Steels for hot stamping

Extract from the product catalogue -European edition

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Steels for hot stamping
Very high strength steels

Description

Usibor® 1500 P and 22MnB5, which have very high mechanical strength after hot stamping, are two steels in the range of products developed to meet vehicle weight reduction requirements. Usibor® 1500 P and 22MnB5 are intended for use in automobile structural and safety components. These steels are designed to be heat treated and then quenched during the hot stamping process. The mechanical properties of the final part make significant weight savings possible (up to 50% compared to standard high yield strength steel). The very high yield strength of these steels after heat treatment and hot stamping make them suitable for anti-intrusion components (fender beams, door reinforcements, B-pillars, windscreen uprights, etc.).

The manufacturing process of these steels and the thermo-mechanical treatment they undergo during hot rolling lend them excellent quenchability and good structural homogeneity, ensuring good response to mechanical stress.

The main advantages of Usibor® 1500 P and 22MnB5 are:
- Separation of forming and service properties;
- High hot formability and total absence of springback;
- Exceptional fatigue and impact strength, allowing substantial thickness and hence weight reduction.

ArcelorMittal was the first steelmaker to offer the automotive industry a coated press hardened steel: Usibor® 1500 P.

Usibor® 1500 P has an aluminum-silicon pre-coating and was developed to protect the metal from oxidation (scale) and decarburization during hot stamping. The pre-coating is applied to the coils in a continuous process and offers excellent resistance to hot stamping heat treatment; final parts using this forming technology have improved corrosion resistance after painting, eliminating the need for anti-corrosion post-treatment. The additional advantages of Usibor® 1500 P (above and beyond those of 22MnB5) are:
- Elimination of the shot-blasting step required for conventional uncoated hot forming steels (no scale);
- Very good final part geometric tolerance (no shot-blasting, hence no deformation);
- Excellent final part corrosion resistance;
- No decarburization;
- Simplified process and cost savings (no shot-blasting, no inert atmosphere in ovens).

Two safety data sheets are available for each steel, one for the as-delivered product and one for the product after heat treatment. These steels require no special precautions.

ArcelorMittal has now added the new Ductibor® 500 P grade to its range of hot stamping steels. This product is offered in association with Usibor® 1500 P for use in Tailor Welded Blanks (TWBs), where it locally provides softer, more ductile properties than those of Usibor® 1500 P. This enables automotive manufacturers to meet new crashworthiness requirements by precisely controlling the crash deformation of specific vehicle parts such as the B-pillar in lateral impact and the longitudinal beams in front and rear impact.

Applications

Because of their high impact and fatigue strength, 22MnB5 and Usibor® 1500 P are particularly well suited for the entire range of structural parts and especially for safety parts.

Most of the current applications are intrusion-resistant passenger and engine compartment components:
- Front and rear bumper beams;
- Door reinforcements;
- Windscreen upright reinforcements;
- B-pillar reinforcements;
- Floor and roof reinforcements.
ArcelorMittal has a complete set of data relating to the forming and the service properties of steels for hot stamping. To integrate these steels at the design stage, a team of experts is available to carry out specific studies based on modeling or laboratory tests.

**Technical characteristics**
Technical characteristics

Mechanical properties

As delivered, before hot stamping (for information only)

<table>
<thead>
<tr>
<th>Material</th>
<th>YS (MPa)</th>
<th>UTS (MPa)</th>
<th>$\varepsilon$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usibor® 1500 P</td>
<td>350-550</td>
<td>500-700</td>
<td>≥ 10</td>
</tr>
<tr>
<td>22MnB5*</td>
<td>320-550</td>
<td>500-700</td>
<td>≥ 10</td>
</tr>
<tr>
<td>Ductibor® 500 P</td>
<td>450-650</td>
<td>550-680</td>
<td>≥ 20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>YS (MPa)</th>
<th>UTS (MPa)</th>
<th>$\varepsilon$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usibor® 1500 P</td>
<td>1100</td>
<td>1500</td>
<td>6</td>
</tr>
<tr>
<td>22MnB5*</td>
<td>1100</td>
<td>1500</td>
<td>6</td>
</tr>
<tr>
<td>Ductibor® 500 P</td>
<td>400</td>
<td>570</td>
<td>22</td>
</tr>
</tbody>
</table>

* Please consult us about size availability.

After hot stamping according to best practices □ typical values* (for information only)

<table>
<thead>
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<td>Usibor® 1500 P</td>
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<td>22MnB5*</td>
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<td>6</td>
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<tr>
<td>Ductibor® 500 P</td>
<td>400</td>
<td>570</td>
<td>22</td>
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</table>

* 5 to 10 minutes 900°C to 950°C type heat treatment followed by quenching in perfectly cooled stamping tools (cooling speed > 50°C per second).

Application and use of Ductibor® 500 P and final part performance values are described in the "Multi-thickness laser welded blanks: Tailored Blanks" chapter.

The metallurgy of Ductibor® 500 P was developed to provide, following hot stamping, a Dual Phase type structure with very stable mechanical properties regardless of the cooling speed.

Die-quenched (cooling rate 30°C/s) □ Ferrite + Martensite (10%)

In Usibor® 1500 P and 22MnB5 steels, the addition of carbon, manganese, chromium and boron ensure good quenchability in the hot stamping tool after austenitization in the ovens. Water quenching results in substantially higher mechanical properties (an additional 100 to 150 MPa). Prior to hot stamping heat treatment, Usibor® 1500 P and 22MnB5 exhibit homogeneous distribution of pearlite and an equiaxed grain ferritic matrix. The Usibor® 1500 P coating, with a thickness of about 25µm, consists of an Fe-Al-Si alloy diffusion layer and an aluminum-silicon layer.

Following heat treatment and quenching, the microstructure is 100% martensitic. The Al-Si coating is transformed in the oven into a protective Al-Fe-Si alloy layer adhering perfectly to the substrate.

Microstructure prior to hot stamping heat treatment (as delivered).
Appearance of the coating prior to hot stamping.
Martensitic microstructure following hot stamping heat treatment (example: 5-minute austenitization at 900°C, followed by water quenching or die quenching). Scanning electron micrograph.

Appearance of the coating after hot stamping (optical microscopy)

The chemical composition and microstructure of Usibor® 1500 P and 22MnB5 have been optimized to promote the formation of a homogeneous martensitic structure over a wide range of cooling speeds, which ensures very good, highly regular mechanical properties in the final part.

The Al-Si coating of Usibor® 1500 P has been optimized to withstand heat treatment and the hot stamping process as well as to avoid oxidation and scale formation.

**Heat treatment**

Usibor® 1500 P was specially developed for a direct hot stamping process consisting of austenitization of blanks in the heat treatment oven, hot stamping of these hot blanks in a press and martensitic quenching in the water-cooled stamping tool. All forming is "hot". We advise against cold pre-forming prior to austenitization.

Please consult us for information and advice relating to Usibor® 1500 P hot stamping.

The 22MnB5 grade is well suited to both hot and cold forming and can therefore be used in both direct and indirect processes.

**Surface treatment**

Adhesive bonding parameters are similar to those of other uncoated carbon steels.

After hot stamping and quenching, Usibor® 1500 P components can be painted directly. There is no surface scale and the Al-Fe-Si alloy layer obtained after heat treatment adheres perfectly to the substrate. This layer provides good protection against overall corrosion.

Parts made of Usibor® 1500 P can be painted by cataphoresis or any other organic painting system.
Following hot stamping, the surface of Usibor® 1500 P is not affected by immersion in phosphating baths and it does not contaminate the latter through dissolution of aluminum.

Most adhesives, including structural adhesives, can be used on hot stamped Usibor® 1500 P components.

Please consult us for information and advice relating to surface treatment of Usibor® 1500 P after hot stamping.

Following hot stamping, quenching and shotblasting, the surface of 22MnB5 can receive the same treatment as most uncoated carbon steels.

After phosphating, parts made of 22MnB5 can be painted by cataphoresis or any other organic painting system. Compatibility with adhesives is comparable to that of other uncoated carbon steels.

**Welding**

Usibor® 1500 P has excellent spot weldability for both matching and non-matching joints at both 50 and 1000 Hz.

The product has a wide welding range and the mechanical (tensile, shear) performance of the joints complies with automotive manufacturer requirements and with standards. Thanks to the alloy layer obtained after hot stamping, welding electrode life is considered exceptional (several thousand spots without deterioration) compared to that of conventional metal coatings. MAG, MIG and conventional metal welding techniques, including brazing, can readily be applied.

Based on long shop-floor experience in the characterization of its products for purposes of resistance spot welding and arc welding, ArcelorMittal can provide technical support for welding parameter adjustment.

The weldability of 22MnB5 is comparable to that of other carbon steels of similar composition.

Matching Usibor® + Usibor® joint

Triple thickness non-matching joint with multiphase steel

MAG weld

**Fatigue strength**

Fatigue strength can be expressed as an endurance limit (maximum stress). Usibor® 1500 P offers excellent fatigue properties (superior to those obtained in uncoated steels for hot stamping) with decarburized surface.
The table below shows 2 million cycle endurance limits, expressed in MPa, in a uniaxial tension-compression test for $R = 0.1$ and $R = -1$.

<table>
<thead>
<tr>
<th></th>
<th>$\sigma_n$ A $10^6$ cycles (MPa)</th>
<th>$\sigma_n$ A $10^6$ cycles (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usibor® 1500 P</td>
<td>727</td>
<td>475</td>
</tr>
<tr>
<td>Standard uncoated 22MnB5 (without pre-coating)*</td>
<td>617</td>
<td>305</td>
</tr>
</tbody>
</table>

* Decarburized surface after hot stamping with a thickness of approximately 30 µm.

These tests were carried out on 1.5 mm specimens. This example again shows the weight saving potential of Usibor® 1500 P.

**Impact resistance strength**

Impact strength is the area in which Usibor® 1500 P and 22MnB5 come into their own. We can supply detailed information about the exceptional impact strength and the anti-intrusion properties of these two products.

When these steels are used, the thickness required to achieve the same performance as standard drawing steels can be halved.

The example below shows the results of a three point bending flexural test at 29 kph with 10 kJ energy equivalent. The maximum loads recorded on specimens with an top-hat type cross-section and 1.5 mm thickness are shown. This example demonstrates the potential weight reduction offered by hot stamped steels compared to more conventional steels.

Specimen shape used in the three point bending flexural test

Ultimate load measured during a bending flexural test at 29 kph (10kJ) (thickness: 1.5 mm)

Three point bending flexural test specimen before and after crash test

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