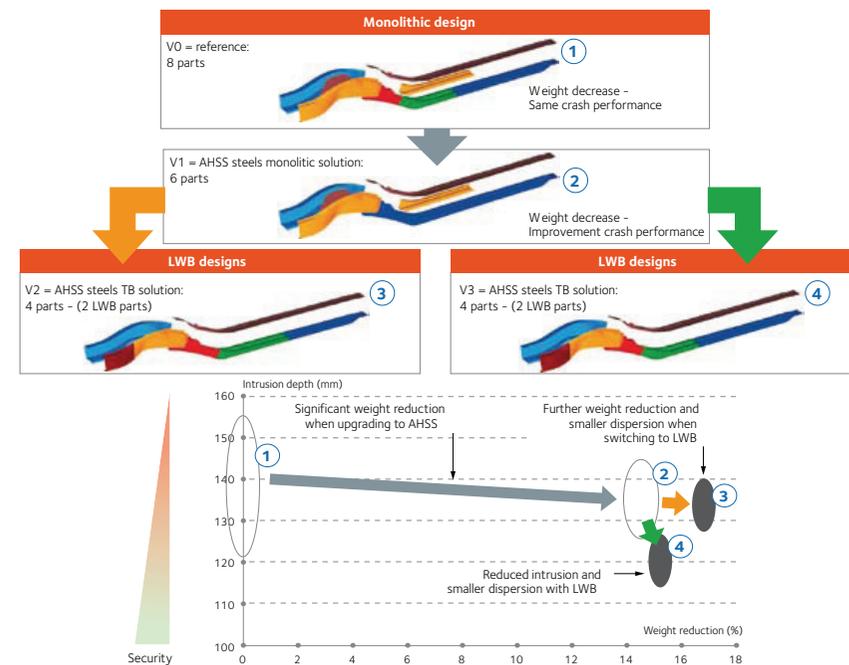
6.4. Rails and side members

Rail structures are a very common tailor welded blank application as the variation of grade and thickness allows a very cost efficient crash management.

Both front and rear rails and also closing plates are made in tailor welded blanks in order to have consistency between the parts. A big advantage with tailor welded blanks in crash parts is the robustness of the solution. As the parts are butt-welded to each other, the load transfer will be made butt to butt and not by means of shearing of spot-welds. Any dimensional deviation of a spot-welded assembly may also give variations to the behavior of the part. Furthermore, the laser butt-welded solution is more robust as the angle of the load may vary.

Tailor welded blanks are also used to reduce the number of parts in the rail structure (see Fig. 33). This will give shorter tolerance chains and a better reproducibility of the rail structure geometry.

FIG. 33 - Picture of generic rail structure with 8 parts for monolithic and 4 for tailor welded blanks Diagram showing the intrusion depth in the area of the dash panel according to the weight of the rail for the different solutions



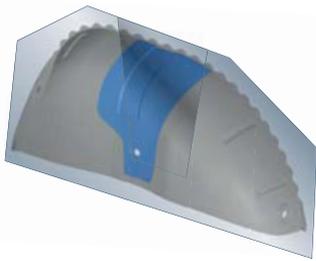
As there is no overlap between the parts, the weight of the part is reduced and the corrosion resistance is improved. The rail consists of a deformation zone where the intrusion is used to absorb energy. In this area a relatively softer grade (TS = 600 MPa) will be used with a limited thickness. Behind the deformation zone there will be a stiffer zone made of steel with a tensile strength in the range of 800 -1000 MPa and a higher thickness to transfer the loads through the car and absorb energy of high speed crash to avoid intrusion in passenger compartment.

Rear rails and closing plates are often stamped in two parts (left and right) per stroke to reduce cost.

6.5. Rear wheel house

Wheel houses are often made of tailor welded blanks to integrate the suspension reinforcement for the rear wheel. This allows the car maker to save one part which leads to gains in stamping, assembly, sealing, logistics and parts administration. The reinforced part can be made of High Strength Steel, which is normally not needed for the rest of the wheel house. By this approach the steel cost is kept to a minimum and the steel grades can be optimized in each area depending on its forming requirements.

FIG. 34 - Wheel house with suspension reinforcement integration



Tailor welded blanks in wheel houses allow weight savings thanks to the continuous weld that gives a perfect interaction between the reinforcement and the wheel house sheet. This keeps the total thickness down to a minimum for all parts of the wheel house and thus the total part weight can be optimized.

Wheel houses are often stamped in two parts (left and right) per stroke. Nesting of monolithic wheel houses for high volumes cars where the engaged material should be kept as low as possible can sometimes be quite difficult.

When cost is the main driver, the wheel house can be conceived as a patch solution. By adding the reinforcement to the wheel house before the stamping, the complete part can be stamped in one operation avoiding a separate stamping operation for the reinforcement and the subsequent assembly of the two parts.

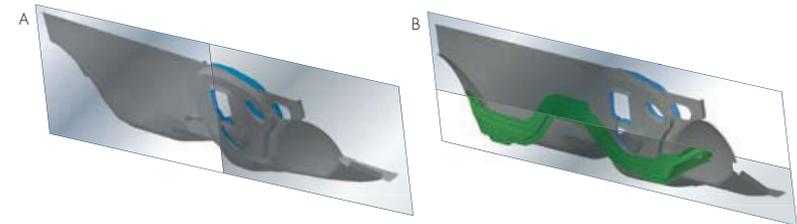
6.6. Dash panel

The aim of the tailor welded blanks is to integrate the reinforcements for the pedals and in some cases the closing plate for one of the cross members that supports the part. The main driver of the tailor welded blank solution is to reduce cost as the number of parts to be stamped is reduced with less assembly cost as a subsequent benefit.

The continuous weld enables thickness reductions as the interaction between the parts is perfect. However, the reinforcements often become big if the welding costs should be kept reasonable which limits the weight reduction potential of the application.

If weight is a major concern it may be interesting to explore a patchwork solution that will also give a cost benefit as the number of stamping and assembly operations is reduced.

FIG. 35 - Dash panel with pedal reinforcements integration (A) and with integration of cross member closing plate (B)



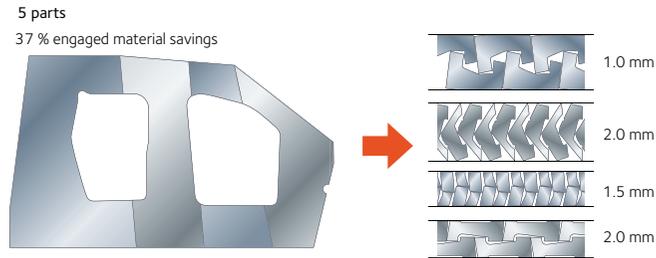
6.7. Body side inner

The tailor welded blanks concept has an important cost saving potential for body side inners. For a body side, a number of parts such as A-pillar lower and upper, B-pillar, roof rail, sill and the C-pillar, can be replaced by one single large tailor welded blank. As the part can be cut up into small subblanks, the nesting will be as good as in the monolithic post-assembled case. In fact the weight can be even further reduced as the overlaps for spot welding can be removed and the continuous weld lines give a perfect interaction between the parts. Furthermore, thickness reductions may even be possible.

The cost saving potential is huge as the number of stamping- and assembly operations is considerably reduced. The thickness and the grades of the various parts are differentiated to give the same performance as for post-assembled, monolithic parts.

There are often as many as six welds in a body side inner and the part is produced efficiently on non-linear machines. With Tailored Blanks technology, all welds are produced in one weld cycle in order to get closer dimensional tolerances which is a prerequisite for good weld quality and in order to keep the costs low.

FIG. 36 - Example of body side with nesting solution



6.8. Body side outer

Body side outers in tailor welded blanks present both weight and cost advantages if conceived in the right way. The tailor welded blanks allow the use of non-exposed Extragal™ sheet where the body side is not visible behind the doors in the B-pillar and A-pillar and in the sill where a weld can be accepted. This gives the benefit of the cost difference between exposed and non-exposed Extragal™ for more than half of the body side panel.

The yield of a body side panel is normally around 20-40 %. If cut up into sub-blanks this yield rate can be increased considerably (up to 60 %) which will reduce the cost of the engaged material. By varying the thickness of the body side, we can furthermore integrate A- and B-pillar reinforcements in the body side outer in order to work with a two layers pillar instead of three parts.

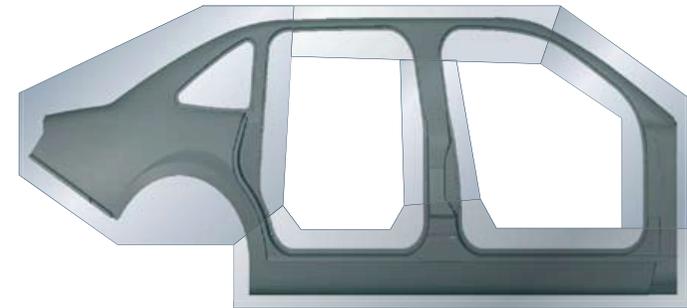
A key to reduce the engaged material is to be able to cover welds somewhere along the roof rail. This is traditionally made with wrap over doors. The weld seam is then only visible as the door is open which has been considered acceptable given the gains provided by this concept.

FIG. 37 - Detail of wrap over door covering weld seam



In the ArcelorMittal Body Concept car from ArcelorMittal Auto, a weld seam is hidden by a cover plate on the C-pillar and by the fender in the front which is another possibility of achieving a high esthetic value of the body side outer.

FIG. 38 - Nesting based on ULASAB if wrap doors are used



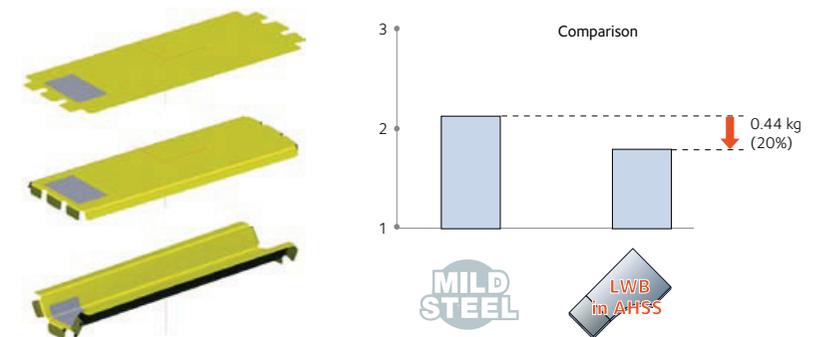
6.9. Seat cross member

Seat cross members are a suitable application for patchworks. Reinforcements are needed locally where the seat bolts are attached to the seats in order to avoid punching of the bolts in case of a crash. Furthermore, to reduce the weight to a minimum the part can be made in UHSS with an additional reinforcement also made of UHSS. There are practically no limitations to the grade as the part is normally not subjected to any difficult stamping but simple bending.

In order to save a stamping operation the reinforcement can be spot-welded to the cross member before stamping as a patchwork tailor welded blank.

Compared to a monolithic structure with the necessary thickness of the whole cross member, the patch solution does not present a considerable economic advantage but a weight reduction of 20% at no extra cost.

FIG. 39 - Seat cross member



6.10. Cross member

Cross members are made in tailor welded blanks to reduce the weight if the same thickness of the part is not necessary all across the vehicle. In some cases the thickness can be reduced if AHSS is used for the central part of a cross member. A steel with better forming properties can then be used in the extremities of the cross member where the stamping is sometimes complex.

6.11. Bumper beam

Tailor welded blanks are used in bumper beams for crash management purposes. The idea is to make a stiff centre part and softer extremities in order to create two deformation nodes instead of one and thus limit the maximum intrusion depth. By this approach, the thickness can be considerably reduced in the extremities whereas the centre part is kept thicker. This results in a weight reduction potential of 25%.

6.12. Floor panel

Floor panels in tailor welded blanks give a good opportunity to reduce both weight and cost. The idea is to integrate reinforcements either for the tunnel resulting in a tailor welded blank with two longitudinal weld seams (central floor panel), or for the closing plates for cross members resulting in a tailor welded blank with one or two transverse welds (central and rear floor panel). Furthermore, it is possible to reinforce the front part to prevent intrusion in the case of crash (front floor panel).

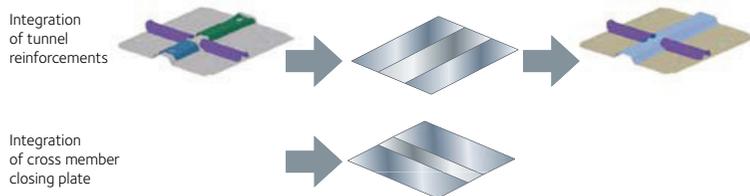
The weight saving comes from the stiffness contribution of a continuous weld allowing not only to decrease the total thickness of base blank plus reinforcement when going to a tailor welded blank but also the thickness of the whole base blank as the interaction between the reinforced area and the rest of the floor is perfect. A reduction of some 0.05 mm in the entire floor normally compensates normally for the fact that the reinforcements are local. The total thickness of the reinforced area is of course reduced as the monolithic post-assembled structure depends on the interaction created by the spot-welds which is far from optimum.

The continuous laser weld is guaranteed perfectly waterproof and the tailor welded blanks provide an enhanced corrosion protection without any costly mastic sealers which are necessary for multicomponent floor panels.

As the total steel consumption is reduced and as the number of stamping and subsequent assembly operations are reduced, the economic gains with a floor panel in tailor welded blanks are considerable.

Nesting is often quite favourable as the floor panel is composed of several rectangular or trapezoidal parts. Due to stamping constraints nesting gains will be limited for more complex parts given the size of the floor panel subblanks.

FIG. 40 - Floor panel in monolithic post-assembled blanks and two examples of function integration with tailor welded blanks



6.13. Shock Tower

Shock towers in patchworks combine the two benefits of monolithic shock towers that are cost efficient and shock towers with a reinforcement in the top area that are favourable from a weight point of view.

The patchwork shock tower is stamped in one operation as the reinforcement is already attached to the blank before stamping. This gives a cost in the range of a simple monolithic shock tower but with a weight reduction of about 25%.

FIG. 41 - Shock tower in monolithic, post-assembled and patchwork design



The patchwork solution enables us to reduce the thickness of the base blank from 1.50 to 1.35 mm as the patch reduces the risk of necking during the stamping operation. On the other hand we need to compensate on the reinforcement thickness to have the same total thickness in the top. The weight reduction increases from 20% in the monolithic post-assembled case to 25% in the patchwork.

As only one stamping operation is necessary the cost is reduced by approximately 10%.

On top of this, the driving comfort is enhanced by the perfect match between the shock tower and the reinforcement as the two parts are stamped together in the patchwork case. The response of the structure is better as there is no play between the parts. This is a feature that is especially expected in bigger cars where the comfort and driveability are main features.

From a production point of view, the patchwork blank presents a considerable advantage during stamping as only the thin thickness is deep drawn, thus the strain is reduced in the flange. The material is kept in the top area that needs to be reinforced which helps to avoid necking.

The access for welding the reinforcement to the already stamped shock tower is often limited. It is simpler to perform the welding operation on the flat blank before the stamping as is the case in the patchwork solution with less overall cost as a consequence.

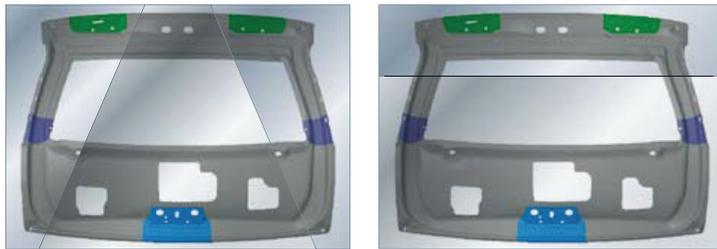
6.14. Tailgate

Tailgate is a fairly common tailor welded blanks application for vehicle with big tailgates such as station wagons, vans and sport utility vehicles. This is due to the fact that these tailgates need to be reinforced in the area of the hinges and the fixing points for the hydraulic cylinders and that these reinforcements become big enough to justify tailor welded blanks. The perfect interaction between the laser welded reinforcement and the tailgate sheet gives the opportunity to reduce the total thickness of base blank plus reinforcement.

In some cases the tailor welded blanks are made with an horizontal weld across the tailgate and in some cases with one vertical weld at each side of the tailgate reinforcing the whole side.

A local reinforcement can also be added for the lock by means of patch technology. Cost saving due to less stamping operations and no subsequent assembly is the main driver for the application, even though some weight saving potential can be shown.

FIG. 42 - Tailgate blanks for integration of reinforcements

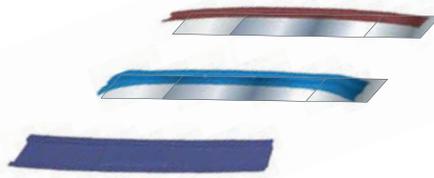


6.15. Roof reinforcement

The roof reinforcement in tailor welded blanks is used to reduce the weight of the roof structure of the car and to respond to increased safety requirements for the roll over situation recently introduced in the USA. The roof reinforcement can be designed to contribute to an improved performance in lateral crash.

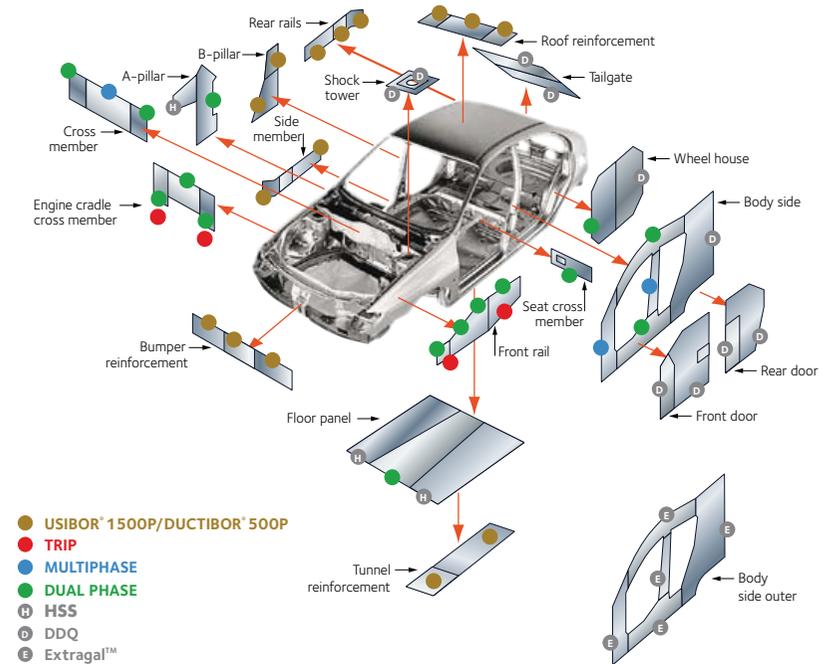
Tailor welded blanks are also used as reinforcements of sunroofs. Monolithic sunroof reinforcement structures are either stamped out from one sheet or post-assembled. In the event where they are stamped out from one sheet, it has to be studied on a case by case basis if a better nesting with a tailor welded blank can pay for the material gains. In the case that a supplementary reinforcement is needed to support the engine that drives the sunroof hatch, the tailor welded blanks can be designed with different thicknesses and stamped in one operation. In this case the economy offered by the concept becomes even more interesting.

FIG. 43 - Roof rail in Usibor® 1500P in different thicknesses



7. State of the Art applications

FIG. 44 - Tailored Blanks State of the Art proposal for tailor welded blank applications in generic vehicle



Typical weight of a C-segment car body in white without tailor welded blanks: 390 kg. Weight of a state of the art body in white with the maximum weight saving with tailor welded blanks in AHSS as shown in the example hereunder: 355 kg.

FIG. 45 - Examples of crash safety contribution and weight reduction

