

DOCOL®
HIGH STRENGTH STEEL

ADVANCED HIGH STRENGTH STEELS FOR THE AUTOMOTIVE INDUSTRY
Because green and safe cars will never go out of style



/ **SSAB**

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The automotive industry is focused on developing cars with higher safety levels, reduced fuel consumption and cost-efficient production methods. This will be accomplished through smarter design and the continuous introduction of newer, lighter and stronger materials.

It is no longer enough to keep the weight of new models constant; growing awareness of the need to reduce CO₂ emissions has become an important driving force. Today, and in the future, automotive manufacturers must reduce the overall weight of their cars. The most cost-efficient way to do this is with SSAB's Docol Advanced High Strength Steel (AHSS).



The future is made from Advanced High Strength Steel

Docol Advanced High Strength Steel (AHSS) is most advantageous when used for safety components, structural parts of the car body and the chassis. As a general rule, the weight reduction is about 50 percent, i.e. when compared to mild steel the thickness is halved without sacrificing strength.

As a result, Docol AHSS has become the material of choice for sill reinforcements, A-pillars, B-pillars, waistline reinforcements, bumpers, side impact beams, roof bows and seats.

AHSS steel has also been introduced in all other vital areas of the car and many new cars are already composed of 30–40 percent AHSS. In only a few years, AHSS is predicted to make up 40–50 percent of the sheet steel used in cars contributing to a 5 percent reduction in total GHG (Green House Gas) emissions.

According to EU goals, fleet-average emissions from new cars sold in the EU by 2012 must not exceed 130 g CO₂/km. At SSAB, we see it as our mission to do everything we can do to support the automotive industry in meeting this important goal.

The advantages of using AHSS are evident in all types of cars. Small cars benefit from greatly improved crash safety while heavier cars, like SUVs, can be made much more fuel efficient.



A comfortable journey
always requires the highest
safety standards.

DOCOL AHSS – A WELL PROVEN PRODUCTION PROCESS

The smooth and cost-efficient transition from mild steels, or conventional high strength steels, to AHSS is one of the factors behind the success of AHSS within the automotive industry. This is because AHSS can be formed and joined in much the same way as milder steel, but with only half the thickness. The cutting and forming of AHSS can be done without increased force and common welding and joining techniques can be used with only minor adjustments.

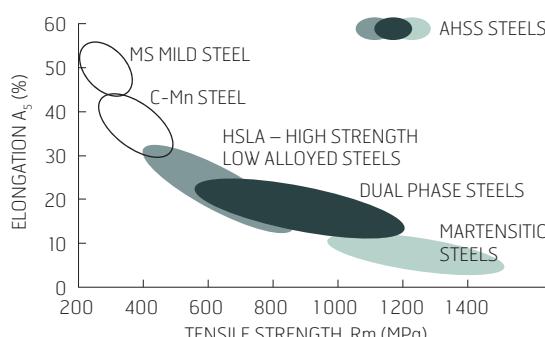
Even greater benefits can be gained when switching to new forming methods, like roll forming. This process enables the manufacturer to produce complicated profiles in a single run – roll forming can be done with lower tool wear and very tight radii of the profile when using AHSS.

... AND MORE COST EFFECTIVE THAN ALUMINIUM

The advantages of Advanced High Strength Steel over aluminium are easily summarised: lower cost with the same weight and strength.

The ability to form complicated profiles is another of the many benefits offered by AHSS compared to those of aluminium. For example on beams inside the car, aluminium must be three times the thickness of AHSS to provide the same strength. When compared with new materials, such as composites, the cost benefits of using AHSS is even more apparent.

The automotive industry of today has decided that AHSS is superior to aluminium for nearly all applications.



WHAT'S IN THE NAME DOCOL AHSS?

Docol is SSAB's brand product towards the automotive industry. Docol is currently one of the strongest cold-rolled AHSS steels on the market. The term Advanced High Strength Steel (AHSS), is generally used for dual phase steels, complex phase steels, TRIP steels and martensitic steels, it means primarily multi phase steels. At SSAB, the high yield strength micro-alloyed steels also belong to AHSS group.

Conventional high strength steels are single phase ferritic steels.

Advanced material, smart production

Advanced High Strength Steel is the most competitive material on the market today. With well proven production processes requiring minimal investments, the higher price of AHSS is quickly offset by reduced volumes. One steel grade of AHSS replaces several traditional steel grades.

CUTTING COSTS

DURA Automotive Systems is a leading supplier of door modules and structures for the automotive industry. DURA Automotive Systems in Germany has constantly strived to rationalize, yet they still have to meet the demands for decreased fuel consumption and increased safety. All of these objectives have been met with a new side impact beam manufactured from AHSS.

The steel DURA chose was Docol martensitic steel with a minimum tensile strength of 1200 MPa. It is one of the strongest AHSS available on the market, with good weldability and roll forming properties.

The side impact beam is a closed square section profile that is necked on the sides. The design of the profile has been optimised to provide the side impact beam with a very high-energy absorption capacity. The thickness of the steel in the beam is only 2.00 mm, which results in a weight of 1.75 kg for a 1.1 metre long beam.

The company has also developed a system for volume production of the beam that can be produced for a number of different car models with only minor modifications.

All operations take place on a production line where the steel runs in a continuous strip directly from the coil. The bottom part of the profile is first roll formed and is then closed and joined together by laser welding. Finally, the beam is cut to the appropriate length.

The beams can be tailored to suit the requirements by varying the cross-section and length. The type of mounting can also be varied: riveting, welding or securing with screws. The benefit to car makers is that the beam can be readily adapted to several different variations of a given car model.



DURA side impact protection beam
made of Docol 1200 M + ZE surface.

A bumper case for lower weight

Advanced High Strength Steel is the straightforward way to reduce weight and improve the performance of the application at the same time.

REDUCING WEIGHT

Shape Corp., a leading automotive supplier in the arena of impact energy management, has achieved a breakthrough in bumper system applications, providing engineers a better opportunity to improve fuel economy by shaving weight from the vehicle while enhancing bumper performance.

Specializing in forming Advanced High Strength Steels (AHSS) into complex shapes for impact energy management applications, Shape Corp. produces automotive bumper beams and other structural components utilizing innovative lean manufacturing processes. These processes allow for piercing, forming, welding, sweeping and cut off, all of which are done in a highly efficient inline roll forming operation.

To meet new impact requirements set by the Insurance Institute of Highway Safety (IIHS) in the US and the Research Council for Automotive Repair (RCAR) represented in many other countries, Shape Corp. reinvented one of its current products and developed a low-cost, lightweight solution for bumper systems without the high cost of alternative materials such as aluminum.

For many model years, the earlier conventional B-section bumper met the needs of the tens of millions of vehicles it was used on, but new testing standards and the ever increasing need for mass reduction required Shape to extensively study and refine the design of the B-section. The results are amazing. The bending strength has been significantly increased compared to the original B-section bumper by using engineered “power ribs” that are formed on the compression face of the beam. This increased bending strength allows Shape Corp. to take full advantage of the Advanced High Strength Steel properties by specifying thinner gauges to reduce the amount of steel used by 20 percent or more, while also helping automotive OEMs meet new, tougher global impact requirements.



Shape's bumper beam (Power B-Section) is made of Docol 1300 M.

In head-to-head competition, it was common for the conventional B-Section bumper to be very cost competitive to aluminum designs, but at a 1.0 to 1.5 kg weight penalty. Today, by utilizing the Power B-Section design and AHSS, Shape Corp. is able to offer bumper solutions that match or are within 0.5 kg of what has typically been considered the “low mass solution”, but without the high cost penalty of aluminum.

In short, Shape Corp. has combined creative design with lean manufacturing methods in forming steels with strengths up to 1300 MPa. The new Docol Advanced High Strength Steel Power B-Section reduces the mass of vehicles and improves fuel economy without the high cost of alternative materials.

A five star success for safer cars

Crash safety is an important sales argument – five stars in Euro NCAP is a key to success. The increased use of AHSS is leading the way in crash safety – other materials are far behind.

INCREASING STRENGTH

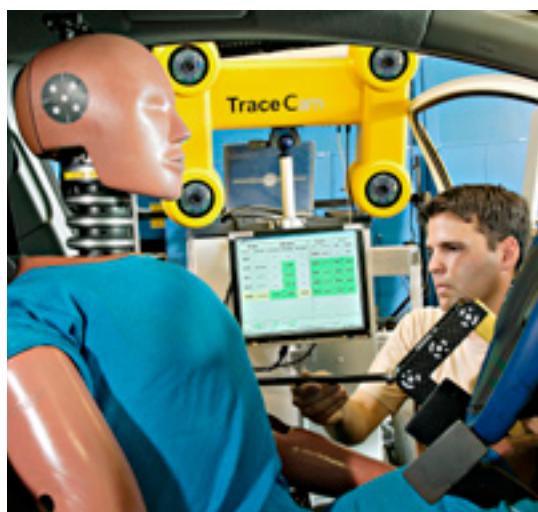
When Fiat started to design the Grande Punto their demands were very high. All safety aspects were highly prioritized. One was the ability to withstand side impacts.

High energy absorption capacity and compact design characterize the internal waistline reinforcement mounted in the doors of the Fiat Grande Punto. This structural component is designed to be accommodated in the small space just below the side windows. It also meets the strictest demands on protection in a collision from the side or in a head-on crash and owes its success to its optimized design and to the efficient roll-forming production method.

Apart from the safety aspects, the internal waistline reinforcement had to be lightweight

and suitable for cost-efficient production. The solution was a roll formed beam made of Docol Advanced High Strength Steel with a minimum strength level of 1000 MPa. The beam has an electro galvanized surface for corrosion protection and was developed by Fiat working in close collaboration with its supplier Wagon Automotive Italy. Fiat specified a very advanced geometry for the beam that could only be produced by roll forming and Wagon Automotive succeeded in producing a closed profile with an asymmetric geometry that is bent longitudinally in two planes.

The Fiat Grande Punto has been a great success for Fiat, having been awarded the maximum 5 star rating for occupant safety in Euro NCAP safety tests.





Source: © Fiat Group Automobiles

Low weight, compact design and good protection performance characterize the roll formed internal waistline reinforcement for the Fiat Grande Punto made from Docol 1000 DPZE.

Strong product development together with SSAB – a customer case

SSAB can be a partner in every step of the development of a new AHSS application. When an automotive company or supplier considers a switch to AHSS from other materials, our technical advisors and specialists are available to support – from the very first design concept, to final production.

WORKING WITH SSAB

Let us take a look at one recent case where SSAB was asked to support the improvement of an existing car model. The car had a door beam made from hot stamped boron steel. The automotive manufacturer wanted to retain the high level of safety that the door beam provided, however, the high cost of hot stamping needed to be reduced. SSAB was given the task of developing a cold formed beam instead.

– In this case we were given the opportunity to take part from an early stage of the development, says Dr. Björn Carlsson, one of SSAB's technical advisors based in Europe.

– Once we received the desired geometry of the beam from the manufacturer, as well as the strength and energy absorption figures that needed to be achieved, our designers were immediately able to start simulation of different new designs of the beam. Quite soon, we had developed a design which performed equal to that of the hot stamped beam, but with the benefits of lower weight and a much lower unit cost. This was a step-by-step process and we constantly re-evaluated the design and the choice of material until we decided upon our final proposal.



INVESTIGATING EVERY ALTERNATIVE

The possibility of increasing the strength through stiffeners, grooves and flanges was investigated and to some extent used in the new design. SSAB presented the next stage of the new design to the manufacturer and SSAB was given the go ahead with further development. Forming tests were carried out at the SSAB in-house laboratories in Sweden, welding methods were compared and tooling and production requirements were discussed.

– When both the automotive manufacturer and the designated supplier were satisfied with the basic design, prototype production began. The timeline was very tight, but the SSAB stock of test and prototyping material meant that we could deliver the specified steel grade and the right volumes to the supplier in France within only a couple of days. This was a great value for the whole project, says Dr. Björn Carlsson.

The test and prototyping material stock is unique within the industry, providing SSAB with the ability to deliver exactly the right test material at a moments notice.



PERSONAL CONTACT AT EVERY STAGE

The specialists at SSAB dealt personally with all parties involved during the entire development process and when the prototype stage was reached, a dedicated SSAB specialist was always on hand to quickly response to any problems in the pre-production stage.

In this case the time from the first contact between SSAB and the automotive manufacturer to the first finished prototype was only ten weeks.

– Our normal lead-time for a project like this is three to four months, says Dr. Björn Carlsson. In this specific case we worked very closely with the supplier that was going to produce the door beam and this shortened the process considerably. Our lean organisation makes distances short between the customer and our local technical advisors and specialists in Sweden, which allow us to cooperate very intensely and rapidly.

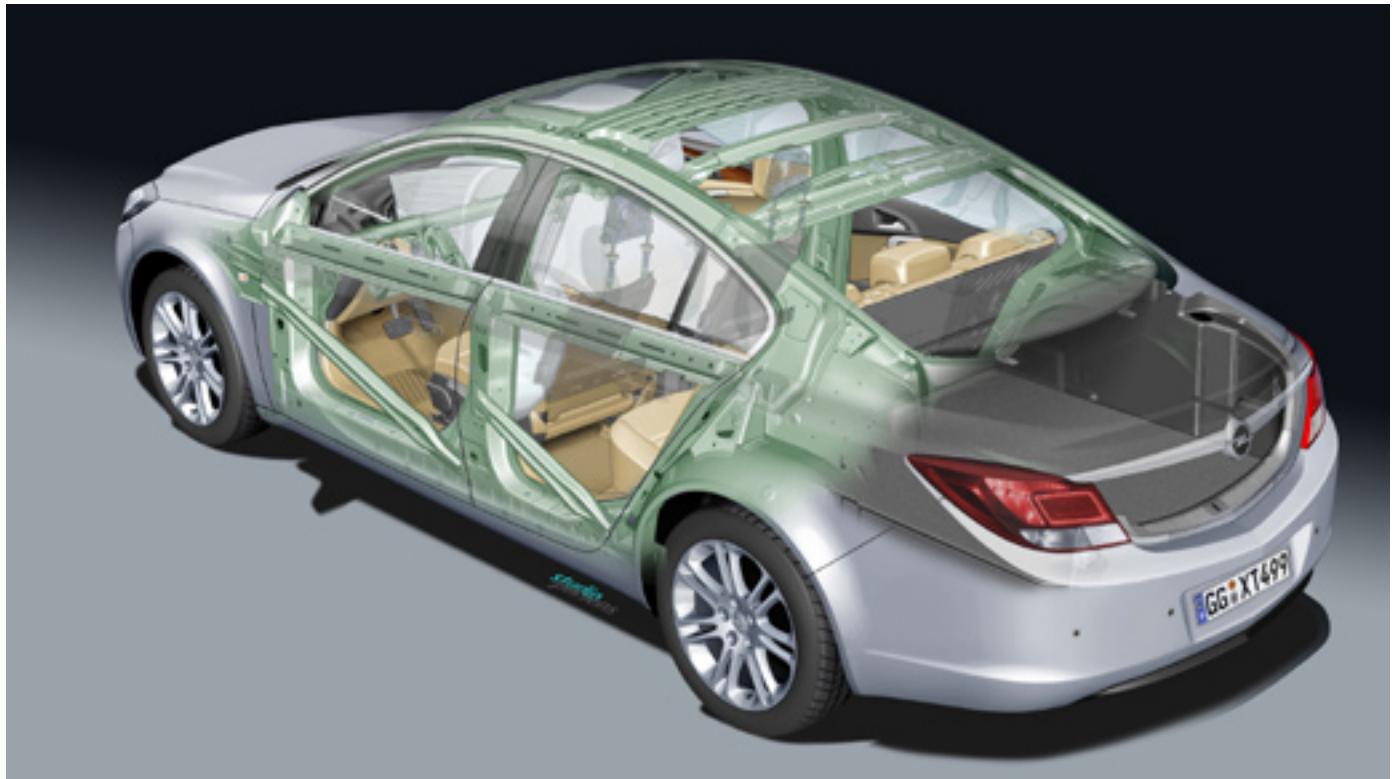
SAVINGS OF NEARLY 50 PERCENT

The implementation of Docol AHSS steel in the production of this door beam went very smoothly. Cold forming is a well-proven production process and even the strongest grade of Docol AHSS has a high formability, requiring only minor tooling adjustments.

In this case, the automotive manufacturer had calculated that changing from hot stamping to cold forming, would reduce costs for the door beam by 30–40 percent. In reality, the figures showed an even higher savings of almost 50 percent.

Increased focus on design in order to realize the potential of AHSS

Advanced High Strength Steels (AHSS) provide an excellent way to reduce weight and improve performance. Dual phase and martensitic steels show a good combination of strength, formability and weldability. This, together with the cost-effectiveness of cold forming results in very attractive solutions for body-in-white structural parts, as well as safety parts such as door impact beams, bumper systems and seat structures.



Source: © Opel

The Opel Insignia was elected Car of the Year 2009. With a remarkable 5 stars passenger safety result the Opel Insignia obtained 35 out of 37 possible points in the Euro NCAP test. The sill reinforcement of the Opel Insignia is made from Docol 900 M with ZE surface. Structural parts in roof and floor are made from Docol 980 DP.



Source: © Opel

DESIGNING WITH AHSS

From a design point of view, AHSS is generally a favored solution. However, the high stresses and low thickness puts emphasis on finding a solution that uses the full potential of the material. Design challenges can include local buckling effects, loss in stiffness, robustness and fatigue issues. With the right production process and design, it is easy to deal with these challenges. SSAB supports all customers in all design related questions, directly from the start of product development.

THE STRENGTHS OF AHSS

Dual phase and martensitic steels are available with very high initial yield strength. In addition to this initial strength, they also exhibit a pronounced work-hardening when formed, as well as a bake hardening effect from the painting process.

Typically the work-hardening effect is about 150 MPa at a strain of two percent and the corresponding bake hardening effect another 50 MPa for a typical painting process.

In addition to the work and bake hardening effect, AHSS exhibits a strain rate hardening effect, i.e. they sustain higher stresses at an increased deformation speed. This effect corresponds to an increase of about 100 MPa for the high strain rates that are involved locally in a car crash.

POTENTIAL FOR WEIGHT SAVINGS

The high strength of AHSS is a useful tool to reduce the weight of the body-in-white (BIW), bumpers systems, door side impact beams, seat structures etc. In order to fully highlight the potential, two theoretical cases can be reviewed. If there is a pure membrane stress state in the sheet (Fig. 1a), the stress is linear proportional to one over the thickness. If there is a pure bending stress state, the stress is proportional to one over the square of the thickness (Fig. 1b).

By introducing a material, which sustains greater stresses the thickness can be reduced, maintaining a performance that is equivalent. In Figure 2, the potential for weight reduction for the two theoretical cases is shown.

In true safety components, the possible weight reduction is in many cases between these two extremes. The bending case is, however, not a conservative lower limit due to the fact that local buckling may occur in slender designs.

As indicated in Figure 2, AHSS put increased focus on measures to avoid local bending in order to use the full potential of the material. Measures must be taken in order to avoid a pure bending stress state. A global bending moment is best transmitted by use of beams. Roll formed profiles or tubes constitute an excellent instrument in order to design and produce an optimal geometry sustaining bending moments.

FIGURE 1

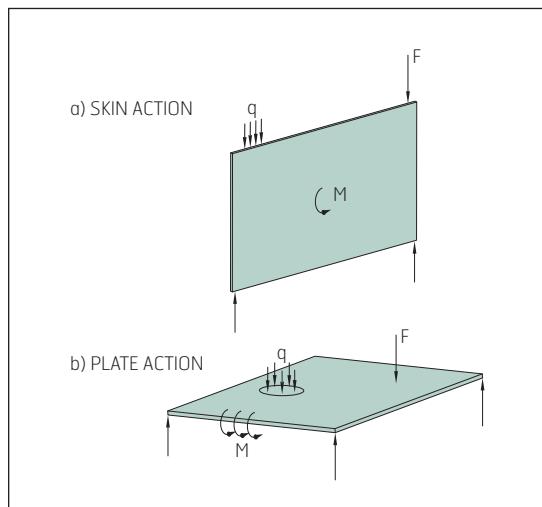
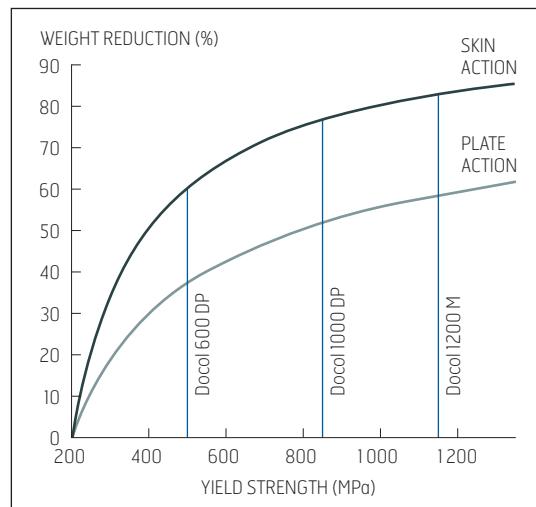


FIGURE 2

FIGURE 1
Plate- and skin action.FIGURE 2
Weight reduction by using AHSS for membrane and bending stress states. The yield strength of the indicated steel grades corresponds to the yield strength at 2 percent work-hardening and after painting.

LOCAL STIFFENING TO REALIZE THE FULL POTENTIAL OF AHSS

As mentioned above, local buckling may occur when reducing thickness during an upgrading process. This is initially an elastic instability phenomenon, where local buckles form at slender compressed and sheared segments at stresses below the plastic limit and in doing so, do not use the full potential of the material. Introducing local stiffeners to reduce the slenderness and improve the constraint of the edges (Fig. 3) will help realize the potential of AHSS.



FIGURE 5
Examples of local geometrical stiffeners at a lump bar in Docol 1300 M.

SMALL DESIGN CHANGES CAN IMPROVE STIFFNESS SUBSTANTIALLY

Since Young's modulus¹ is equal for mild steel and high strength steel, the stiffness of a single component is lost in an upgrading situation where the thickness is reduced if all other parameters are kept constant. One way to fulfill the stiffness demands on a design is to change the outer geometry. Increasing the outer dimensions, still resulting in a significant weight reduction, may compensate for the loss in stiffness from reducing the thickness.

Other measures to be taken are local geometrical stiffeners, e.g. grooves, flanging of holes, edge folds and stiffening darts (Fig. 5). Such stiffeners could also restrain local buckling, reduce the springback when forming, as well as improve the shape accuracy.

In many cases the joints influence the stiffness considerably. Putting more efforts into the design of the joints could result in a significant improvement. Typical examples are an increased number of spot welds, increased number of weld planes or to change to continuous welds. Closed sections will also contribute to increased stiffness compared to open sections.

OPTIMISING THE ENERGY ABSORPTION

There is a potential to reduce the weight in components, by upgrading the strength of the steel (Fig. 4). Generally the absorbed energy is proportional to the square of the thickness and linear to the tensile strength of the material. If for instance the tensile strength of the steel is doubled, the thickness and the weight can be reduced by 30 percent, resulting in equivalent energy absorption.

One of the main challenges when using AHSS for energy absorption by folding is to secure robust behaviour. Progressive folding gets harder to achieve in axial crushing as the material strength increases and the thickness is reduced. To increase the robustness, an effective pattern of triggers or change of the global geometry can be introduced.

FIGURE 3

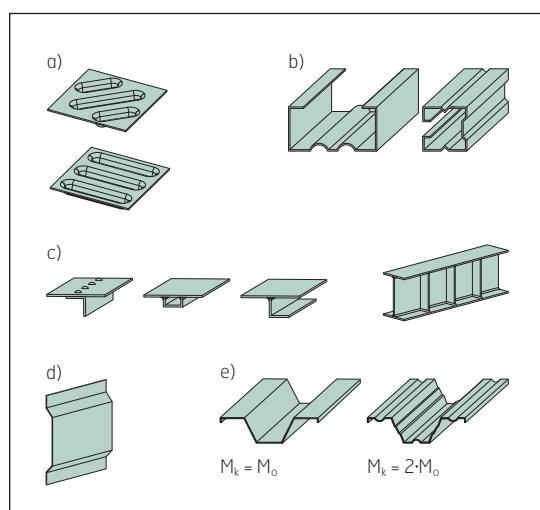


FIGURE 4

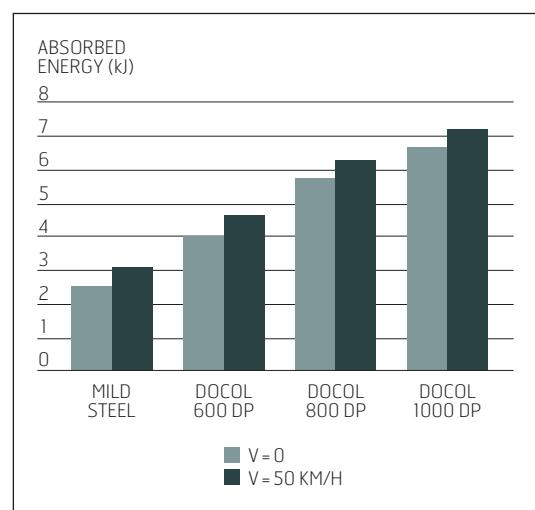


FIGURE 3

Examples of stiffeners:
 a) indentations
 b) grooves and edge folds
 c) additional stiffeners
 d) jogging
 e) example where the bending moment capacity is doubled by use of stiffeners¹.

FIGURE 4

Experimental results from axial crushing of quadratic tubes. Quasistatic- and dynamic crushing (initial impact speed 50 km/h) compared.

1. SSAB "Sheet Steel Handbook"
ISBN 91-971592-0-4.

Regular folding of Docol 1000 DP
absorbs a lot of energy.



Totally new possibilities with well proven forming methods

Most AHSS have good formability and can be formed using traditional processes. In some cases, however, the production process needs to be adjusted with greater consideration to the properties of the material. A re-design of the component can often compensate formability compared to mild steels. In fact, AHSS can often be processed in the same way as the material it replaces, because thickness is one of the factors that determines the pressing, bending and shearing forces. Presently, roll forming is the forming technique that shows the greatest potential within the automotive industry.

FORMING AHSS

ROLL FORMING

For roll forming, the Docol Roll family is the premium product in the SSAB range. These steels have ideal properties for roll forming, e.g. good forming stability and the possibility to roll form to very small radii.

Although Docol Roll is optimised for roll forming, this forming process is well suited for all types of AHSS steels. The roll forming process is less demanding on the material than press brake bending, and therefore enables profiles of complicated cross-sections and tight radii to be produced.

Roll forming can be combined with simultaneous or subsequent operations such as punching, welding and bending.

DRAWING RATHER THAN STRETCHING

Drawing is characterized by the entire or majority of the blank being forced through the die. In stretch forming, all deformation occurs over the punch, as the material is totally clamped by a blank holder.

When comparing these two forming techniques, drawing is the process best suited for

AHSS as the drawability is very good in relation to its strength. By paying close attention when optimizing blank geometry the draw-in of material will be further improved. However, to prevent wrinkling, a blank holder should be used, but only with moderate force that still allows the material to be drawn-in rather than stretched. If no blank holder is used, i.e “crash forming”, one can obtain very positive results in terms of spring-back reduction. To further reduce this effect, the entire process can begin with a crash forming step and end with a stamping sequence, where a blank holder is applied and the material is stretched.

FLANGING

The ratio of the hole diameter before and after flanging is known as the flanging ratio.

It is very important to consider the location of the shearing burr when flanging AHSS steels. The blanks should be positioned so that the shearing burr faces towards the punch when flanging. This is because the outer fibres of the material sustain the heaviest deformation. Therefore any surface defects, e.g. shearing burrs, should be placed along the inner fibres, to get the best flangability result and to minimize the risk of cracks.

BENDING AND SPRINGBACK

During bending, a bending moment is applied to the sheet until the outside of the sheet experiences tensile strain and the inside undergoes compression. The bendability decreases with increasing strength.

When bending AHSS steels, the springback effects will be more pronounced. However, increasing the plastic deformation of the material at the bend can compensate springback. This can be done by over-bending the material and reducing the punch radius or die opening width. The springback may also be reduced by the introduction of stiffeners.

The right punch radius combined with the right die width is therefore particularly important in bending AHSS steels.

The springback effect can also be reduced by applying an initial deep drawing step and a final stretching of the material.

It is not recommended to increase the friction during the whole process, e.g. by reducing the draw radii and consequently preventing the material from being drawn into the die and also larger springback effects such as sidewall curves.

FORMING LIMIT CURVES

The forming limit curve (FLC) shows the amount of deformation that the material can sustain at a certain deformation path or during a certain deformation condition.

The FLC can be used for documentation or as an aid in solving pressing operations.

The figure shows three versions of profiles formed in different ways. One optimal profile (grey) with straight and perpendicular sidewalls (crash formed followed by stretching).

The next profile (yellow) is very similar to the first one, however, it has not been stretched.

The third profile (orange) shows the effects of sidewall curves due to the high stretching of the material against the die radius during the drawing sequence.

When measuring the strains on a pressed part, a chequered pattern is etched on the blank, i.e. the sample material. The change in size of each square is recorded digitally and is a measure of the plastic strains in the forming operation.

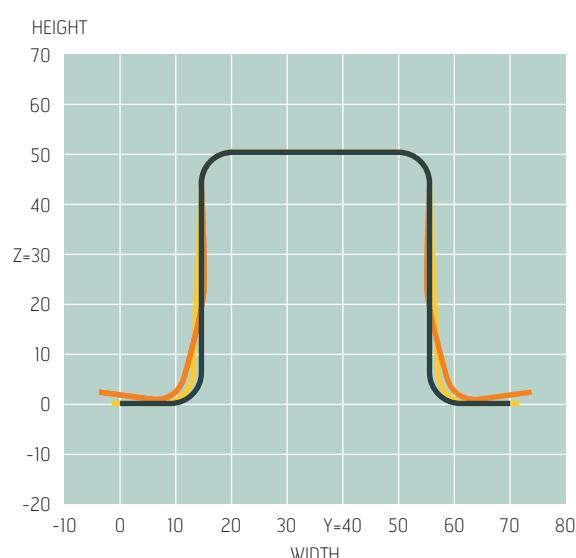
The results of principle strains are measured for a given pressing operation or results from a corresponding Finite Element Simulation are then plotted in a graph and compared against the forming limit curve for the specific material used. If the results are below the curve, the relevant material can withstand the deformation.

SHEARING AND PUNCHING

When Advanced High Strength Steel is sheared, the shearing operation must be adapted to suit the hardness, thickness and shear strength of the steel, as well as the design, rigidity and wear of the power shears or machine being used.

Use of the correct cutting clearance for the power shear blades is of particular importance. The cutting clearance is governed by the sheet thickness, strength of the steel and demands on the appearance of the sheared edge. The thicker the material and the higher the strength, the larger the cutting clearance must be.

The cutting force increases with tensile strength, but changing to AHSS usually leads to reduced thickness, thereby substantially reducing the necessary cutting force. In most cases, cutting forces are the same level as softer types of the material. In such cases there is no need to upgrade current shearing machinery.



Cold forming or hot stamping?

New materials do not necessarily require new methods for forming. The increased demand for AHSS in the automotive industry has led to the development of new advanced forming techniques. It has also increased the knowledge about how to manufacture AHSS using conventional forming methods. One of the main issues today is determining which forming method to use for automotive components – cold forming of AHSS or hot stamping of boron steels?

Cold forming AHSS is a proven method that has been widely used for many years. Production costs and return on investments can also be easily calculated.

Hot stamping of boron steel has grown rapidly during recent years, but the number of producers using this process is still small in comparison to cold forming. One reason for this is that cold forming is a competitive and efficient method of forming for all but the most demanding automotive components, such as parts with a complicated geometry and in addition also those requiring extremely high strength.

All arguments generally favor cold forming AHSS. For example when producing side impact beams and bumper reinforcements the same strength is achieved with both methods, but the cost advantages of cold forming are significant. In fact, hot stamping is on average 40–60 percent more expensive than cold forming. One of the

reasons for the vast difference in price is the fast production cycle for each cold formed part.

Another great advantage of cold forming AHSS is that major investments in machinery and tooling are already done, which makes converting to AHSS swift and simple. The issues of formability and springback in cold forming can be dealt with through a combination of design and tool changes.

The fact that cold forming is easier to weld and can be protected against corrosion by hot-dip or electro galvanizing is another advantage offered by the process. The continued development of new cold forming methods, such as 3-D roll forming, are also constantly increasing the scope for more advanced products. On top of that, cold forming AHSS offers a higher consistency of the product quality than hot stamping of boron steels.



Chang'an Lingyun, a joint venture of Lingyun and Chang'an Auto, China, has produced a new side impact beam for car doors using Docol 1200 M. The beam used to be produced from hot stamped boron steel, but has now been changed to cold formed AHSS steel in an effort to reduce cost. The same crash performance was reached with the new beam.

ABOUT CHANG'AN LINGYUN: Chang'an Lingyun produces automobile parts with a focus on the manufacture and sale of rolling, stamping, 3D bending and forming products. With wide-field products, Chang'an Lingyun has established good partnerships with companies such as Changan Group, Changan Ford, Changan Suzuki, Hebei Changan and Chongqing Isuzu.

Welding with well-known methods and minor modifications

Advanced High Strength Steels are suitable to use with all common welding methods in the automotive industry such as electrical resistance welding, arc welding and laser welding. In many cases, the same welding parameters as for mild steels can even be used when joining AHSS.

WELDING AHSS

ELECTRICAL RESISTANCE WELDING

Resistance spot welding is the most common welding method for sheet steels in the car body production. Both AC (Alternating Current) and MFDC (Medium Frequency Direct Current) spot welding machines can be used for AHSS along with conventional single pulse welding. Using an electrode force that is increased in comparison to the normally level for mild steels combined with slightly longer weld times will obtain the best results (Fig. 1).

Weldability studies normally use weld growth curves (weld size vs. weld current) and weldability lobes with the aim of maximising the welding range to achieve the greatest safety margin on weld quality. Studies for AHSS have shown that wide welding current ranges can be obtained for AHSS when optimised welding parameters are used.

HIGH FREQUENCY WELDING

High frequency (HF) welding is the main welding process used in the manufacturing of cold formed welded steel tubes often used in automotive applications. During the welding process the sheet edges are quickly heated to a high temperature and are then pressed together at high pressure to form a strong joint. This process can also be used for AHSS. However, for very high strength AHSS (e.g. Docol ultra-high strength steel) there will be a hardness drop in HAZ. However, in the majority of instances, this does not create a problem.



FIGURE 1

Influence of electrode force on welding current range in resistance spot welding of Docol 1000 DP, 1.2 mm.
Welding data: Electrode tip diam 6 mm, weld time 14 cy, hold time 10 cy. Minimum plug diam 4 mm.



Source: Volkswagen AG

Advanced High Strength Steels are suitable to use with all common welding methods in the automotive industry.

ARC WELDING OF UNCOATED STEELS

Many different welding methods such as GMAW, TIG and plasma can be used for uncoated Docol AHSS steels. At the same time, the shielding gases used for mild steels can also be applied to AHSS. Despite the increased alloying content for AHSS, there is not an increase in welding imperfections compared to arc welding mild steels. There are many filler metals available for arc welding AHSS. The strength of arc welds for Docol AHSS steels increases with increasing base metal strength (Fig. 2).

ARC WELDING OF ZINC COATED STEELS

Zinc coated AHSS can be welded in the same way as zinc coated mild steels. For thin zinc coatings (e.g. Z100, ZE 70) conventional solid wires can often be used with the recommendation to reduce the welding speed to avoid problems with pores and spatter. For difficult joint geometries (e.g. lap welds and fillet welds) combined with thick coatings, a flux cored arc wire has been specifically developed for use in the welding of zinc coated steels.

LASER BUTT-WELDING

Laser butt-welding can be used for both uncoated and zinc coated Docol AHSS. Some examples are the production of tailor-welded blanks and the roll forming process when closing a profile in the roll forming line. The requirements for edge preparation of AHSS are similar to those for mild steels, as in both cases a good quality edge and a good fit-up are needed to obtain the best results. Too large of a gap between the sheet edges can

create an undesirable underfill on the topside of the weld or lack of fusion in the weld seam.

Both Docol dual-phase and martensitic steels can be used in the production of roll formed profiles that are closed with laser welding. However, if the hardness of the laser weld for AHSS is considered too high, it can be reduced using a post heat treatment. A high frequency induction device is recommended for heat treatment.

One of the benefits of laser welding very high strength Docol AHSS is that the strength of the laser welds can be increased in comparison with ordinary gas metal arc welding. The reason for this is that the heat input is much lower for laser welding and the material is therefore less affected by the heat.

LASER LAP WELDING

Different kinds of lap welds are often used in assembly laser welding such as a lap fillet weld (edge weld) or a conventional penetration lap weld. For lap welds of thin sheets, full penetration in the lower sheet is often utilized due to an easy quality control process. For lap welds of thicker sheets approximately 50 percent penetration in the lower sheet can be recommended.

In the case of lap welds in combination with zinc coated steels a small gap (0.1–0.2 mm) between the sheets is beneficial. In this way, pores and other defects can be avoided as the zinc vapour has the possibility to escape from the weld. To avoid underfill on the topside of the lap weld, an excessive gap should be avoided. Another way to avoid problems with laser lap welding of zinc coated steels is to use twin spot laser welding. A small interdistance between the two spots in the welding direction will enlarge the weld pool and give the zinc vapour more time to escape.

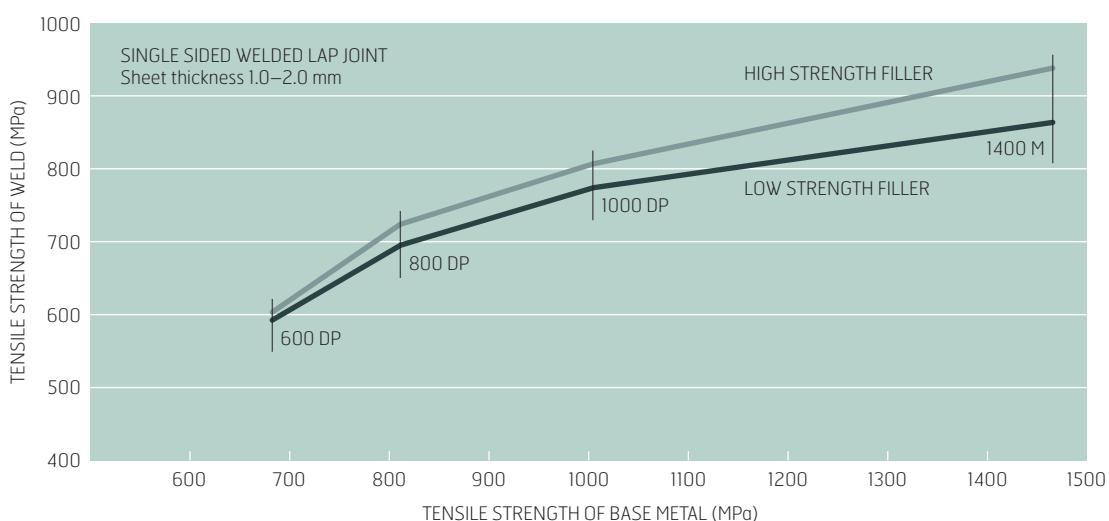


FIGURE 2
Influence of base metal strength on weld strength in gas metal arc welding of Docol AHSS. Results given for two strength levels of filler (low strength filler Rm 560 MPa, high strength filler Rm 890 MPa).

Industrialisation and tooling with Advanced High Strength Steels

To ensure a reliable and stable manufacturing process with AHSS, a number of issues need to be considered. The optimal solution is obtained when focusing on these issues as early as possible during the development of a new application, i.e. in the concept and design phase. As a result, the process window will be wider and down-time problems during production will be reduced. The following recommendations can be used as a checklist during the design phase through production.

DESIGN FOR PRODUCTION

- Consider the formability criteria and formability data of the material to be used.
- Stay on the safe side and do not try stretching to close to the formability limits.
- Take all variations in consideration, e.g. worn tools, temperature variation, performance in formability from time to time, otherwise it can give you production disturbances in the end.
- Try to optimize the blank of geometry as much as possible, making it easier for material to be drawn-in.

STRETCHED EDGES

- In every case of a stretched flange or edge, be aware that the burr, such as a defect from the cutting and trimming operations, should be positioned on the side of the cut edge where the lowest plastic tensile strain level is expected.
- Be observant that when laser-cutting blanks (often done in the initial prototyping phase) the edges are perfectly smooth without any burrs. If you do not take this into account, burrs may give you problems later on when the final tool has been made. Design the tool to make every cut from the right direction due to the next following flanging operation.

Docol AHSS is used in the seat frame of the Volvo XC90. It is 25 percent lighter, weighing only 16.4 kg and capable of withstanding collision forces of up to 60 kN.

FORMING STABILITY AND SPRINGBACK

- In order to reduce the springback, for example sidewall curves use mainly a crash forming process and in the end clamp the material with or without draw beads and make a final stretch forming.
- It is also possible to put stiffeners in the bend to reduce the springback effect after bending or increasing the stiffness of the bend.

CHOICE OF TOOL-STEEL

- Reliable and cost-efficient production using AHSS requires the right choice of tooling steel. Choosing the optimum tooling steel for a specific purpose is often more expensive than other alternatives, but in the long run the total cost will be lower with a better return on investment.
- SSAB has developed a set of guidelines for choosing the right type of tooling called “Tooling solutions for Advanced High Strength Steels”. The guidelines have been developed in cooperation with the tool steel manufacturer Uddeholm Tooling AB, and provide customers with recommendations preventing problems such as galling, chipping etc.



Roll forming and tubes enable smarter and lighter solutions

Tube forming and roll forming are methods where the ability of AHSS to work harden can be put to use. In these processes, controlled deformation of the material takes place and leads to an increase in the yield strength and tensile strength of the finished part. If the finished part is heat-treated, for example, during painting, the strength will increase further.

TUBES

 Due to the good combination of strength, formability and weldability, AHSS steels are well suited for tube production and represent an excellent structural element whenever high strength is needed.

In the automotive industry, AHSS steel tubes are principally used for seat structures and also for side impact door beams and IP beams. The tubes are typically circular, although square, oval and crescent-shaped tube sections can be produced in subsequent stages.

Since AHSS steel tubes can be hydro formed, it provides the opportunity to use these tubes for components with a varying cross-section.

Cold formed tubes are made by continuous roll forming of flat sheet into a tube, and then making the joints by high frequency welding. Such tubes have excellent fatigue properties and can be used in chassis parts that are subjected to fatigue stresses. Even AHSS with strengths of more than 1000 MPa, can be used for welded tubes if the heat supply is controlled during welding.

Tuper S/A, Brazil has a leading position as a provider of innovative and competitive solutions in steel focusing also on tubes for the automotive industry. The tubes are made from Docol 1400 M and are applied as side impact door beams in cars. The Docol 1400 M Advanced High Strength Steel allows the OEM to offer this component with higher resistance and safety and to make it more than 30 percent lighter.

Generally, fewer problems with dimensional tolerances are seen, compared with bending or stamping, even if the scatter in the mechanical properties of the material is large.

Roll forming also allows for calibration steps to be added after the final forming step, in order to further reduce dimensional deviations, or to introduce a curvature to the profile. The benefits of roll forming AHSS in general are even more significant at the highest strength levels available.

Even for cold forming steels with a tensile strength up to 1500 MPa, the contrast with other forming methods is striking.

BENDING RADIUS

Internal bending radii in the order of the sheet thickness have been achieved in roll forming of Advanced High Strength Steels, while the same material requires radii of three to four times the sheet thickness in V-bending to avoid fracture.

Very stiff profiles can therefore be made in roll forming, which makes further weight reduction possible. The tighter radii are possible in part by the roll forming method as such, but it is also helpful if the material does not have a significant work-hardening. In this case, the strip conforms better to the forming rolls and has less tendency to "bend ahead". A sharp bending radius of course also requires that the micro structural cleanliness of the material is high.

ROLL FORMED PROFILES

Roll formed profiles in AHSS are used mainly for seats, side impact door beams and bumpers. Roll forming is a very cost-effective method of forming as it results in low costs per-item, particularly in long production runs.

Roll forming has proven to be less sensitive to the formability and springback issues of AHSS. Compared to conventional bending, significantly tighter bending radii can be obtained in roll forming without material fracture whilst springback is also reduced and even eliminated in some cases.

Docol Roll and Dogal Roll – developed for roll forming

A new group of steels has been developed with only one process in mind. Docol Roll and Dogal Roll perform better in roll forming than other materials of the same strength. There are two tensile strengths available, 800 MPa and 1000 MPa.

Both steels are characterized by:

- High yield stress – a high yield stress minimizes flatness problems and ensures plastic deformation will be confined to the radii.
- High YS/TS ratio – a high yield ratio means that stresses in highly formed regions are comparable to the stresses in slightly formed regions. Small differences in residual stresses over the cross section reduce the tendency for bending and twisting of the profile.
- High internal cleanliness and a microstructure with homogeneous hardness distribution – extremely important when roll forming into narrow radii.



STRAIGHTNESS OF PROFILE

The straightness of the roll formed profile improves with the material strength. The following case will explain the straightness of profiles in more detail. Two profiles are made in the same roll forming line. One profile is made of a deep drawing grade (DC04) and the other profile is made from Docol 1000 DP. The tensile strengths are about 300 MPa and 1000 MPa respectively. Both profiles have the same thickness and were formed with the same machine settings.

The Docol AHSS profile is straighter because the plastic deformation is confined to the radius. High yield strength is beneficial in preventing plastic deformation of the “legs” so twisting and bending of the finished profile is reduced. The risk of “oil canning” is also reduced, since the residual forces will be lower.

The ratio between yield- and tensile strength relates directly to the straightness of the roll formed profile, in other words the work-hardening of the material. A profile, which has a complex cross-section with heavily and slightly deformed areas, will exhibit a large difference in residual stress levels if the material has a high work-hardening.

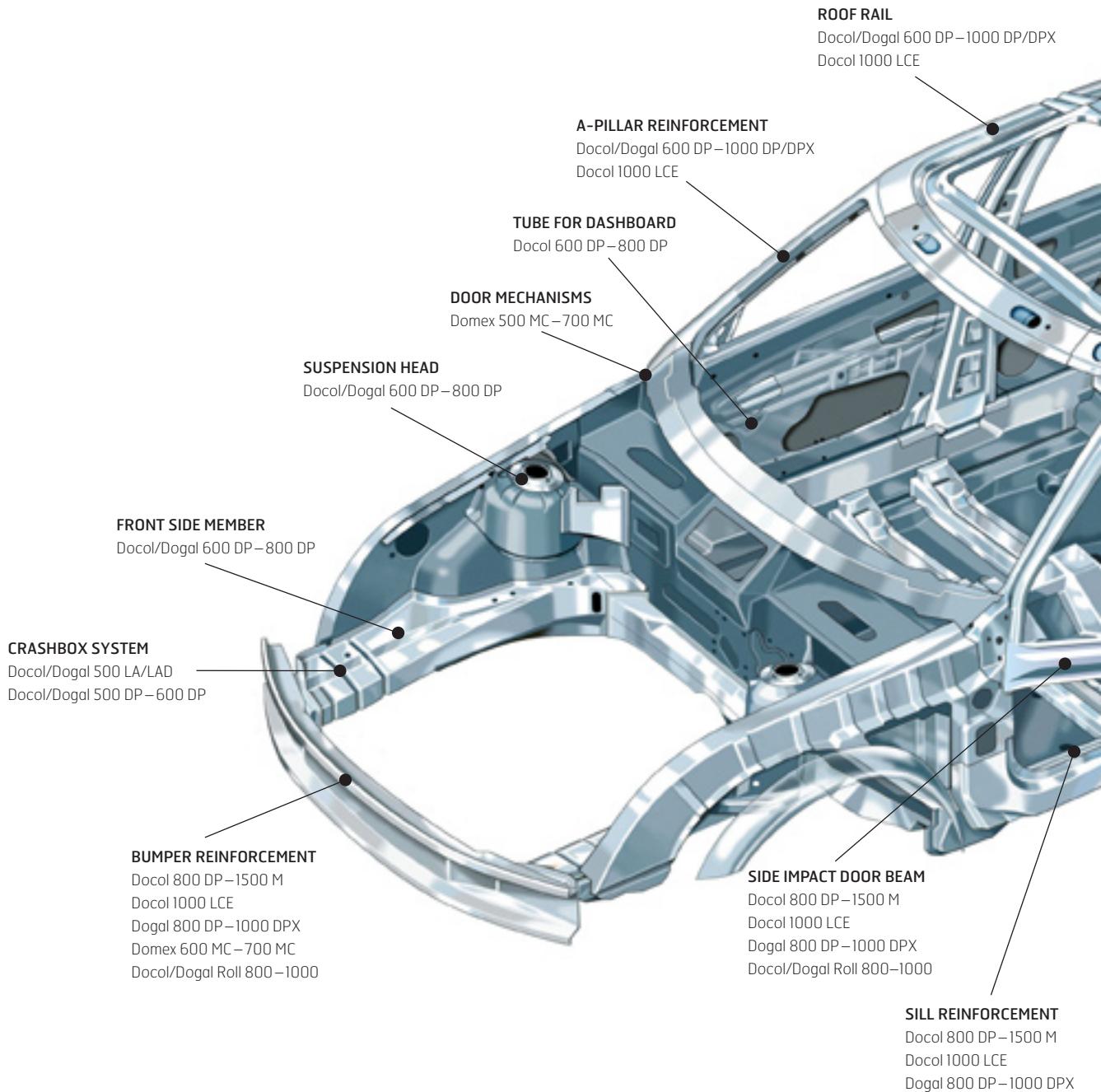
If the ratio of yield stress to tensile strength is close to equal, there will only be small differences in residual stresses between heavily and slightly deformed areas, and therefore fewer tendencies for the finished profile to bend or twist.

MICROSTRUCTURAL ASPECTS

Roll forming is virtually always done in the same direction as the rolling direction of the strip, therefore inclusions in the material will be oriented in the same direction as the bends. From a metallurgical standpoint, it is therefore important that the steel material has the highest possible cleanliness, which means absence of slag and inclusions – this makes Docol AHSS the favorite choice. The Docol AHSS microstructure is very homogeneous which reduces the risk that deformation will be concentrated in certain microstructural phases, which can lead to cracking.

STRIP THICKNESS TOLERANCES

As in most forming methods, dimensional tolerances of the finished part depend on the sheet thickness tolerances. Roll forming is no exception – narrow strip thickness tolerances contribute to process stability and a high accuracy of the manufactured parts.



All Docol AHSS steel grades can also be obtained with electro galvanized surface.

Recommended AHSS steel grades

Several parameters are used to determine the AHSS steel grade that is best suited for a given automotive application.

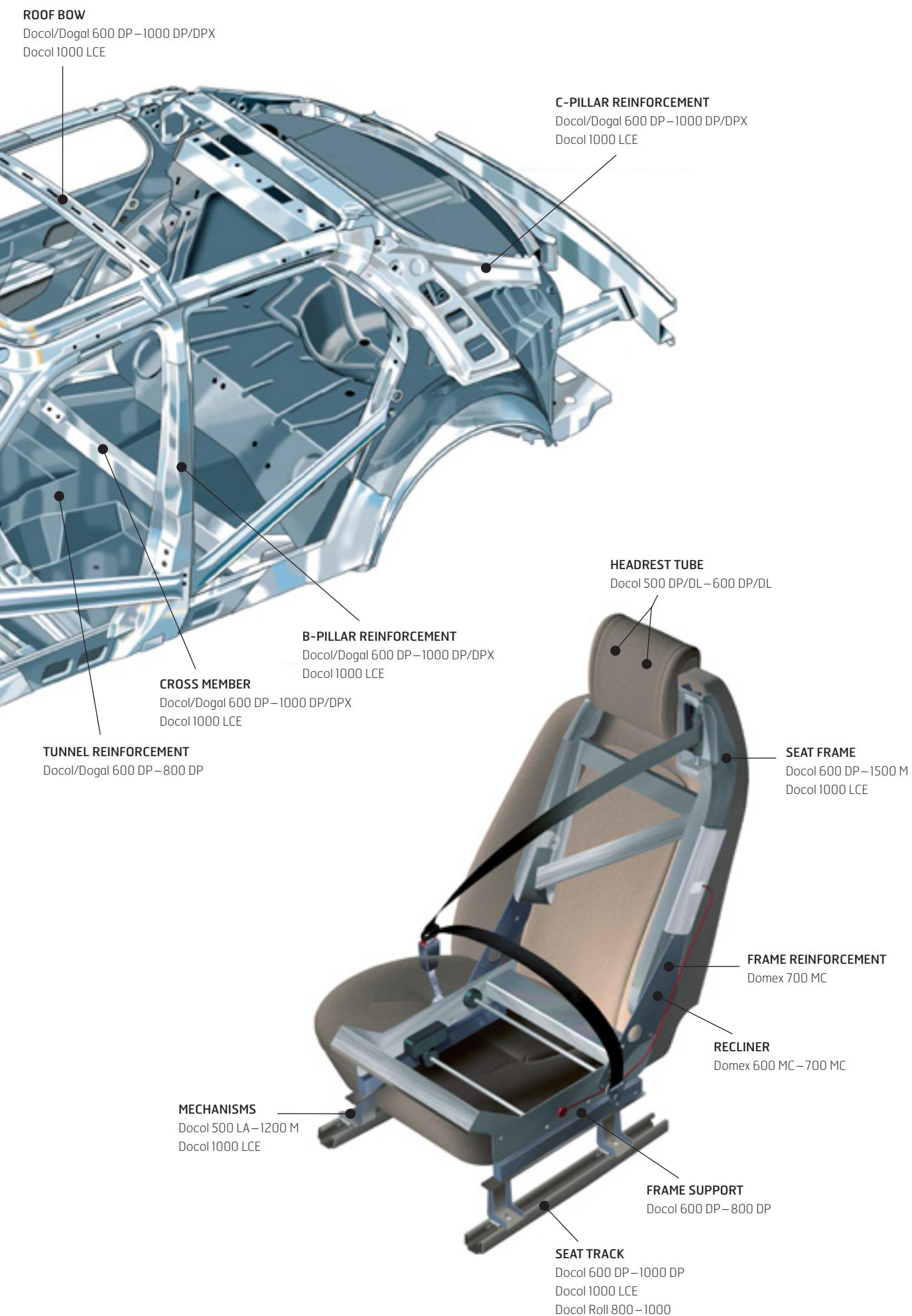
The demands of the stiffness of the car body could determine the possible reduction of the thickness of an individual part. The geometrical design of the part also influences the material choice.

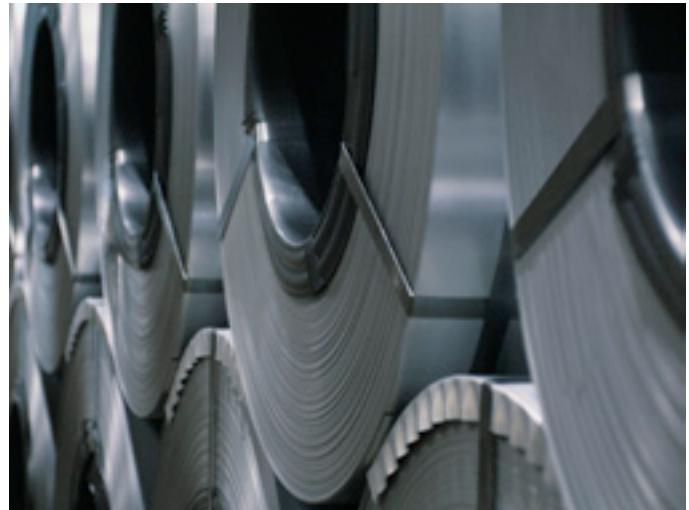
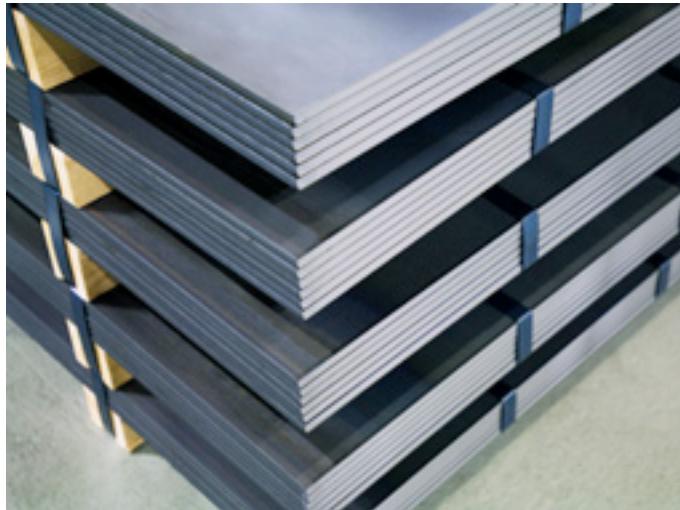
The method of forming also determines the grade of steel that should be specified. In a roll forming operation, tighter radii can normally be achieved and springback can be handled better than in press forming.

Upgrading parts such as bumper reinforcements and side

impact beams can often contribute to major weight savings, as the demands on energy absorption are high and these parts do not contribute to the stiffness of the body. Therefore, the strength of Advanced High Strength Steels can be optimally used.

Parts such as front side members, cross-members and various beams that must have both a high energy absorption capability, as well as contribute greatly to the stiffness of the car body are usually of a more complex geometrical shape. For these parts, a lower grade of Advanced High Strength Steel is appropriate.





AHSS product range of SSAB

RECOMMENDED AHSS STEEL GRADES FOR VARIOUS APPLICATIONS

APPLICATION	HOT-ROLLED STEELS			COLD-ROLLED STEELS										
	MC			LA	DP				M			SPECIAL STEELS		
	600	650	700	500	500	600	800	1000	1200	1400	1500 ¹	Roll 800	Roll 1000 ¹	1000 LCE ¹
BODY-IN-WHITE	Bumper reinforcement													
	Crash box													
	IP beam													
	Front side member													
	Cross member													
	Door beam													
	Waistline reinforcement													
	A-B-C pillar reinforcement													
	A-B-C pillar													
	Rocker/sill													
	Roof bow/Roof rail													
	Window member													
SEAT	Header front/rear													
	Package tray													
	Seat track													
	Recliner													
	Seat frame													

Our range of Advanced High Strength Steels for the automotive industry consists of:

- Micro-alloyed steels
 - Dual Phase steels
 - Complex Phase steels
 - Martensitic steels

MICRO-ALLOYED STEELS (I A)

SSAB's micro-alloyed cold forming steels derive their high strength from the addition of very small quantities of micro-alloying elements such as niobium and titanium. These steel grades are designated according to the lowest guaranteed yield strength. The difference between their yield strength and tensile strength is small. These steel grades have excellent bendability, press forming and flanging properties in relation to their yield strength.

DUAL PHASE STEELS (DP)

Dual Phase cold forming steels have a micro-structure that contains two phases: ferrite and martensitic. Ferrite is soft and contributes to good formability, whilst martensitic is hard and contributes to the strength of the material. The

strength increases with a larger proportion of the hard martensitic phase and depending on the application, DP steels with different yield ratios (YS/TS) can be produced. The figures in the steel designation specify the minimum tensile strength.

COMPLEX PHASE STEELS (CP)

The microstructure of complex phase steels contains small amounts of martensite, retained austenite and perlite within the ferrite/bainite matrix. CP steels are characterized by high yield strength, moderate strain hardening, good bendability and flangability. The figures in the steel designation specify the minimum tensile strength.

MARTENSITIC STEELS (M)

Martensitic steels contain 100 percent martensite. Martensitic steels have very high yield and tensile strength. The figures in the steel designation specify the minimum tensile strength.

Most often used steel grade for this application.

 Technological opportunity
for this application.

STEELS TO SPECIFIC STANDARDS

Cold-rolled AHSS can be adapted to the standards of car manufacturers by request.

Some examples of this are the Toyota TSG3100G, Honda HES C052-00, Nissan M 2032, Fiat 52815, Renault RNUR 11-04-002 and GM GMW 3399M-ST-S. The table below shows the steel grades belonging to the most common car manufacturer standards, available as cold-rolled material.

The hot-dip galvanized steels Dogal 500 DP, Dogal 600 CP and Dogal 780 CP are available to meet the European standard EN 10336.

All steel grades required to meet the specifications of a specific car manufacturer need to be evaluated case by case.

The hot-rolled steels Domex 460-700 MC are available according to European standard EN 10149-2.

More data about AHSS is available at www.ssab.com.

SPECIFY THE RIGHT GRADE OF STEEL

Several parameters determine the steel grade that is best suited for a given automotive application:

The demands for car body stiffness determine the possible reduction in the thickness of an individual part.

The geometrical design of the part determines the highest possible strength of the material used.

The method of forming is also an important factor in choosing the grade of steel that should be specified.

Major weight savings can often be made by upgrading parts, such as bumper reinforcements and side impact beams. This is because the demands on energy absorption are high and these parts do not contribute so much to the stiffness of the car body. The strength of AHSS can therefore be put to optimum use.

Front side members, cross-members and various beams that must withstand high energy absorption as well as contribute greatly to the stiffness of the body are usually of a more complex geometrical shape. For these parts a lower grade of AHSS can be specified.

TYPE OF STEEL	HOT-ROLLED STEELS	COLD-ROLLED STEELS	HOT-DIP GALVANIZED STEELS	ELECTRO GALVANIZED STEELS
Micro-alloyed steels	Domex 460 MC Domex 500 MC Domex 550 MC Domex 600 MC Domex 650 MC Domex 700 MC	Docol 420 LA Docol 500 LA	Dogal 420 LAD ^a Dogal H 420 LAD ^b Dogal 460 LAD ^a Dogal H 460 LAD ^b Dogal 500 LAD ^a Dogal H 500 LAD ^b Dogal H 550 LAD ^b Dogal H 600 LAD ^b Dogal H 650 LAD ^b Dogal H 700 LAD ^b	
Dual Phase steels	Docol 500 DP Docol 500 DL Docol 600 DP Docol 600 DL Docol 800 DP Docol 800 DL Docol 980 DP Docol 1000 DP	Docol 500 DP Docol 600 DP Docol 800 DP Docol 800 DPX Docol 1000 DPX	Dogal 500 DP Dogal 600 DP	Docol 500 DPZE Docol 600 DPZE Docol 800 DPZE Docol 1000 DPZE
Complex Phase steels			Dogal 600 CP Dogal 780 CP	
Martensitic steels	Docol 900 M Docol 1200 M Docol 1300 M Docol 1400 M Docol 1500 M ¹			Docol 900 MZE Docol 1200 MZE Docol 1300 MZE Docol 1400 MZE ² Docol 1500 MZE ²
Special steels	Docol Roll 800 Docol Roll 1000 ¹ Docol 1000 LCE ¹		Dogal Roll 800 Dogal Roll 1000	

a) LAD = cold-rolled substrate. b) HLAD = hot-rolled substrate.

1. Available by request. 2. Under development.

All Docol AHSS steel grades can also be obtained with electro galvanized surface.

DIMENSION RANGE

Thickness: Docol 0.50–2.10 mm (some grades up to 3.00 mm)
Dogal 0.50–2.00 mm (some grades up to 2.50 mm)
Domex 2.00–10.00 mm

Max width: Docol 1500 mm
Dogal 1500 mm
Domex 1600 mm

SSAB's Knowledge Service Center supports your product development

One of the most important tasks for the SSAB Knowledge Service Center is to immediately supply the automotive industry and its suppliers with facts, information and experiences that support them in making products lighter, stronger and safer.

Through the Knowledge Service Center help-desk or via e-mail, we provide assistance and technical support in all areas of the automotive industry including, choice of materials, designing for optimum performance and the complete production process, from tooling to joining.

The Knowledge Service Center puts our 30+ years of experience working with AHSS at the disposal of our customers through personal contact with our application engineers, material experts and technical advisors.

In fact, many of our customers say that the Knowledge Service Center is like having an expert team of consultants working in-house.

Instant support around the clock is also available on our website at www.ssab.com. This is a comprehensive database containing detailed product facts, downloadable auxiliary programs, material graphs and other information that simplifies analysis and design work.

Our manuals – the Sheet Steel Handbook, the Sheet Steel Forming Handbook and the Sheet Steel Joining Handbook – contain a wealth of information on all aspects of design and production with AHSS. The manuals also provide information on which types of AHSS are suitable for certain applications.

THE SHEET STEEL HANDBOOK

- Choice of materials and design philosophy
- Product range and material properties
- Design practice
- Structural design
- Fabrication

THE SHEET STEEL FORMING HANDBOOK

- Material Properties
- Size Shearing
- Plastic Forming
- Formability and material behaviour
- Tooling materials, surfaces and tribology
- Surface treatments and coatings

THE SHEET STEEL JOINING HANDBOOK

- Fusion welding
- Resistance welding
- Mechanical joining
- Adhesive bonding
- Soldering and brazing
- Fatigue – comparison between different joining methods
- Joining to other materials





ALWAYS A STEP AHEAD: Innovation is a top priority at SSAB

SSAB is the largest steel producer in Northern Europe. We are pioneers and market leaders in the field of Advanced High Strength Steel products, with more than 100 years of market success.

The automotive industry is one of our most important customers and we are strategic partners with a large number of leading automotive manufacturers. Our position as a highly specialized producer in our niche ensures that we are well tuned to the needs of our customers – and can take quick action.

The SSAB Swedish Steel Group had annual sales (2008) of more than SEK 54,000 million (about 5,100 Mio EUR), with deliveries to more than a hundred countries around the world and offices in more than 45 countries. The SSAB Group has 9,200 employees worldwide, with 3,800 of them working for SSAB Strip Products (formerly SSAB Tunnplåt). SSAB Strip Products produces more than 2,6 million tonnes of strip steel every year.

SSAB was formed in 1978 by the merger of three steelworks in Sweden. In 2007 the group expanded by acquiring IPSCO, a leading producer of Advanced High Strength Steel and other steel products in Canada and the U.S.

CONTINUITY, QUALITY AND STRINGENCY

SSAB Strip Products is a pioneer in the field of AHSS and started developing, marketing and producing AHSS over 30 years ago.

During the production of AHSS, very strict demands on continuity, precision and expertise are upheld. Our advanced production methods fulfill these demands in every step of the process. The dimensions, tolerances and internal properties of our steel is consistent in every delivery. This ensures smooth and trouble free production for our customers.

To achieve the consistency of quality that characterizes our steels, advanced production techniques are used in the steelworks and rolling mills. From the exact chemical composition of the steel slabs to the advanced post-treatment processes, SSAB is devoted to quality.

SWIFT AND RELIABLE DELIVERIES

One of the most important factors behind our leading position is providing efficient logistics solutions. Regular shipments from the mill in the middle of Sweden and centrally located buffer stocks around Europe ensure swift deliveries to all of our customers.

Our logistics network is now swiftly expanding to many other markets in Eastern Europe, Asia and North America. SSAB has also recently opened a Steel Service Center in China to serve the Chinese market.

SSAB is a global leader in value added, high strength steel. SSAB offers products developed in close cooperation with its customers to reach a stronger, lighter and more sustainable world.

SSAB employs 9,200 people in over 45 countries around the world and operates production facilities in Sweden and the US. SSAB is listed on the NASDAQ OMX Nordic Exchange, Stockholm.

SSAB is environmentally certified in accordance with ISO 14001 and has also obtained the ISO/TS 16949 and ISO 9001 certifications.

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