

Innovative Press Hardened Steel Based Laser Welded Blanks Solutions for Weight Savings and Crash Safety Improvements

Daniel Duque Múnera, Aurélien Pic, Damien Abou-Khalil and Francis Shmit
ArcelorMittal Automotive Applications Research Center

Fabrice Pinard
Noble International

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ABSTRACT

This paper summarizes our latest developments in the field of Press Hardened Steel (PHS) based Laser Welded Blanks (LWB). New PHS steel named Ductibor 500P has been developed to enlarge the range of LWB applications in combination with Coated Boron Steel (CBS). Laser welding of these materials is presented through static and dynamic test results of laser welded specimens. Mass analysis and crash simulations results for three different applications are presented and analyzed. For these applications weight savings ranging from 4.1 to 5.4 kg/veh were achieved.

INTRODUCTION

For the last few years, the use of PHS for the body-in-white structure has grown tremendously. For example, the new Volkswagen Passat is comprised of 10% hot-stamped monolithic parts. The same trend will be seen in many new vehicles coming off European or American production lines in the coming years.

The success of PHS can be explained by its various advantages: highly complex parts can be drawn avoiding spring-back problems; significant weight reduction can be achieved thanks to the outstanding structural performance of boron steels, offering important crash safety improvements. If a vehicle is involved in a collision or gets turned upside down, the Ultra High Strength Steels (UHSS) in these parts help prevent intrusion, thus preserving the integrity of the passenger compartment.

In support of our initial proposal to use CBS-based Laser Welded Blanks as B-pillars and then continuing support to use the same concept on other parts, we studied some innovative applications, where it was possible to combine the advantages of CBS with tailored blanks. Furthermore, in order to increase the number of hot-stamped LWB applications, a brand new steel, called Ductibor 500P, has been designed for the most demanding energy absorption areas.

The objective of this paper is to present the most recent developments regarding three applications with large importance in crash safety: (1) door ring, (2) rear rail and (3) front rail, where significant weight savings can be achieved.

First some in-use properties of actual physical specimens are discussed; then the results of crash-test simulation - made to validate the behavior of proposed solutions - are analyzed. These LWB solutions are compared to the monolithic reference parts in terms of mass and crash performances.

LASER WELDING METALLURGY OF USIBOR 1500P / DUCTIBOR 500P LWB

For few years, PHS based LWB are being more and more envisaged as efficient crash management and weight saving solutions. For this purpose, Coated Boron Steel (e.g.: Usibor 1500P) is a very good candidate but need some cares during welding to reach optimal performances. Indeed, AlSi coating dilution in the molten pool leads to the creation of brittle FeAlSi intermetallic phases which make the LWB not functional: failure in the weld seam with low elongation (<2%) and then very low absorbed energy in a crash load. A dedicated process is now available to take a full advantage of such solutions and carry on laser welding regardless AlSi coating dilution problems.

C	Mn	P	S	Si	Cr	Mo	Nb	V	Ti	B
223	1217	18	2	260	203	2	2	5	38	3.7

Table 1. CBS Usibor 1500P composition in 10-3 wt%

To expand possibilities, Ductibor 500P – a brand new PHS – has now been developed specifically for LWB issues. This steel grade is characterized by a very good stability during the hot-stamping process and high ductility after hot-forming: UTS is around 600MPa and elongation can overcome 20%. It is a ferritic steel – close to HSLA steels range – with specific micro-alloying to guaranty good stability during hot-stamping. The final

microstructure is a combination of ferrite and martensite, with stable ferrite grain size even with large cooling speed variations.



Figure 1. Final microstructure of Ductibor 500P at 30°C/sec (Die-quench). Ferrite + Martensite < 10%



Figure 2. Final microstructure of Ductibor 500P at 100°C/sec (Water-quench). Ferrite + Martensite 10% to 20%

PHS-based LWB are always welded before hot-stamping. The specific process developed applies before hot-stamping stage.

Laser welding of CBS / Ductibor 500P requires some cares as for CBS / CBS LWB: some AISi coating dilution occurs in molten zone, resulting in Fe-Al-Si intermetallic particles creation. The specific process has to be applied to avoid these problems and guarantee full performances of the LWB.

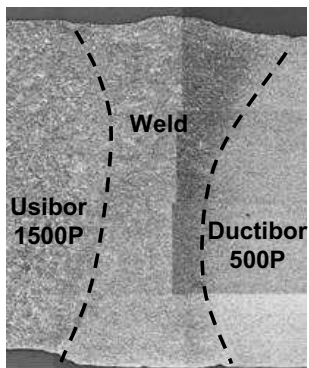


Figure 3. Usibor 1500P / Ductibor 500P laser seam section after heat treatment

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

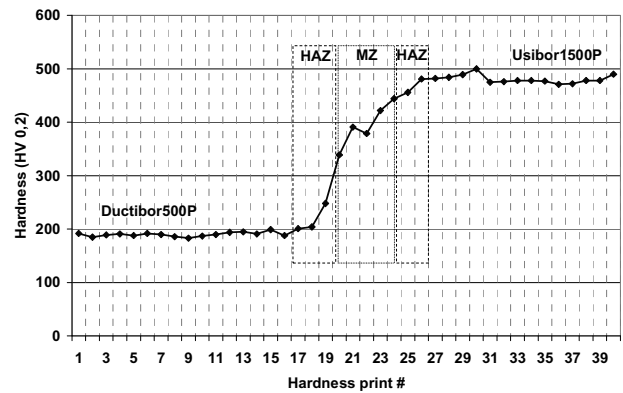


Figure 4. Hardness measurements after heat treatment through base metals and molten zone on Usibor 1500P/Ductibor 500P LWB

IN-USE PROPERTIES OF USIBOR 1500P / DUCTIBOR 500P LWB

STATIC PROPERTIES - Quasi static tensile tests performed on CBS 1.5mm / Ductibor 500P 1.5mm LWB shows that in case of loading perpendicular to the weld line, failure occurs on Ductibor 500P side. In this configuration, only Ductibor 500P deforms: in other words only one half of the sample deforms, leading to a measured elongation that is half of the elongation of Ductibor 500P base material (see figure 6).

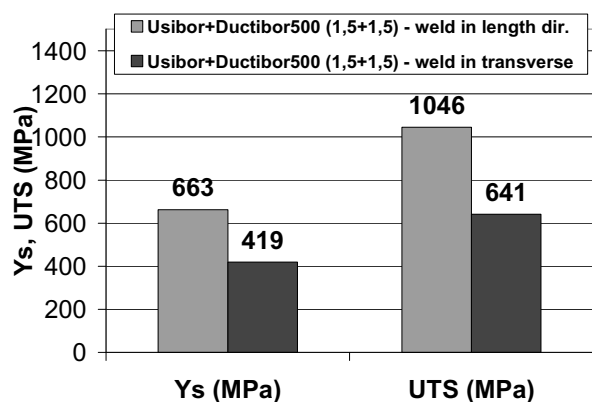


Figure 5. UTS results for LWB specimens after heat treatment welded in length and transverse direction

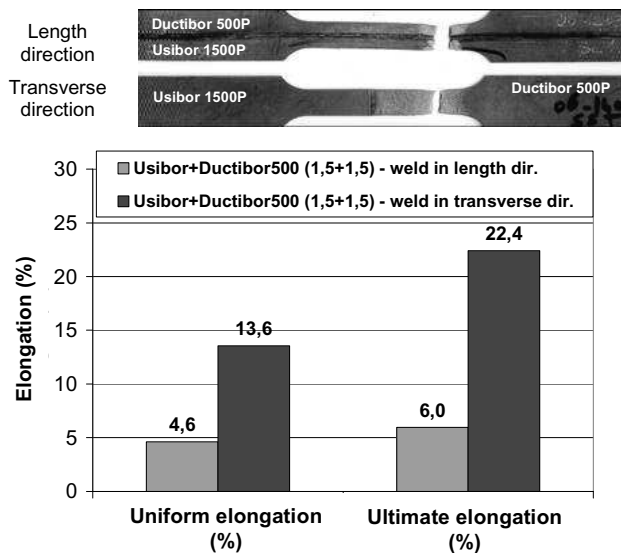


Figure 6. Elongation results for LWB specimens after heat treatment welded in length and transverse direction

DYNAMIC PROPERTIES - Several dynamic tests have been performed: 3 point bending tests and high speed tensile tests to assess weld quality, crush test to evaluate the performances of CBS / Ductibor 500P LWB as for front or rear rail concepts.

Three point bending tests have been performed on industrial parts, at a test speed of 8m/s with an impactor mass of 380kg. The kinetic energy developed is then of 12kJ. The impact is weld centered: this is the most critical configuration to check if the weld could be a weak point.

The failure occurred on Ductibor 500P base metal side, at some millimeters from the weld line, just next to the mechanical-properties-transition zone.

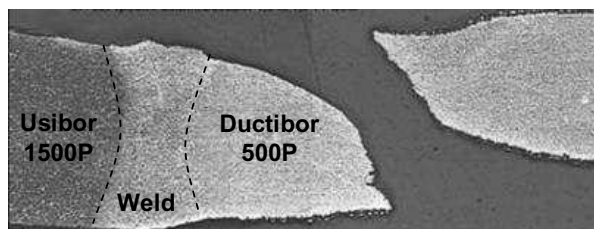


Figure 7. Three point bending failure zone

This test shows that even with very stringent test conditions, the weld zone is not critical. The performances of the part will be driven by thicknesses optimization and weld positioning. A small impact offset on Ductibor 500P side leads to a strong deformation of this material without exceeding any critical limit.

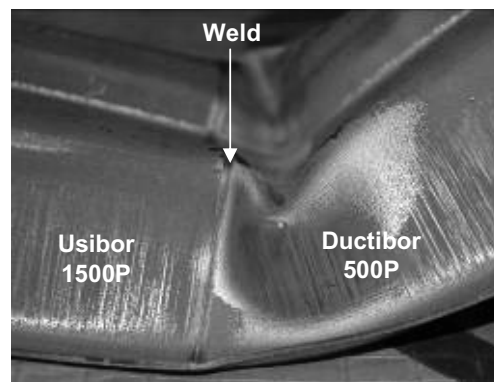


Figure 8. Three point bending specimen

To complete those tests, high speed tensile tests have been performed on welded samples with the weld line in transverse direction. In all cases, failure occurs on Ductibor 500P base metal side.

Crush test on laser welded omega samples have been performed to evaluate the performances of a front or rear rail concept: CBS ensures anti-intrusion function and Ductibor 500P absorbs energy while deforming.

The test sample was defined as follow:

- A CBS 1.5 mm / Ductibor 500P 1.5 mm blank has been hot-stamped with an omega tool. The CBS side is 115mm long and the Ductibor 500P side is 145mm long.
- A CBS 1.5mm / Ductibor 500P 1.5mm closing plate has been hardened and then spot welded on the omega-shaped test sample. The CBS / Ductibor 500P ratio is the same as on the omega part.

The crush was done at a speed of 16m/s with an impactor mass of 350kg. The developed kinetic energy is then of 45kJ.

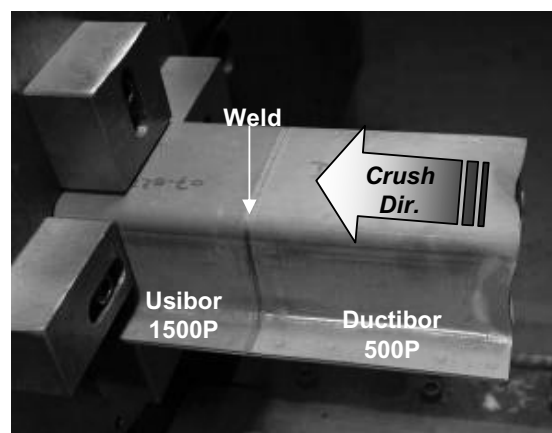


Figure 9. Crush test LWB specimen