New heating technology for the furnace-free press hardening process

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Abstract: The paper presents a new furnace-free technology for heating-up a sheet of boron steel. It is based on the use of the contact heat treatment of steel sheets due to direct contact with the massive induction heated hot plates. The new method makes possible rapid preheating of sheets for the hot forming process. During the heating, the sheet of boron steel is protected against oxidation and the temperature distribution is precisely controlled through the temperature of the heating plates. Investigations show, that the Al-Si-coating transformed after contact heating is in the same state as after the much longer furnace heating process. The combination of contact heating with contact cooling opens the way to realize the production of car body parts with properties graded “on demand” due to different thermal cycles prior to the hot stamping process. In comparison to the furnace heating, the new technology represents an energy efficient as well as a space- and cost-saving alternative.

Key words: press hardening, graded properties, induction heating and contact heating.

1. INTRODUCTION

The heating of steel blanks to austenitisation temperature (usually more than 900 °C) is a necessary preconditioning step in the press hardening process chain. At present the conventionally used technique is the heating in roller hearth furnaces. Besides the immense space requirement such furnaces have further disadvantages. The
most important of them are inflexibility, long shut down and maintenance times and complicated realisation of different temperatures within a metal sheet. The latter is necessary for obtaining parts with graded material properties for better crash performance.

For this reason the development of an alternative heating concept remains one of the important challenges in the press hardening technology [Kolleck et al., 2008].

Requirements for the new heating process can be specified as following:
- low investment costs;
- small space necessity;
- high flexibility;
- easy maintenance;
- production of structural components with tailored properties.

In this paper the heating process called “contact heat treatment” and its application for the preconditioning of steel blanks for press hardening are described.

2. CONTACT HEAT TREATMENT

The process of contact heat treatment allows thermal preconditioning of blanks without the use of a furnace. The heat treatment of a blank takes place between two massive heating plates made of a heat resistant steel. These plates are preheated to the desired temperature and this temperature is kept constant due to the correspondingly adjusted further energy supply. The heat transfer takes place as far as a cold blank is positioned between the plates and they are brought in contact as shown in Figure 1. The preheated plates serve as an energy reservoir and guarantee rapid heating of a steel sheet. The conductive heat transfer is much faster compared to the heat transfer rates which could be achieved by radiation and convection in a furnace.

![Figure 1; Principle of contact heating](image)

Generally, the heating of contact plates can be realised by different heat sources. At the present stage of development, induction heating has been chosen as energy source. Induction heating provides very high energy supply rates and thus meets industrial requirements for a serial production.

Besides a rapid heating a precise temperature control of the heating plates and thus of a metal sheet is easily possible. Furthermore, a segmentation of the heating plates into regions of different temperatures provides a way for the production of structural
components with tailored properties. Such components have very high strength but can yield in specific areas [Merklein et al., 2010]. In the next sections the technical realisation of the contact heat treatment in form of a pilot laboratory station is described and results of heating experiments are shown.

3. TECHNICAL REALISATION

The first step of the realisation of such a contact heating technology was to build a small-sized automated pilot station which can be used for producing small series of sample sheets under reproducible conditions.

Such a pilot station has been successfully developed by Neue Materialien Bayreuth GmbH (NMB). This station consists of four main components: an electronic sequence control system, a system for the transfer of sheet metals including a feeding station, a contact heating and a contact quenching module. The central component of this pilot station is the contact heating device which consists of two identical modules. With the current version of the heating device it is possible to make heat treatment of sample sheets with dimensions of 210 mm × 120 mm at temperatures up to 1050°C. This temperature is the application limit of the chosen material for the heating plates. Thus, the operation temperature can be potentially increased by the use of another material.

The heating module is typically used in a temperature range from 920°C to 1020°C. The hot plates are powered by water cooled inductors. The thermal losses between hot plates and inductor are reduced by high quality insulation material. In Figure 2 an overview of a contact heating module is presented.

![Figure 2; Contact heating module](image-url)
The cooling module consists of two massive water cooled aluminium plates. These plates allow cooling rates which are significantly higher than the critical ones for the hardening process of 22MnB5 steel.

Figure 3: Automated pilot station. Lower left corner: quenching module; right side: contact heating module

Figure 4: Test sheet in contact heating device shortly before removal (a) and test sheet at removal (b)

Figure 3 and Figure 4 show the pilot station in action. Using this device it is possible to simulate the thermal conditions of a press hardening process. The heat-up and cool-down curves of the sample blanks which are achievable with the current configuration of the pilot station are shown in Figure 5.
4. EXPERIMENTAL RESULTS

In order to proof the applicability of the new heating process for the preconditioning of the coated steel for the press hardening a series of experiments were carried out. The steel blanks of the aluminised 22MnB5 steel were heated and hold at different temperatures and time intervals. Then the heated blanks were automatically transported to the cooling unit and quenched between two massive water cooled aluminium panels. The microstructure of the surface layer was investigated by means of optical and scanning electron microscopy. Also hardness and mechanical properties of the treated steel sheets were proofed.

Figure 6 shows the microstructure of the Al-Si coating before (a) and after heat treatment (b, c, d). The coating state after short contact heat treatment of 60 s at 940 °C (Figure 6c) can be compared with the coating condition after much longer stay (7 min) in a furnace at 920 °C (Figure 6b). Even shorter preparation times can be achieved using contact heat treatment at higher temperatures for example at 1020 °C, Figure 6d). In all cases at high temperatures through the diffusion of Fe into the Al-Si layer, which is melted already at 580 °C, different intermetallic compounds can be formed and an isothermal solidification takes place [Veit et al., 2010]. Also a thin ferrite layer at the boundary between coating and base material can appear. In Figure 6 b, c and d the ferrite layer is clearly visible as a narrow light film. The main requirements for the layer state after heat treatment prior to forming is an entire solidification of the coating and a
relatively small thickness of the ferrite film. As Figure 6 c and d show both of these requirements are completely fulfilled after contact heat treatment.

![Microstructure images](image)

**Figure 6; Microstructure of the Al-Si coating before (a) and after heat treatment in a furnace (b), in the pilot station at 950°C (c) and at 1020°C (d)**

Another criterion for the preconditioning of metal sheets for press hardening is the achievement of the necessary austenitisation level. Usually a full austenitisation is required. Figure 7 shows results of a tension test of 22MnB5 samples before and after contact heat treatment of different durations at 950 °C with subsequent quenching.

![Tensile test graph](image)

**Figure 7; Tensile test results of steel samples treated for 5 min and 15 s at 950 °C compared to a sample at the initial state**
No difference in the mechanical behaviour of samples treated for 5 min and 15 s has been observed. It can be concluded that even such a short time interval as 15 s is sufficient to achieve a full austenitisation during contact heat treatment.

5. CONCLUSIONS AND OUTLOOK

The first experimental tests on the newly developed pilot station for the contact heat treatment show high application potential of this technology for the heating and tempering of steel blanks for press hardening. Higher heating rates and temperatures make it possible to reduce the cycle time for preheating of metal sheets from 5-7 min in a furnace to 20-40 s with contact heating. The space requirement of a contact heating device is significantly lower compared to a conventional continuous furnace. In downtimes the possibility of easily shutting down the heating device to reduce operating and maintenance costs is beneficial too. One of the main advantages of the contact heat treatment is the flexibility of the preconditioning process, i.e. the possibility of parameter variation of the heating process in a wide range in order to create parts with targeted mechanical properties. The application of the contact heat treatment for the preheating of steel blanks opens the way for the realisation of a flexible furnace-free process for serial production of press hardened components with graded properties.

6. ACKNOWLEDGEMENTS

The present research work has been done within the collaborative research project FlexWB (flexible heat treatment for achieving targeted material characteristics and increasing energy efficiency of hot forming processes).

This research and development project is funded by the German Federal Ministry of Education and Research (BMBF) within the Framework Concept ”Research for Tomorrow’s Production” and managed by the Project Management Agency Karlsruhe (PTKA). The author is responsible for the contents of this publication.
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