

Steel of Boron with Dual Structure for Automobile Screws, Reducing Manufacturing Costs and Environmental Impact

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Abstract

This paper tries to obtain the same mechanical performance with boron steel parts obtained by stamping, conventional quenching and tempering, with a subcritical annealing and tempering aimed at obtaining a dual structural steel. Thus, energy is saved in the annealing treatment to reduce the product temperature, and residence time, and the tempering treatment is suppressed. This results in process economics leading to the final product costs and environmental impact.

This process is designed to equal the boron steel used in high-performance screws in the automotive industry, compared to dual structural steels used with for high manganese content and low carbon content. This is boron steel used in these applications and subjected to quenching prior subcritical annealing, can achieve the same strength and toughness values than conventional treatments.

Keywords: Dual structure; Boron steel; Heat treatment; Metallographic structures; Mechanical properties

Introduction

Dual structure steels with ferrite-martensite are currently used in the automobile industry. The biggest development has been that of steels of low carbon content and high manganese content. The hardenability of carbon steels increases with the presence of certain alloying elements such as: nickel, chromium, tungsten, molybdenum, vanadium, manganese and boron [1-4]. Of these, those that produce a marked increase are manganese and boron.

The manganese appears in all of carbon steel as it is added to neutralize the action, very negative, of the presence of sulfur and oxygen. As an alloying element increases the strength and hardenability, and we can say that this influence is significantly higher than that of molybdenum. However, it is also frequently used for this application by the tendency of these steels by high possibility to tear. Manganese dissolves in the ferrite hardening it. Their tendency to form carbides is stronger than iron, but less than that of chromium, tungsten, molybdenum, vanadium and titanium.

For boron has been found to very low percentages, between (0.001-0.006) mass% greatly, improve hardenability. In this aspect, it is the most effective and most mitigating power of all alloying elements. Its effectiveness is such that for a steel 0.4 mass% of carbon, its effect is approximately 50 times that of molybdenum, 75 times that of chromium, about 400 times the nickel.

Presents great difficulty its addition to the casting, because is a strong deoxidizer. The maximum action of this element is in percentages of between (0.002-0.004) mass%. Although an addition of 0.001% by mass may have noticeable effects [5,6].

Currently, steels have been developed dual structure with manganese widely used in the automotive industry, for elements such as tires, light sections, damper for seats, fasteners, chassis, etc. In the industry today, these dual phase steels, ranging from (0.09 to 0.18%) by mass carbon and manganese content (1 to 2.4%) by mass; getting resistors between 450 MPa up to 1180 MPa, for carbon content and manganese content of 0.18 mass% and 2.4 mass%, respectively. Some of the available steels are (EN 10338: 2009): HCT450X (1.0937), HCT500X (1.0939), HCT600X (1.0941), HCT780 (1.0943), HCT980X (1.0944),

and soon. For screws and other elements of high performance engine, in the automotive industry, have been used almost general, boron steels, the carbon content (0.2 to 0.33)% by weight and manganese content (1.1 to 1.45%) by mass. Two of these steels are very commonly used (EN 10083-3: 2006): 22MnB5 and 30MnB5 (Table 1).

These steels are used in quenched and tempered state, reaching 45 and 50 HRC hardness, and between 1200 and 1500 MPa ultimate strength. Tempering generally 1200 to 1100 MPa and an elongation of between (8 to 10%).

Our research suggests replacing the conventional quenching from 880°C and tempering, by a single subcritical quenching, at a lower temperature and with a subcritical annealing at lower temperature and shorter. Avoiding temperatures of 880°C and removing the tempering step. This involves reducing operating costs, processing times and minimizes environmental impact.

	22MnB5	30MnB5
C	0.200-0.250	0.230-0.330
Mn	1.10-1.40	1.15-1.45
P	≤ 0.025	≤ 0.025
S	≤ 0.008	≤ 0.035
Si	0.15-0.35	≤ 0.40
Al	0.015	-
Ti	0.020-0.050	-
B	0.0020-0.0050	0.0008-0.0050

Table 1: Compositions of steels (EN 10083-3:2006): 22MnB5 y 30MnB5.

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Experimental Technique

The steel used for the research was the 30MnB5, to which we referred before. Steel wires received in 10 mm thick are shown in Figure 1. For metallographic examination of the structures obtained with the heat treatments employed, specimens 20 mm long and 10 mm diameter were prepared (Figure 2).

Hardness tests Rockwell C (Galileo durometer universal type) and Vickers microhardness (Vickers microhardness AKASHI MUK-E3) were performed on the same type of samples used for the metallographic observation. The tensile test specimens machined adjusted to the UNE EN ISO-377:2013 was performed. The initial length (L_0) was 44 mm and the diameter of the circular opening section 6 mm (Figure 3). Heat treatments were performed in a muffle furnace thermal electric resistance heating capacity 1100°C and tempering, it was made in water at room temperature. Metallographic observation was conducted in scanning electron microscopy using a JEOL JSM-6400 microscope with EDX system built-EDS analysis.

Results and Discussion

The initial structure of the steel is received in a state of globulization. Is observed, clearly, iron carbides spheroidized, bands aligned in a ferrite matrix in the direction of drawing. Also, they are elongated ferrite grains in this direction shown in Figures 4 and 5.



Figure 1: Segments of steel wire 30MnB5 of starting.



Figure 2: Specimens taken from the starting wire, heat treated, examined and tested by metallographic tests of hardness and microhardness.



Figure 3: Samples machined for tensile testing, heat treated.

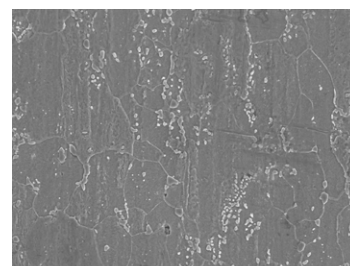


Figure 4: Steel (30MnB5) microstructure starting obtained by SEM; in it a ferritic structure is observed in the form of fibers in the direction of drawing with globalization iron carbide in gaps.

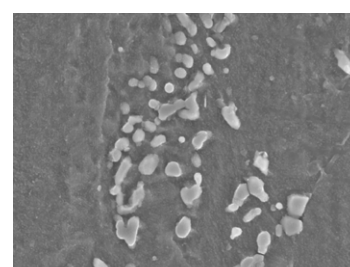


Figure 5: Detail, at higher magnification, the microstructure of the Figure 4.



Figure 6: Prints screws preforms cold, quenched and tempered.

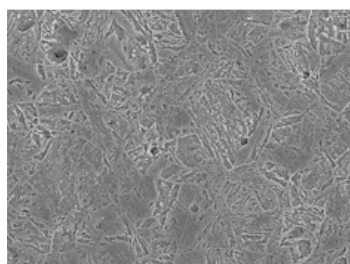


Figure 7: Microstructure Figure 6 preforms obtained by the SEM. Tempered martensitic structure is observed.

This steel wire 30MnB5 this metallographic structure is subjected to forging cold-formed shapes the screw. Figure 6 shows preforms in cold formed and then subjected to water quenching and tempering they are observed. After cold forming, quenching and tempering, the resulting structure is tempered martensite, resulting from the treatment of quenching and tempering after the cold forming are depicted in Figures 7 and 8. These resulting structures often have (45-50) HRC hardness and strength of (1100 to 1500) MPa. Ideally for this

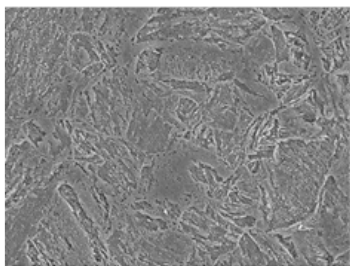


Figure 8: Detail, at higher magnification, of the structure of Figure 7.

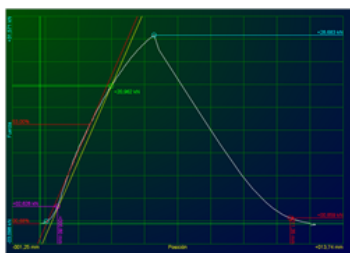


Figure 9: Stress-strain curve of a specimen with subcritical annealing at 770°C for 18 minutes and water quenching.

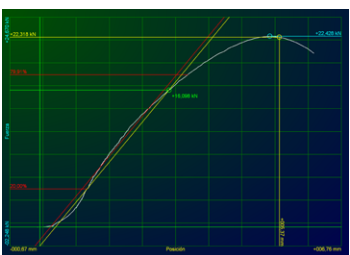


Figure 10: Stress-strain curve of a specimen with subcritical annealing at 770°C for 10-12 minutes and water quenching.

type of fastener is getting around (1100-1200) MPa, with a significant lengthening of (6-8%).

The most widely used treatment for these mechanical characteristics is the quenching in water after 40 minutes at 880°C austenitizing and tempering tenacious, to 220 [7].

In our research we have proposed an alternative to conventional heat treatment quenching and tempering. This treatment involves a subcritical quenching: heating for a short time at temperatures below the critical temperature and water quenching. Saving the austenitizing treatment at 880°C and a dwell time of 40 minutes, and the tough tempering operation.

To achieve a resistance of between 1100 and 1200 MPa, for obtaining high-performance hardware to the car, we set a goal to achieve a hardness of between 43 and 50 HRC. To this hardness resistances ranging between 1100 and 1300 MPa, suitable resistance to such automotive products. To achieve these hardships warmed to 770°C for 15 minutes resistors 1100 MPa (43HRC) and elongations (6-7%). To a slightly higher time 2 to 3 minutes, the hardness rose from 46 to 50 HRC, and the acquired resistance (1200-1300) MPa, an elongation dl (4-5%) (Figure 9).

To test the mettle subcritical treatment we set out to obtain

specimens with hardness (34-36) HRC, which would correspond to resistors (800-900) MPa, elongation of 9%. After quenching subcritical tests, the appropriate times ranged to 770°C, between (10-12) minute hold at this temperature (Figure 10).

Metallographic examination by scanning electron microscopy showed images corresponding to steels in fiber form structures in the direction of the drawing, which are one very interesting for the mechanical behavior of the dual type fasteners (Figures 11 and 12) feature. Martensite (Figure 13) and ferrite (Figure 14). In (Figures 13 and 14) Vickers microhardness traces on the two phases obtained with subcritical heat treatment were observed. When compared, it can be seen how the Vickers martensite footprint is smaller than that of the ferritic phase. In Figure 15 the dimensions of the diagonals of any footprints made Vickers microhardness can be seen.

Summary and Conclusions

It has been seen how the presence of boron steels allows Templar carbon content (0.25-0.35%) by mass, performing a subcritical annealing small and very controlled times; obtaining a dual phase structure (dual phase) ferrite-martensite. Treatment is similar to that

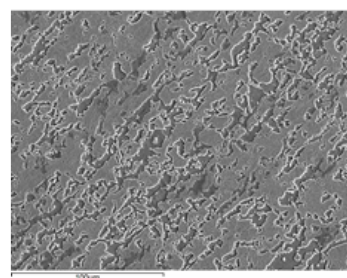


Figure 11: Microstructure resulting from subcritical annealing at 770°C for 18 minutes and water quenching, obtained by SEM. A dual structure of martensite (light tone) and ferrite (darker) is observed.

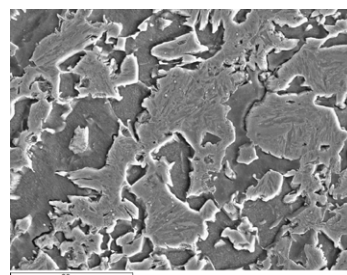


Figure 12: Detail, at higher magnification, the structure of the Figure 11.

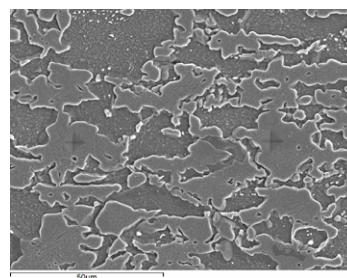


Figure 13: Micrograph, SEM obtained, in which two tracks Vickers microhardness crystals observed in the martensitic phase.

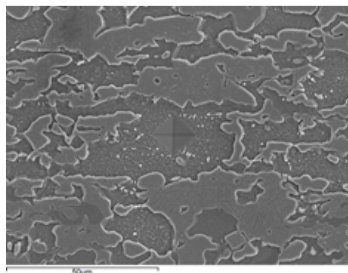


Figure 14: Micrograph, SEM obtained by, in a footprint Vickers microhardness in the ferritic phase was observed.

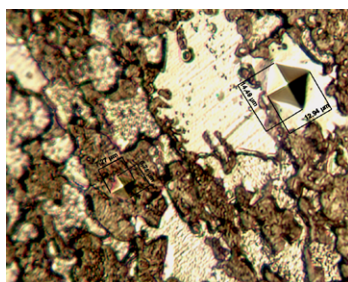


Figure 15: Micrograph, obtained by MO, measuring two traces observed Vickers microhardness; left at martensitic phase and the right ferritic phase.

which has been done with the steels of low carbon and high manganese content, to obtain dual phase steels. The temperature shown subcritical suitable for tempering is 770°C, for time intervals ranging from 10 to 15 minute hold at that temperature, then water tempering.

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