ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 14, Issue, 08, pp. 66361-66363, August, 2024
https://doi.org/10.37118/ijdr.28544.08.2024

RESEARCH ARTICLE OPEN ACCESS

# INFLUENCE OF AUTOMOTIVE PRE-PAINTING TEMPERATURE ON THE BAKE HARDENIG (BH) EFFECT IN HOT STAMPED PARTS

**Júlio Henrique Pimentel Medrano*[1] and Márcio Teodoro Fernandes[2]**

[1]Mechanical Engineering Coordinator, UNINGÁ Centro universitário Ingá, Rod. PR 317, 6114 Parque Industrial 200, Maringá - PR, 87035-510; [2]Master's and Doctoral Program in Metallurgical Engineering Fluminense Federal Universityc (PPGEM), Av. dos Trabalhadores, 420 - Vila Santa Cecília, Volta Redonda - RJ, 27255-125

## ARTICLE INFO

***Article History:***

Received 11th May, 2024
Received in revised form
17th June, 2024
Accepted 19th July, 2024
Published online 30th August, 2024

***Key Words:***

Automotive industry, Different temperatures, Mechanical properties, Characterize.

***Corresponding Author:***
***Júlio Henrique Pimentel Medrano,***

## ABSTRACT

Management High-strength steels recently used to obtain parts for the automotive industry, with multiphase microstructures, have interesting bake-hardening (BH) properties. The aim of this research work is to pre-deform and quantify the effect of BH on 22MnB5 steels, during the pre-painting phase, obtained by hot stamping. Different temperatures, 180 °C and 200 °C, and different times, from 15 to 40 minutes, were used as heat treatments to simulate the effect on hot stamped material at a temperature of 900 °C. The mechanical properties used to characterize the effect were: the strength limit, the yield limit and elongations, which were obtained through the tensile test. It was concluded that the 22MnB5 steel studied has bake hardening (BH) properties when subjected to pre-painting thermal conditions and it was observed that there was an improvement in yield strength, an increase of 102MPa, in sample S2020, condition 200 °C x 20 min.



***Citation*: *Júlio Henrique Pimentel Medrano and Márcio Teodoro Fernandes. 2024.*** *"Influence of Automotive pre-painting temperature on the bake hardenig (BH) Effect in hot stamped parts". International Journal of Development Research*, 14, (08), 66361-66363.

# INTRODUCTION

Advanced high strength steels (AHSS) are characterized by unique microstructures and metallurgical properties that allow car manufacturers to meet the various functional requirements of vehicles. According to (Faria Neto *et al*., 2020), advanced high-strength steels are complex and sophisticated materials, with carefully selected chemical compositions and multiphase microstructures resulting from precisely controlled heating and cooling processes. Various mechanisms are used to obtain an interesting variation in mechanical strength, ductility and toughness. The family of advanced high-strength steels includes dual-phase (DP), complex-phase (CP), ferritic-bainitic (FB), martensitic (MS or MART), transformation-induced plasticity (TRIP), hot-formed (HF or HS) and toll-induced plasticity (TWIP) steels. The use of HF or HS steels for hot stamping has increased significantly, especially in this sector, as these steels have high mechanical strength, allowing the use of small sheet thicknesses, resulting in better safety performance (WORLD AUTO STEEL, 2018). In order to illustrate this group of steels, the diagram in Figure 1 shows the different classes of special steels distributed according to their strength and elongation properties. In Figure 1, advanced high-strength steels (AHSS) are divided into:first generation (multiphase steels), second generation (high manganese content) and third generation (medium manganese content).

Bake hardening (BH) steels consist mainly of ferrite containing a minimum of carbon in solid solution. They are used in the automotive process mainly in the forming of exterior panels and are subsequently painted in the temperature range of 150ºC to 200ºC, the carbon is dissolved and diffuses to some free points in the migration of disagreements in the forming operation (CASTELO, 2011). They have very good formability before heat treatment and can withstand moderate and deep stamping and, after heat treatment, can reach higher resistance levels. As such, they have low mechanical properties in the newly produced condition, suitable for stamping and forming processes, which after painting, show a considerable increase in these properties, making the part of thin thickness suitable for use and better resistance to indentation (CASTELO, 2011). For a steel to show a consistent bake hardening effect, it must have a soluble C content of at least 0.0005% (less than 25 ppm), so that the increase in mechanical strength after ageing is equal to or greater than 30 MPa. On the other hand, excessive levels of soluble C are inconvenient: above 0.0015% the bake hardening effect becomes more intense, exceeding 60 MPa, but it also increases the risk of excessive ageing of the material at room temperature before the specified period of use. This leads to the occurrence of so-called stress lines when the sheet is stamped, which can degrade or even render the part unusable (GORNI, 2010). Thin steel sheets with a bake hardening effect and r values of less than 2.0 can be produced in two ways. In the first case, a steel with low C (0.02 to 0.06%), hardened to Al, is processed on a continuous annealing line.

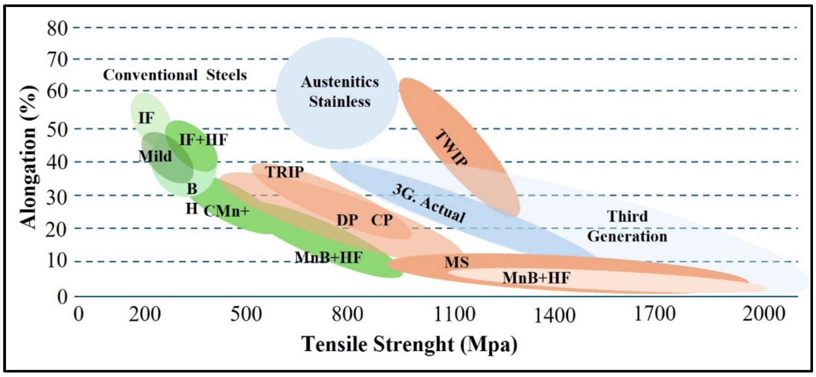


**Figure 1. New steels used in the automotive industry (FARIA NETO *et al*., 2020)**

**Table 1. Chemical composition of boron steel in mass percentage**

| Element | C | Mn | Si | Mo + Cr | Ti | Al | B | S + P | O H N |
|---|---|---|---|---|---|---|---|---|---|
| % by Weight (min) | 0.19 | 1.00 | 0.12 | 0.10 | 0.02 | 0.01 | 0.00015 | 0.020 | < 8 ppm |
| % by Weight (min) | 0.30 | 1.41 | 0.35 | 0.22 | 0.07 | 0.06 | 0.00038 | 0.032 | |

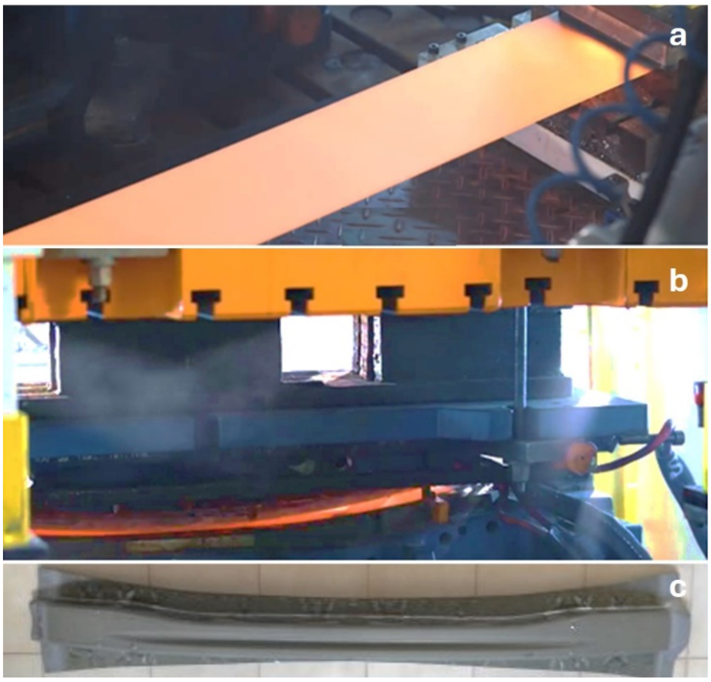


**Figure 2. Shows: a) heating the sample by the Joule effect, b) hot stamping with a cooled die and c) the prototype obtained**

This material is subjected to high coiling temperatures in the hot strip mill, which coalesces the carbides and stabilizes the N in the form of AlN (GORNI, 2010). Cold rolling and continuous annealing result in the formation of an intense crystallographic texture [111], resulting in products with an anisotropy coefficient r of around 1.5 to 1.7. Part of its carbides dissolve during the heating and soaking phases of annealing, thus obtaining high levels of C in solution. The super-aging stage during cooling tends to stabilize part of the dissolved C in the form of Fe3C. It is therefore possible to control the conditions of this last phase of the process so that the C content in solution becomes equal to approximately 0.0010%, thus providing adequate levels of bake-hardening (GORNI, 2010). The BH effect is a controlled diffusion that results from the migration of carbon and nitrogen atoms in solution in the network to the discordances, forming the Cottrel Atmosphere. The formation of these atmospheres causes the stress required to cause plastic deformation to increase again, resulting in yield strength gains that can vary between 30 and 40 MPa (ZANG *et al*., 2008). As a result, it will be necessary to apply a higher stress to cause the discordance to free itself from the atmosphere or to move along with the atoms. The diffusion of these atoms is a function of time, temperature and the amount of atoms in solution present in the material.

The grain size and density of the disagreements can also influence this process (ZANG *et al*., 2008). Among the steels most commonly used in the automotive industry, BH has an approximate strength limit of 200 to 350 MPa (before stamping and painting) and elongation of 30 to 40%, placing it in a range of steels with high ductility but low to medium strength (MACHADO, 2005). These characteristics mean that it is used in stamped parts that do not act as structural reinforcements, but which require resistance to indentation and the ability to deform widely without breaking, such as doors and fenders. Also known as "controlled ageing", bake hardening is a static process carried out by heat treatment, with the aim of increasing the yield strength of the material. This ageing also takes place at room temperature, but at a slower rate (MACHADO, 2005).

# MATERIALS AND METHODS

The samples were boron steel for hot stamping, called blanques, with specification reference 22MnB5, received in the form of cold-rolled, annealed sheets with a thickness of 1.8 mm and a width of 1240 mm with a zinc coating (BZN), called ZN50, which had 45 to 55 g Zn/m²/face. The chemical composition of the samples received is shown in Table 1, presented in this way for reasons of industrial secrecy. Comparison with the literature (KARBASIAN *et al*., 2010) shows similarities. Hot stamping consisted of subjecting the samples to heating by the Joule effect, where this process can be seen in Figure 2: a) the process of heating the sample to a temperature of 900 ºC, with ZN50 coating, by the Joule effect, b) hot stamping of the blank and c) the prototype obtained. For the evaluation of the BH (bake hardening) effect, samples of prototype parts with ZN50 coating were used, stamped from 900 °C. To simulate the conditions of the effect, the samples were treated in five different temperature, time and cooling conditions, as described in Table 2, in a 1600-liter 160x100x100 cm digital oven with a working temperature range of +5 °C to 250 °C. For each temperature and time condition, four prototype part samples were used, taken as shown in Figure 3, i.e. from the wall of the prototype part.

**Table 2. Sample treatment conditions for simulating the BH (Bake Hardenig) effect**

| Sample | Temperature (°C) | Time (min) | Cooling |
|---|---|---|---|
| S1815 | 180 | 15 | in the air |
| S1830 | 180 | 30 | |
| S1840 | 200 | 40 | |
| S2015 | 200 | 15 | |
| S2020 | 200 | 20 | |

The mechanical properties of the samples were characterized by tensile testing using a 10-ton MTS servo-hydraulic machine. The dimensions of the specimens were defined in accordance with the ASTM E8M standard. The specimen removal position is shown in Figure 3. The GF CUT E600 wire EDM machine was used to remove the samples from the prototype part, as it has a predominantly 100% martensitic structure. An extensometer was used to determine elongation, using the criterion of 0.2% deformation to determine the yield strength. The test speed was 10 mm/min. Uniaxial tensile tests were carried out on specimens according to the ASTM E8M standard from ZN50 samples stamped at 900 °C. Samples were designated according to their treatment, Table 2, and an untreated sample, Untreated Sample (US). The strength limit (LR), yield limit (LE) and elongation were obtained from the test in order to analyze the variations in properties as a result of the heat treatment.


**Figure 3. Position of samples for simulation and tensile tests**

# RESULTADOS E DISCUSSÕES

The uniaxial tensile test for S1815, condition 180 °C x 15 min, which is the closest condition used by the automotive industry, did not show a gain in mechanical strength as occurs with steels classified as BH. Looking at S1830, condition 180 °C x 30 min, there was a gain of 20 MPa in yield strength; while in S1840, condition 180 °C x 40 min there was a gain in yield strength of around 92 MPa and a reduction in tensile strength of around 24 MPa. Increasing the temperature to 200 °C and maintaining the time of 15 min, sample S2015; there was a small reduction in mechanical strength, but a gain in yield strength of around 88 MPa. For S2020, condition 200 °C x 20 min, there was a significant gain in yield strength of around 102 MPa. The increase in yield strength due to bake hardening (BH) is accompanied by a small reduction in tensile strength. If, on the one hand, mechanical strength is increased by the anchoring of disagreements by carbon atoms, on the other hand there is stress relief induced by the increase in temperature of the material. From the point of view of the structural analysis of a part/component, the yield stress is more important than the strength stress, because the higher the value, the stiffer the structure. When the yield strength is exceeded, this indicates total rupture or collapse of the part/component. Looking at the elongation, it has not changed significantly. Therefore, considering the S1815, 180 °C x 15 min condition, which is the closest condition used by the paint line in the automotive industry, the gain in mechanical properties is not significant, however, maintaining the 180 °C temperature with more heating time or increasing the temperature to 200 °C and maintaining the 15 min time, there was a significant gain in absolute values in the yield strength. In percentage terms, there was an improvement of around 9% in yield strength. Compared to the literature (CASTRO, 2017), the results presented are consistent.

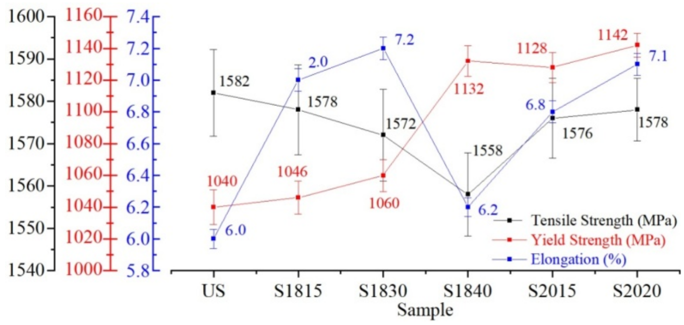


**Figure 4. Results of tensile tests carried out on heat-treated samples. In black the strength limit, in red the yield limit and in blue the elongation**

# CONCLUSIONS

It was found that the boron steel studied has bake hardening (BH) properties when subjected to pre-painting thermal conditions and it was observed that there was an improvement in the yield strength in sample S2020, condition 200 °C x 20 min.

# REFERENCES

Castelo Branco Dias, G. Estudo do efeito "*bake hardening*" nos aços BH180 e BH220 galvanizados pelo processo de imersão a quente. Dissertação (Mestrado) Universidade Estadual Paulista, Faculdade de Engenharia de Guaratinguetá, 2011.

Castro, M.R.; O efeito *bake hardening* na estampagem a quente e a estrutura veicular. Tese (Doutorado). IPEN. Universidade de São Paulo, São Paulo, 2017.

Faria Neto, A.R.; Fukugauchi, C.S.; Pereira, M.S.; Indústria automotiva: aços avançados de alta resistência – revisão. Sinergia. v. 21, n. 1, p. 25-33, 2020.

Gorni, A. A. Novos aços ferríticos garantem alta resistência e conformabilidade a chapas finas laminadas a frio. Corte & Conformação de Metais, p. 34-36, set. 2010.

Karbasian, H; Tekkaya, A. E.. Areview on hot stamping. *Journal of Materials Tecnology, Elsevier*, Dortmund (Alemanha), 2010.

Machado, F. A. Influência do grau de deformação e do tratamento “Bake Hardening” na propagação de trinca por fadiga em dois aços bifásicos usados em rodas automobilísticas. 2005. Dissertação (Mestrado em Engenharia de Materiais) – Universidade Estadual de Minas Gerais, Belo Horizonte, 2005.

World Auto Steel.; Advanced High Strength Steel (AHSS) Application Guidelines, Version 4.0, 2009. Disponível em: http://www.worldautosteel.org. Acesso em: 08 jan. 2019.

Zhang, J. *et al*. Bake hardening behavior of TRIP and DP steels. Journal of University of Science and Technology, Beijing, v. 15, n. 2, p. 132, Apr. 2008.

*******