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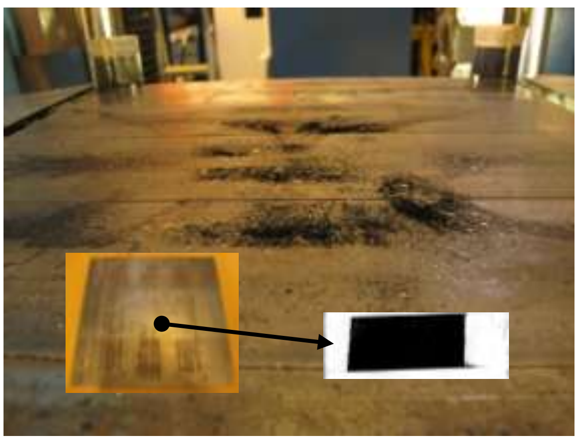
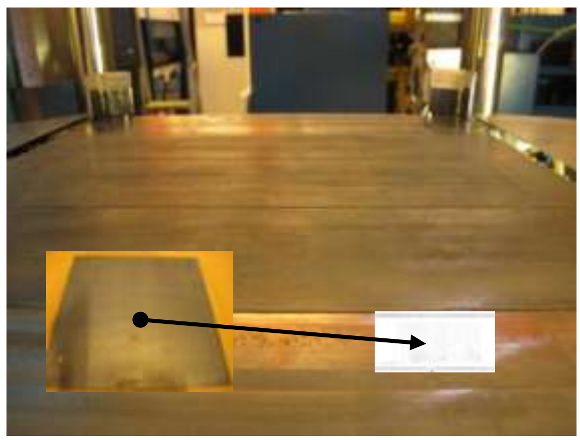
Protective Metal Coating (PMC)





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Sustainable Manufacturing Systems

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Content

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1. Executive summary

Press-hardening, or hot stamping, is a special type of thermo-mechanical forming process for producing thin ultra high strength steel components for the automotive industry such as side impact beams and bumpers. The technique involves heating steel sheets of pre-developed geometries in a furnace at more than 900°C for a few minutes, followed by simultaneous forming and quenching (or cooling).

Existing hot stamping production of uncoated boron steel results in formation of loose oxides on the steel surface (see Fig), and requires shot blasting in order to remove the named oxide for satisfactory painting and welding. Shot blasting is a both costly and energy consuming process step, which also has a negative effect on the component geometry.

In this project, a pre-treatment of uncoated boron steel has been investigated, which after hot stamping results in the formation of an oxide showing excellent adhesion to the steel. The objective has been to build up an understanding of the process, verify its effect, optimize the process, and implement it. Implementation of the new process was expected to lead to elimination of the shot-blasting step.

The project has been carried out in close collaboration between Gestamp HardTech AB, Swerea MEFOS and Luleå University of Technology (LTU). Material showing different degree of scale adhesion has been produced both in lab- and pilot scale, and this material has been investigated, tested, and characterized in order to understand what factors influence the oxide adhesion, and thereby being able to optimize and implement it.

The performed research has resulted in an increased understanding of the oxide growth during press-hardening and the factors influencing scale adhesion, not only in the suggested process but also in the standard process. The effect of the pre-treatment has been verified and knowledge has been acquired to why the process improves the oxide adhesion. Small variations in the incoming material affect the process window, which has made implementation more difficult than expected. The acquired knowledge is however anticipated to enable the development of a stable process where subsequent shot-blasting can be eliminated.

2. Background

Press-hardening, or hot stamping, is a special type of thermo-mechanical forming process for producing thin ultra high strength steel components by simultaneous forming and quenching of rolled steel sheets. The biggest part of the production of press-hardened material is used in the automotive industry for anti-intrusion parts and structural reinforcements such as side impact beams and bumpers.

The hot stamping process was invented in northern Sweden in the 1970s, and hot stamped steel parts were used in automotive applications for the first time in 1984. The yearly production of hot stamped automotive parts has rapidly increased from 3 million parts in 1987 to 8 million parts in 1997, and it has been estimated to exceed 600 million parts by 2015 [1].

The technique involves heating steel sheets of pre-developed geometries (so called *blanks*) in a furnace at 900–950°C for 3–10 min [2] to reach austenitization of the material. The blank is then transported out of the furnace to a press-hardening tool, where it is simultaneously formed and cooled, in order to obtain a martensitic microstructure. An illustration of the technique is given in Figure 1.

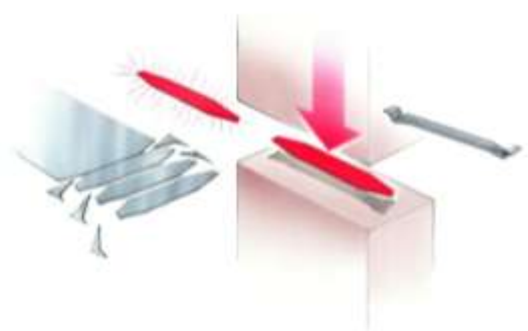

Figure 1. Illustration of the press hardening technique.

The technique has several advantages over the conventional cold forming processes. It allows manufacture of components of much higher strength, which makes it possible to decrease the thickness of the components and thereby decrease the vehicle weight. By heating of the sheets, the forming load is largely reduced and the formability is greatly improved, allowing manufacture of more complex geometries. In addition, the simultaneous hardening results in very low or no springback of the parts.

Existing hot stamping production of uncoated boron steel results in formation of loose oxides on the steel surface (see Figure 2), and requires shot blasting in order to remove the named oxide for satisfactory painting and welding. Shot blasting is a both costly and energy consuming process step, which causes distortion of the formed components, making pre-development of the products more complicated and makes expensive subsequent laser cutting operations necessary. Shot blasting also has a negative effect on the manufacture working conditions, since it is noisy and liberates dust in the production plant. Shot blasting also requires large quantities of shot blasting media, which needs to be disposed or destructed after use.

In order to avoid the formation of undesirable oxides during hot stamping, and thereby eliminating the need for shot blasting, most sheet metal blanks today are pre-coated with a protective layer. However, the existing methods of preventing oxidation involve different problems and drawbacks, such as high costs, an increased risk of hydrogen embrittlement, and cladding of the furnace rolls, which increases the maintenance costs.

Research has been focused on preventing oxidation, while strategies to control the oxidation in hot stamping and to understand what factors influence the adhesion of the produced scale have received very little attention.

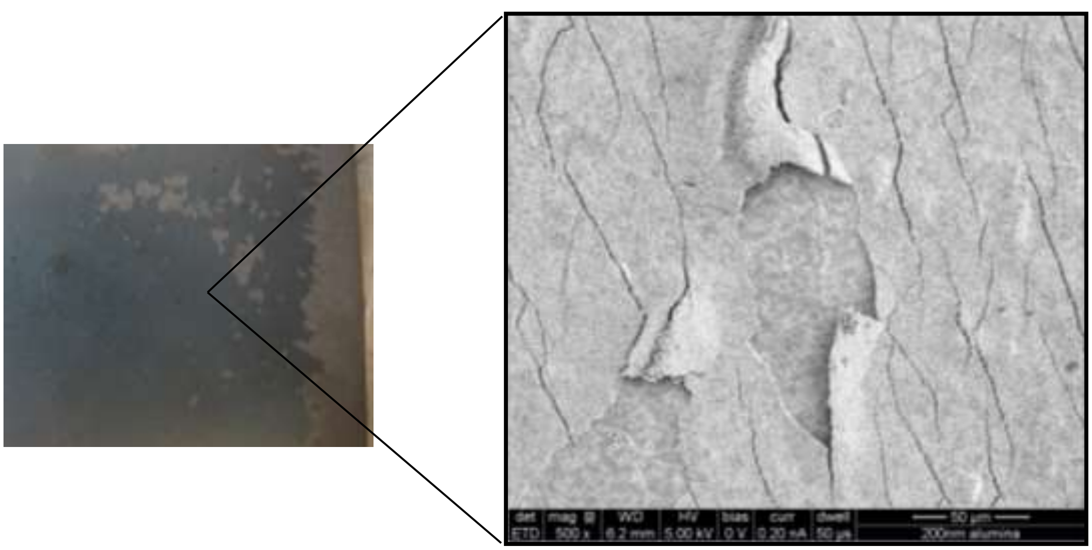

Figure 2. Macroscopical and microscopical image of loose oxide formed on the steel surface during hot stamping of uncoated steel.

3. Objective

The objective has been to build up an understanding of the process, verify its effect, optimize the process, and implement it. Implementation of the new process was expected to lead to elimination of the shot-blasting step.

The objective of the project has been to investigate a specific pre-treatment of uncoated boron steel which, after hot stamping, results in the formation of an oxide showing excellent adhesion to the steel. The effect of this pre-treatment was to be verified and the process parameters related to the properties of the oxide. The process would thereafter be optimized and finally implemented in an existing hot stamping industry.

The knowledge acquired in the project would make implementation possible, which would lead to

- Production of a material possessing better corrosion properties than shot-blasted material produced in the conventional process.
- A reduction of the energy consumption by 30% compared to the conventional process, as subsequent shot blasting can be eliminated, and since the process allows a more rapid heating of the blanks.

4. Project realization

The project has been carried out in close collaboration between Gestamp HardTech AB, Swerea MEFOS and Luleå University of Technology (LTU). Material has been produced both in lab- and pilot scale according to the new process, where the process parameters have been closely controlled and varied in order to narrow down the process window and producing material showing different degree of scale adhesion. This material, together with untreated reference material, has been investigated, tested, and characterized in order to understand what factors influence the oxide adhesion, and thereby optimize the process and finally implement it.

5. Results and deliverables

The performed research has resulted in an increased understanding of the oxide growth during press-hardening and the factors influencing scale adhesion, not only in the suggested process but also in the standard process.

The effect of the pre-treatment has been verified – material has at several occasions been produced, the produced oxide showing excellent adhesion to the substrate, making subsequent shot-blasting unnecessary. The effect is clear, which is evident when comparing pre-treated and untreated reference material, as seen in Figure 3. The pre-treatment also results in faster heating of the blanks. However, results from corrosion testing indicate that the material shows no improvement in corrosion properties compared to shot-blasted material.

A robust, quick, and simple evaluation method of the scale adhesion has been developed – a simple tape test – where loose oxide adheres to the tape while adherent scale does not. The results from the tape test show good correlation with observations of flaking of oxide during press-hardening and from cut edges, as well as with material characterization and other material testing.

The performed research has resulted in an increased understanding to why the process improves the oxide adhesion, and the process parameters have been related to the properties of the produced oxide. The pre-treatment has been made more effective, and the process window has been narrowed down. However, this process window is affected by small variations in the incoming cold-rolled material, which has made implementation more difficult than expected. The acquired knowledge is however anticipated to enable the development of a stable process where subsequent shot-blasting is eliminated.

Figure 3. Hot stamping of non-pretreated reference material (left) as well as pre-treated material (right), the oxides showing very poor and excellent adhesion, respectively. The images show the tool surface after hot stamping and the amount of oxide that has flaked off from the blanks, as well as the produced blanks and the tape tests.

5.1 Delivery to FFI-goals

The project contributes to several of the objectives relevant to *Sustainable Manufacturing Systems*. During this project, Gestamp HardTech, supplier to the automotive industry, has worked together with Luleå University of Technology and the research institute Swerea Mefos, and research has been carried out in a close collaboration between these three parties. The collaboration has led to and will continue to lead to increasing the competence and strengthen the Gestamp R&D department in Luleå.

The project also addresses other programme objectives. Elimination of shot-blasting leads to a more effective production, closer tolerances of the product, and decreased environmental impact. Faster heating of the blanks also leads to reduced energy consumption in the process.

The acquired knowledge of the oxide growth and the factors influencing the adhesion of iron oxides on carbon steel will also be of benefit, not only for the hot stamping industry, but also for other industries as well as for academy.

6. Dissemination and publications

6.1 Knowledge and results dissemination

In the strive to further reduce the vehicle weight, interest has been focused towards material with even higher strength than that produced through hot stamping today. Such solutions can be to use steel with higher strength or to use carbon fiber composites in the press-hardening technique. In both cases, pre-coating of steels is a problem. For these reasons, the new pre-treatment process could become even more interesting for the hot stamping industry.

6.2 Publications

No external publications have yet been published, but are planned during 2015, after performing some supplementary investigation.

7. Conclusions and future research

The results produced within the project are very promising, when it comes to the possibility to eliminate shot blasting from the hot stamping process. The research carried out in the project has resulted in an increased understanding of the oxide growth during press-hardening and the factors influencing scale adhesion. Research will continue to be carried out in order to acquire even deeper knowledge, in attempts to develop a stable process, optimize it, and finally to scale it up to serial production.

8. Participating parties and contact person

Contact person

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