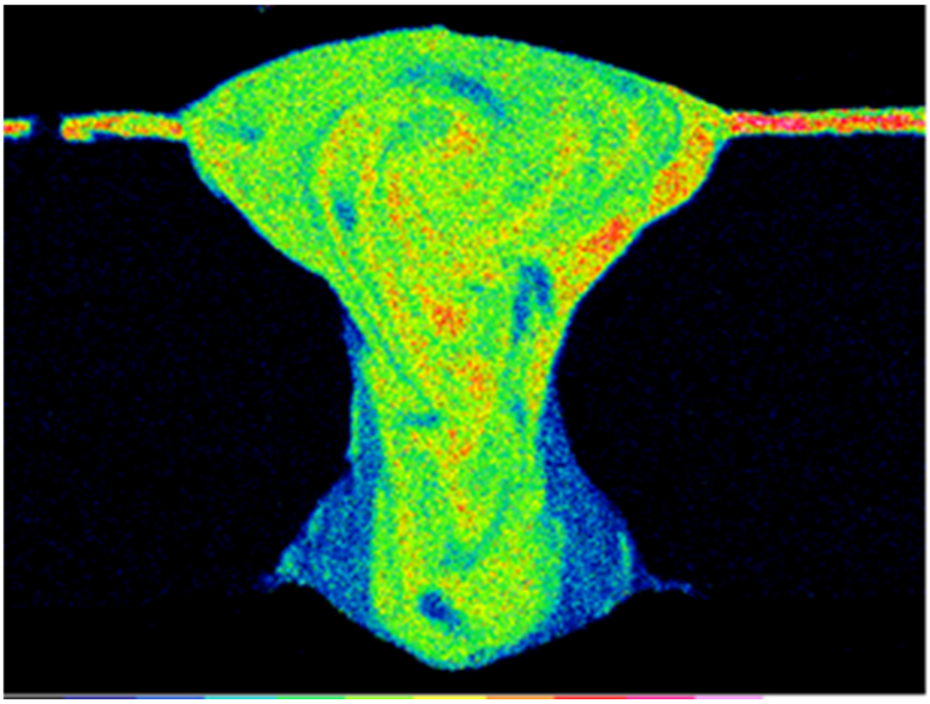
IMTAB

Improved Tailored Blanking



Project within FFI - Sustainable Manufacturing Systems / Production Technology

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Content

1. Executive summary

This project serves to improve weld quality and strength of tailor welded blanks as well as increasing the efficiency when manufacturing TWB's. There are several publications in the literature stating that welding of AlSi coated boron steel without any pre-treatment often results in formation of unwanted phases in the weldment. Such phases reduce the weld strength and generally make the joint more brittle. These problems are normally solved by locally removing the AlSi coating in a separated process step before welding. One of the main goals of this project was to join tailor welded blanks using only one process step without locally removing the AlSi coating and still achieve the required weld strength needed for subsequent forming operations and good crash performance.
By reducing the amount of process steps required for tailor welded blank manufacturing, this project will lead to:

- reduced vehicle weight and increased transport efficiency
- improved productivity and manufacturing capability (larger and more complex parts)
- improved product and joint properties (better weld quality, formability, toughness)
- better competitiveness

By developing a more sturdy joining process a lot can be gained in terms of process efficiency and cost reduction in the manufacturing of tailor welded blanks.
In this project a mixture of two well-known processes were used for welding of TWB's, laser and MAG welding. This process is from now on referred to as laser-hybrid welding. Laser-hybrid is a high productivity process compared to pure MAG welding and the combination of two processes helps to cope with some of the problems associated with pure laser and MAG welding separately. Compared to pure laser welding, laser-hybrid welding does not have the same demand on edge tolerances and set-up, thus less time and money needs to be spent on machining, measurements, and quality assurance.

Results from this project show that correctly used, laser-hybrid can achieve welds in Usibor 1500P materials that reach 95% of the strength of welds made on uncoated 22MnB5 materials, in one process step without locally removing the AlSi coating.

Optimized laser-hybrid welds were also tested on full scale B-pillars where they performed as good as conventionally laser-welded B-pillars (with coating removal) and non-welded B-pillars. All welds were intact after both static and crash testing.

In all, the project has successfully gathered knowledge on the determining factors for a sturdy process with high weld quality, approved crash performance, and improved productivity. All project goals have been fulfilled.

2. Background

Tailored Blanking is a technology already in use to some extent in the vehicle industry. It comprises joining of specially selected materials into one larger sheet or component. The intention is to use exactly the required material thickness or strength in each part of the component, i.e. a tailor made component.

The main drivers for introduction of tailored blank technology are substantial weight and cost savings, which has made it a multi-billion industry in automotive manufacturing with dedicated companies all over the world. The world market for tailored welded blanks in the automotive industry is today estimated to around 200,000,000 units per year, a figure that is growing with between 7-8% for each year. Utilizing this tailored technology the number of stamping tool sets for car body applications can be substantially reduced, as can various assembly and welding equipment. Studies have shown that designing and manufacture of side doors for passenger cars using tailored welding blank technology will mean a cost saving per door of approximately 50 SEK, meaning -200 SEK for a sedan car model.

In Figure 1, an overview of possible tailor welded blank applications are illustrated.

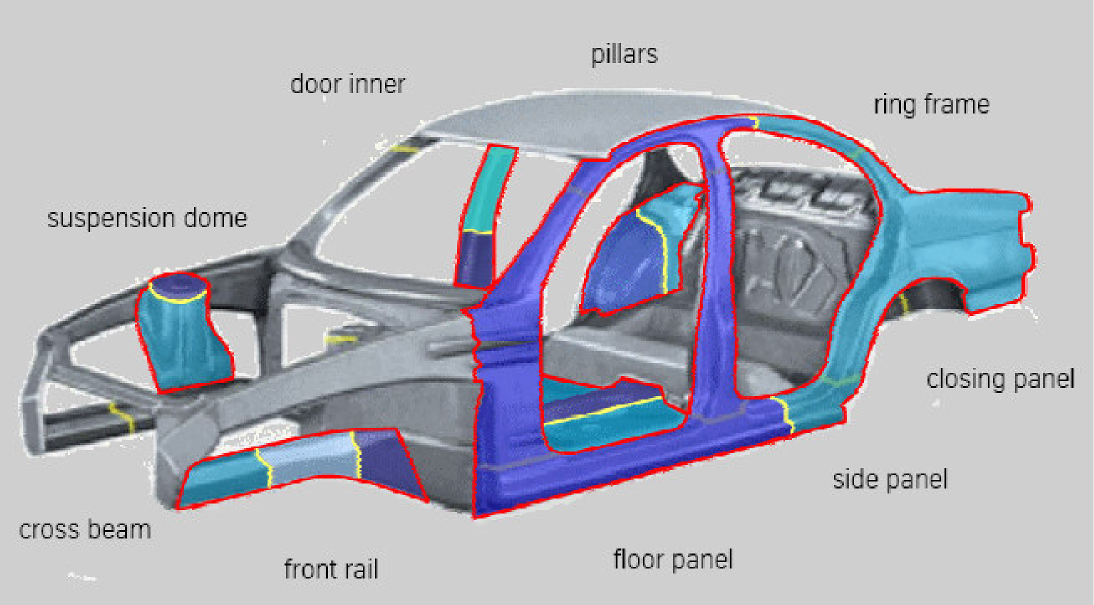

Figure 1 - Tailor welded blank application for vehicles

Tailor welded blank products will contribute to reduced emissions of CO_2 due to the reduced vehicle mass. In Figure 2, the mass reduction of some potential tailor welded parts is shown (source: ArcelorMittal).

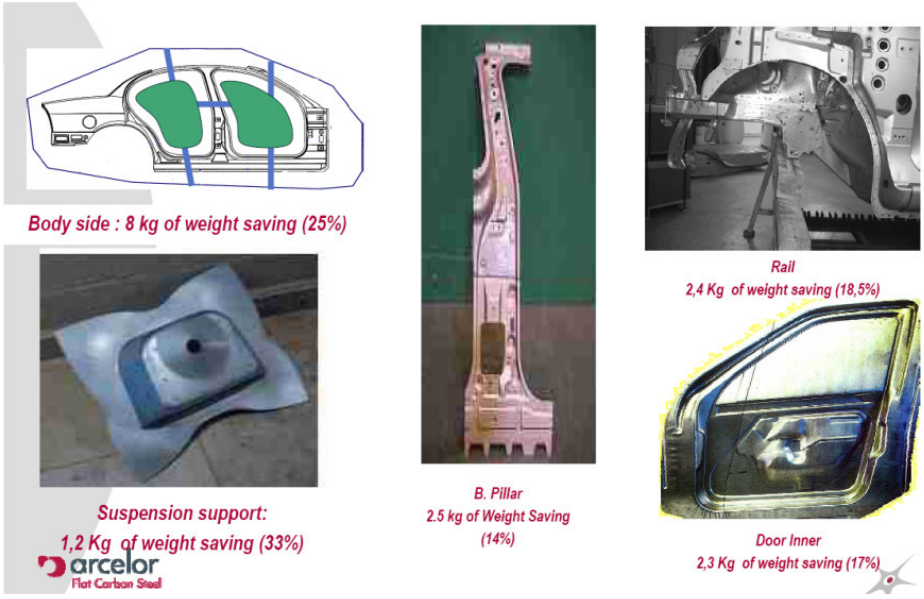

Figure 2 - Weight potential of tailor welded blank applications

Laser welded Tailored blanks is, however, an area where very narrow part and edge tolerances are required to reach sufficient quality and success in subsequent forming operations. For advanced high strength steels there are normally weldability issues to handle and when these steels are coated, there are also process stability and potential cracking issues to handle. A more often used coating for press hardened parts in crash applications is the AlSi coated Boron steel (Usibor 1500P) – this and many other thicker coatings need local removal before joining to avoid process instabilities and reach sufficient weld and product quality (1). For the welding of tailored blanks, this reduces productivity and, when less successful, poor joint quality.
The blanks in the tailored blank manufacturing have very high demands on the cutting edge quality and the accuracy of dimensions. Much is to gain if a more sturdy joining technology could be developed for tailored blanking, enabling direct joining without initial local removal of surface coating and with higher capability for rough cutting edges. This project aimed to do this development, and at the same time also reach improved quality, formability and crash performance.

3. Objective

The objective for this project was to solve important problems for Tailored Blanking and thereby enabling increased use of Tailored Blanks for press hardened components. It should lead to:
- reduced vehicle weight and increased transport efficiency
- improved productivity and manufacturing capability (larger and more complex parts)
- improved product and joint properties (better weld quality, formability, toughness)
- better competitiveness

4. Project realization

The project was divided into eight work packages according to the Gantt schedule in Figure 3 below. In Figure 4 the interaction between different work packages contributing to the experimental part are described visually. Knowledge gained from the initial work packages were later used in the manufacturing and evaluation of a full scale demonstrator.

		2010				2011				2012			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
WP0	Project lead												
WP1	State-of the art pre-study of laser stability improvement techniques			M1									
WP2	Mechanism studies and keyhole enhancement				~~M2~~		M2						
WP3	Influence of manufacturing systems				~~G1~~		~~M3/G1~~		M3				
WP4	Verification of weldability and joint properties						M41		M42				
WP5	Development of demonstrators with Tailored Blanks						G2		M5				
WP6	Evaluation of demonstrators & manufacturing systems												
WP7	Sharing of knowledge, Reporting									M71	M72 M73		

Figure 3 – Gantt schedule of the IMTAB project. Red boxes represent the original time plan.

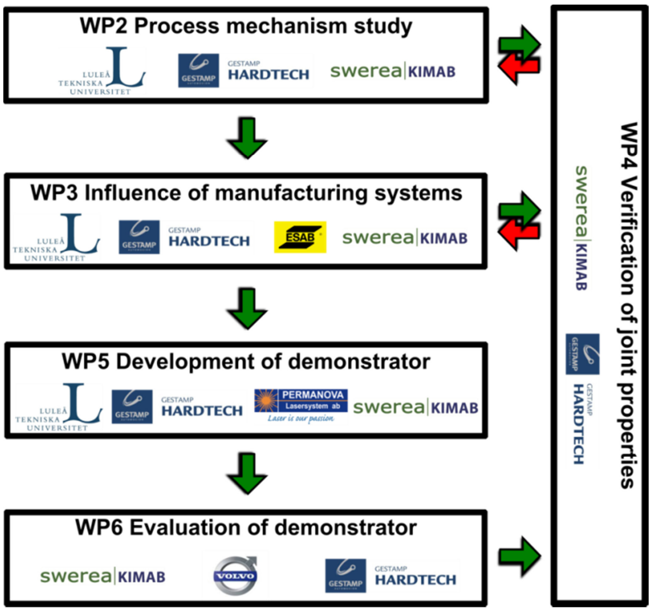

Figure 4 – Flowchart of the experimental part of the project

5. Results and deliverables

Todays' manufacturing of AlSi coated tailor welded blanks involves local removal of the surface coating around the weld. If the AlSi coating is not removed, the joint strength becomes heavily reduced due to the formation of intermetallic phases and ferrite in the weldment as shown in Figure 5 below (1).

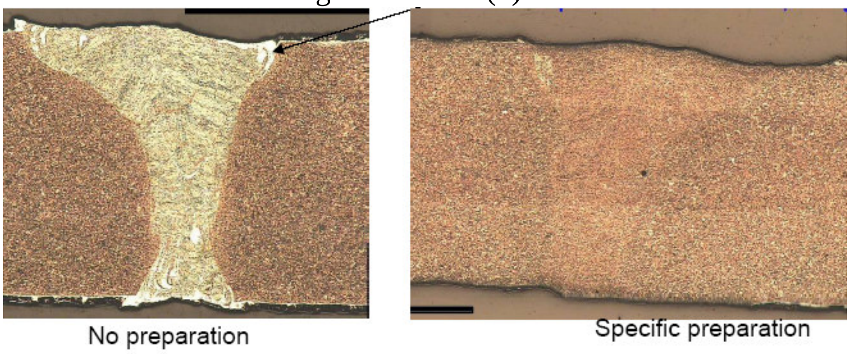

Figure 5 – Conventional laser welding of TWB's with and without removal of AlSi coating

The initial part of the IMTAB project was dedicated to better understanding the influence of AlSi coatings on the reduction of weld strength in Usibor 1500P materials. Laser welds were made in both uncoated and coated boron steels to investigate the difference in metallurgy and weld performance due to the AlSi coating. Figure 6 show the visual effects of the AlSi coating on the metallurgy in the weld as well as the effects on the tensile strength. Laser welds made on AlSi coated boron steel material, without coating removal show roughly a 30% drop in tensile strength compared to uncoated materials.

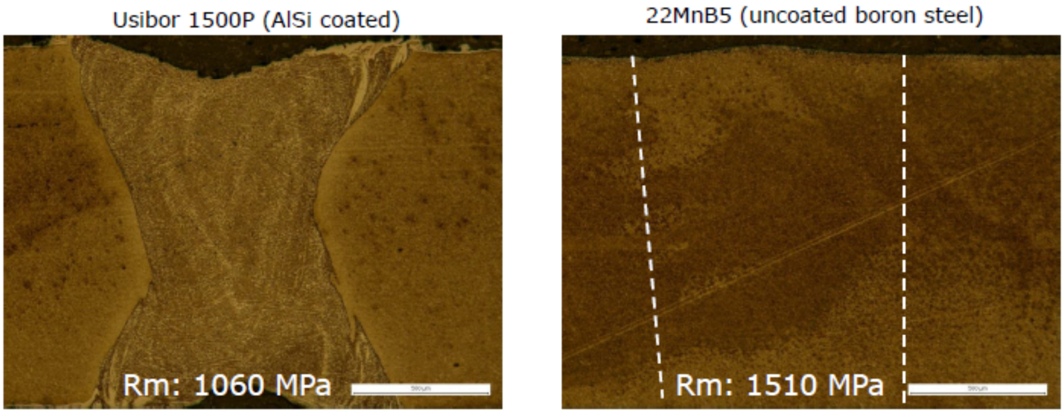

Figure 6 – Laser welds made on Usibor (AlSi coated) and uncoated boron steel

EBSD and EDS measurements were made on laser-hybrid welds showing the same tendencies of formation of unwanted phased in the weldment as the pure laser welded joint in AlSi coated boron steel material without coating removal. Results from these measurements are displayed in Figure 7 & Figure 8 below. EDS composition values show that as much as 4.75% Aluminium was detected in the ferritic areas of the weld joint.

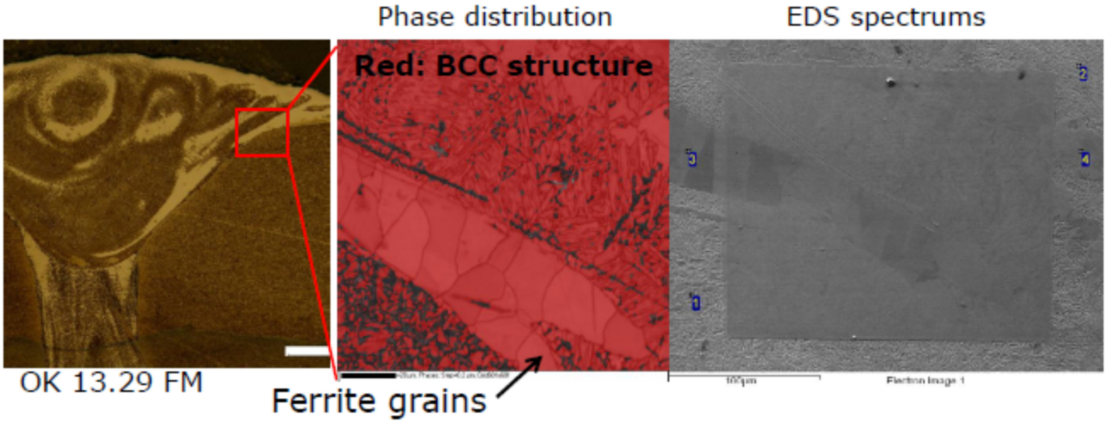

Figure 7 – EBSD and EDS measurements of white areas in a laser-hybrid welded AlSi coated boron steel material. Images from SEM are mirrored compared to the LOM image to the left.

EDS spectrum results

Spectrum	Al	Si	Cr	Mn	Fe	Ni	Total
1			0.38	1.73	97.89		100.00
2	1.30	0.76		1.79	96.15		100.00
3	4.75	1.02		1.51	91.84	0.89	100.00
4	2.46	0.68		1.46	94.37	1.02	100.00

All results in weight%

Figure 8 – Composition values obtained from the EDS measurements

Thermodynamic calculations were used to better understand the influence of the AlSi coating on the metallurgy of the welds in AlSi coated boron steel. Results show that already after solving 1wt% aluminium into the steel, the ferrite phase starts to form at hardening temperatures, Figure 9. If any ferrite is present during hardening of these steels the strength will be heavily reduced.

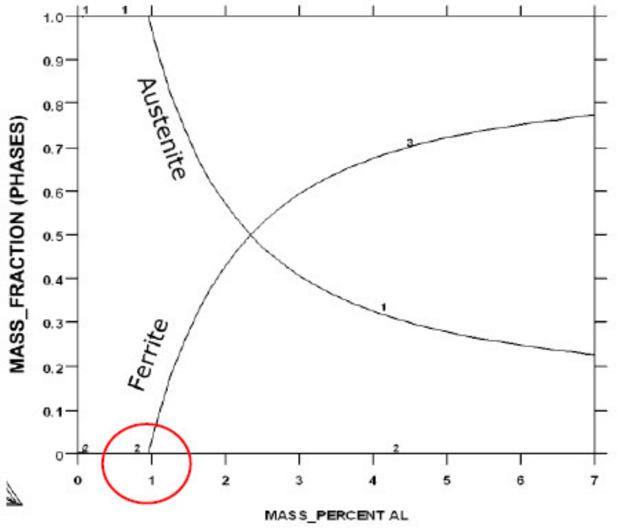

Figure 9 – Thermo-Calc calculation of 22MnB5 material (uncoated boron steel) at hardening temperature.

Additional thermodynamic calculations were performed to investigate possibilities to prevent ferrite formation during welding of AlSi coated boron steel materials. In the case of laser-hybrid welding it is possible to add filler material during welding and thus modify the weld metallurgy.

By adding an austenite stabilizing filler material during welding a larger amount of aluminum can be tolerated in the steel without the formation of ferrite. Figure 10 show that with a hypothetical mixing rate of 50%, 3wt% aluminum can be dissolved into the steel without any formation of ferrite at hardening temperatures. This is three times more aluminium than for the pure laser welding case.

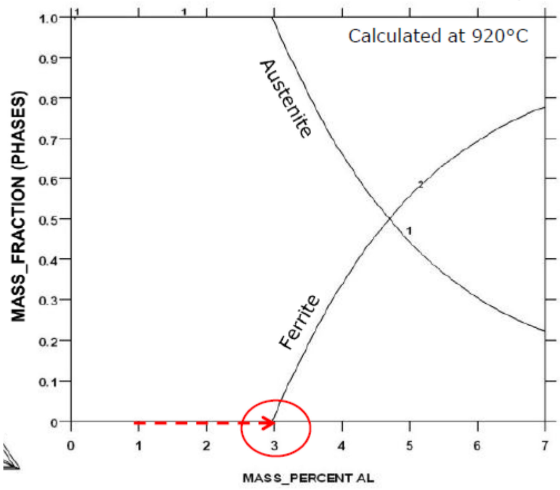

Figure 10 – Thermo-Calc results of base material mixed 50/50 with an austenite stabilizing filler material

The knowledge gained from the initial mechanism study was used to help improve weld strength of laser-hybrid welds in AlSi coated boron steels. Figure 11 shows tensile test results obtained from pure laser welding in AlSi coated boron steel and Laser-hybrid welding using non optimal process setup and filler materials.

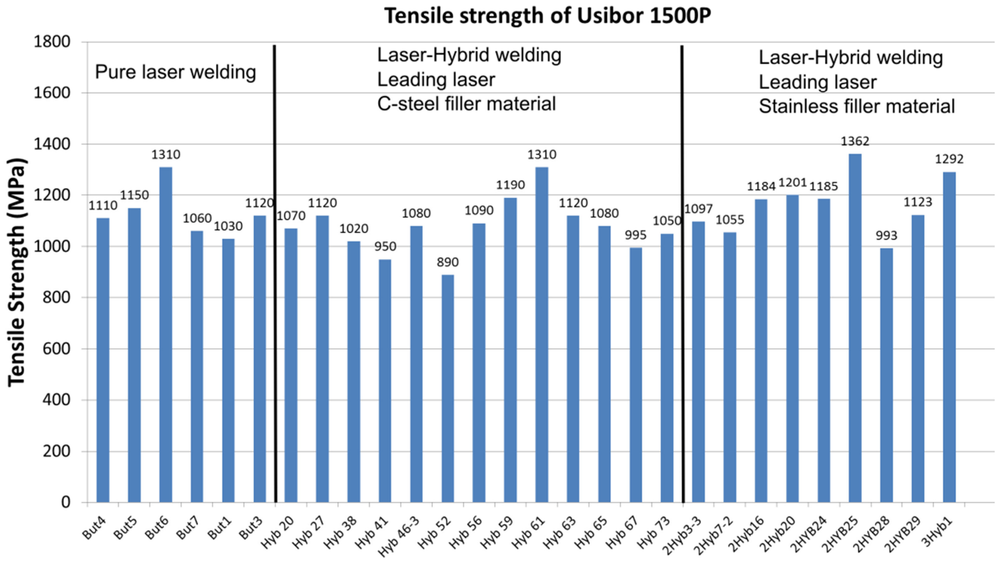

Figure 11 – Tensile strength of welds made in AlSi coated boron steel using laser welding and laser-hybrid welding with non-optimal process setup and filler materials

When optimizing the process setup and using the correct filler material, laser-hybrid welds can reach up to 95% of the tensile strength of welds made in uncoated boron steels as shown in Figure 12. An increase by roughly 25% compared to pure laser welding.

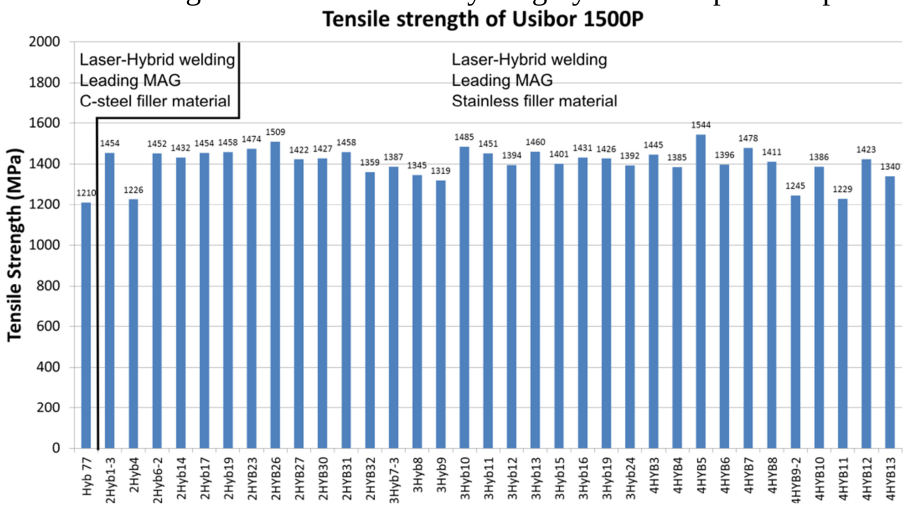

Figure 12 – Tensile strength of welds made in AlSi coated boron steel using optimized laser-hybrid welding.

As seen on the cross section images below (Figure 13 & Figure 14), the formation of ferrite in the weldment can be totally prevented by the use of an optimized laser-hybrid welding process thus minimizing the reduction of weld strength. Figure 13 display a pure laser weld and a laser-hybrid weld with a mixture of ferrite and martensitic structure. The white areas in the laser weld are ferrite as well as the white areas in the root area of the laser-hybrid weld (Figure 13, right). Although Figure 14 shows a completely white weld, it is still fully martensitic. The "whiteness" comes from the stainless filler material that is being used.

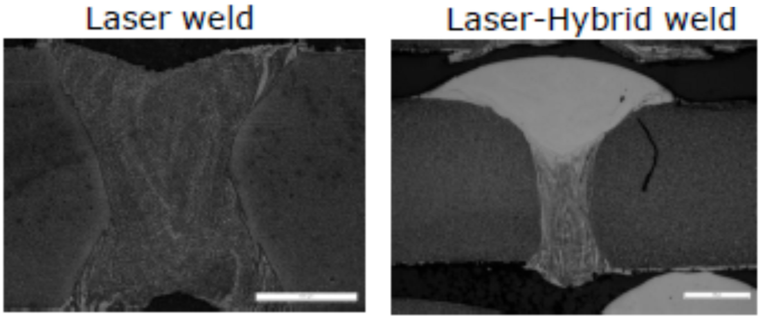

Figure 13 – Cross section images from welds made in AlSi coated boron steel using pure laser welds and laser-hybrid with non-optimal process setup

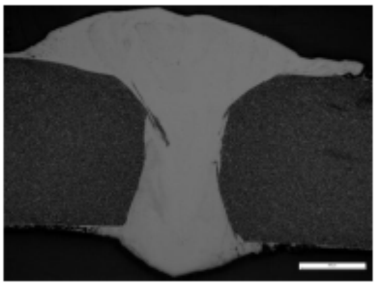

Figure 14 - Cross section images from welds made in AlSi coated boron steel using optimized laser-hybrid welding

The knowledge gained from this project was used to manufacture demonstrators, Volvo V70 B-pillars in different test versions. B-pillars were manufactured using conventional laser welding with coating removal, optimized laser-hybrid welding and without welding. Results from crash and static testing showed that the laser-hybrid welds perform as good as laser welded (AlSi ablated) B-pillars and conventionally manufactured non-welded B-pillars. All welds were intact after testing.

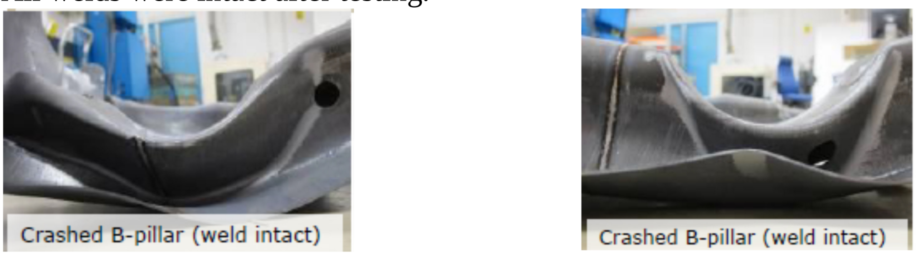

Figure 15 – Crash-tested B-pillars (with AlSi-coating). The laser-hybrid welds are intact. Left image: test No 13; Right image: test No 5. Both were welded without patches.

5.1 Delivery to FFI-goals

Project goals coincide well with the general goals within the Sustainable Manufacturing Systems / Production Technology program. The project has served to investigate the possibility to increase quality and efficiency in the manufacturing process of tailor welded blanks for press hardened components. Knowledge has been generated in close collaboration between institutes, universities and companies which have led to a good platform for future partnerships.

Manufacturing of parts, compartments and car bodies as well as education are areas within the Sustainable Manufacturing Systems / Production Technology program that this project addresses. The IMTAB project has contributed to the following general goals:

- Higher productivity in production processes
- Increased flexibility of manufacturing
- Reduced CO_2 emissions
- Education material

The IMTAB project has provided a study showing possible ways to increase productivity and ease production flow in the manufacturing of tailor welded blanks for press hardened components. The joining method evaluated (laser-hybrid welding) still has a large news-value and although laser-hybrid welding solutions are on the market, it is still an interesting area for research and development.

Laser-hybrid has the capability of generating large manufacturing benefits and can help bring a state-of-the-art production technology with economic benefits to the Swedish industry.

The project has identified the mechanisms behind how the AlSi coating influence the strength of welded press hardened components. This knowledge brings a great benefit for many applications and could be used to improve weld properties in general for applications that include welding of AlSi coated press hardened components.

We expect that this research collaboration can continue in the future and that the need for advanced research and development in the areas of joining and production technology, in this case with laser and laser hybrid welding, keep increasing in Swedish industry.

Project result dissemination has been achieved through presentations at conferences, articles and other networks. Result dissemination will continue in different ways, for example in the education of the next generation of International Welding Engineers and Technicians (IWE & IWT) at KTH in Stockholm as well as International Laser Welders at LTU in Luleå.

6. Dissemination and publications

Project result dissemination has and will be achieved through presentations at conferences, articles and other networks. Result dissemination will continue for example in the education of the next generation of International Welding Engineers and Technicians (IWE & IWT) at KTH in Stockholm as well as International Laser Welders at LTU in Luleå.

Additional articles are planned to be published from the results of this project. Articles will be submitted to international conferences where results will be presented and discussed. Popular articles are also planned in national magazines.

6.1 Knowledge and results dissemination

It is difficult to estimate what drivers of change that can speed up the dissemination of project results. The project group is however determined to continue result dissemination through conference participations, papers and other publications. We are confident in that increased national and international exposure of the project results will promote introduction and implementation of the knowledge gained in industry.

An invitation to present results in “Joining in Car Body Engineering 2013” in Bad Nauheim has been received. It is also of great interest to attend and present at IIW 2013. An article is also planned to be published in the journal “Svetsen” during the autumn of 2012.

6.2 Publications

IMTAB Project, poster session, FFI Conference, Oct. 19th 2010.

Laser & Laserhybrid welding of UHS steels, project presentation, FFI Conference, May 26th 2011.

Comparison of 22MnB5-steel with and without AlSi-coating during laser hybrid arc welding
Peter Norman ; Greger Wiklund ; P. Janiak ; N. Malmberg ; Alexander Kaplan
13th NOLAMP Conference : 13th Conference on Laser Materials Processing in the Nordic Countries, Trondheim, Norway, June 27th 2011.

Fallprovning av V70 B-stolpar med Laserhybrid-, laser- och icke svetsade B-stolpar.
Volvo Test Report No 126059 (in Swedish), Ola Wiberg, Johnny K Larsson 2012-02-22.

7. Conclusions and future research

Conclusions

- The mechanisms behind weld strength reduction in laser welds of AlSi coated boron steel materials are now fully understood and are related to ferrite formation in the weldment.
- Usibor (AlSi) in boron steel weldments promote the formation of ferrite at hardening temperatures resulting in poor weld strength
- Laser-hybrid welding of AlSi coated boron steel materials using an austenite stabilizing filler material prevent ferrite formation thus achieves weld strength comparable to base material strength values, without removal of the AlSi coating.
- Tensile strength of optimized laser-hybrid welds in Usibor 1500P materials reach 95% of the strength of welds made on uncoated 22MnB5 materials.
- Welding speeds up to 8m/min have been successfully used. Faster welding speeds was however limited by the robot movements & acceleration disturbances and not by the laser-hybrid process itself.
- Laser-hybrid welds were optimized to reach weld class B with a high success rate.
- Mainly influencing the tensile strength of these laser-hybrid welds are:
    - Process setup
    - Choice and amount of filler material.
- The laser-hybrid process is capable of tolerating up to 0.7mm gap between sheets and still achieving acceptable welds. This is 3.5 times larger gap than tolerated for non-optimized laser-hybrid welding and pure laser welding.
- Static and dynamic tests of Volvo V70 B-pillars showed that laser-hybrid welded B-pillars performed as good as laser welded (AlSi ablated) B-pillars and conventionally manufactured non-welded B-pillars. All welds were intact after crash and static tests, also on B-pillars without patches.

Future work

- Weld strength of laser-hybrid weldments can be improved additionally by the use of more optimized filler materials. Carbon content is a critical factor due to its effect on the strength of martensite.
- Filler materials can be optimized in terms of price. Chromium content in the filler material could be reduced significantly and still achieve the same effect of preventing ferrite formation in AlSi coated boron steel weldments.
- Laser-hybrid welding speeds could be increased further by the use of improved robot systems (optimized movements).

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8. Participating parties and contact persons

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9. References

1. *Laser ablation for hardening laser welded steel blanks.* **R. Vierstraete, W. Ehling, F. Pinard, L. Cretteur, A. Pic, and Q. Yin.** March/April 2012, Industrial Laser Solutions.