

Contribution to The Knowledge of The Action of Boron in The Dual Structure of a Steel 30MnB5 by Means of X-Ray Diffraction

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Abstract

The new thermal treatment of subcritical annealing and water quenching, applied to boron steels (30MnB5), which we propose in our research, achieve excellent variability in mechanical properties, as a result of obtaining a very versatile dual structure. In addition, there is a significant reduction in energy consumption and process time, which results in the Life Cycle Analysis (LCA) and process costs. The presence of boron favours the success of the thermal treatment. The explanation of the process has been investigated by means of a metallographic study, mechanical characterization and in this work the results obtained by means of the study of the treated and untreated samples by means of X-Ray diffraction are presented. The presence of very small FeB crystals in the structure are the cause of the dual structure and its good characteristics. They have only been detected by X-Ray Diffraction, although we have also tried Transmission Electron Microscopy with unclear results.

Keywords: Boron steel; Dual structure; X-ray diffraction

Introduction

Obtaining a dual structure in hypo-eutectoid carbon steels is a great advantage in these materials, as it allows two structures with very different properties to be combined: ferrite and martensite.

This results in a wide variety of mechanical properties depending on the proportion of both phases present. In addition to this achievement, it leads to a reduction in energy expenditure and processing times, coupled with quenching in a medium such as water. The end result is an excellent material from a mechanical point of view and with a very good Life Cycle Analysis (LCA), contributing to a lower environmental impact.

The dual steel we studied 30MnB5 has a high hardenability because it contains boron in its chemical composition. As with carbon, boron is soluble only in a very small proportion in the iron crystalline network [1]. The presence of small amounts of boron in a carbon steel allows its alphas transformation, favouring its hardenability. By using subcritical hardening thanks to the presence of boron, we save time and temperature in heat treatment, reducing environmental impacts [2,3].

The dual steels, because they have a structure with two phases that provide independent toughness and hardness, represent a very good alternative to other conventional materials. These steels have a homogeneous behaviour during creep, a large deformation hardening zone and a high ductility thanks to the ferrite-martensite combination [4]. This structure has a soft yield mechanical behaviour, low tensile strength/elastic limit ratio and high plastic conformation [5,6]. The steels (30MnB5) are applied in the automotive industry, in the manufacture of high-performance screws, agricultural and mining machinery, and in the war industry [7,8].

For a sustainability study linked to steels, the type of impact, the closed chain of Life Cycle Analysis (LCA) and its effects on the environment must be predicted in an ecological way [9-14].

In this research we have tried to see the possible influence of boron on the formation of a dual ferrite-martensite structure. For this, it is necessary to know where the boron is located. The presence of boron in the form of Fe₂B borides can be in the ferrite, austenite or martensite and, with it, favour or not the formation of martensite in these steels

of low carbon content and for subcritical heating of low temperature and short heating times. With transmission electron microscopy it has not been possible to detect the presence of iron borides in the different phases; however, the use of X-ray diffraction has been able to detect the presence of these borides in the different phases. In this way, the presence of these borides is detected in the ferritic matrix of this steel 30MnB5, in its starting structure, distributed in a regular way. In steel treated thermally by subcritical quenching, borides are selectively found in austenite during heating and, after quenching, in the martensite of the dual structure [15,16].

Experimental Technique

In this investigation boron steel 30MnB5 has been used, in bars of different diameters, in reception state of normalized and cold drawn. Specimens of different dimensions have been cut (Figure 1).

The composition of 30MnB5 steel is shown in Table 1.

The thermal treatments applied to the samples for their observation in Scanning and Transmission Electron Microscopy, were:

- Reception status: normalized and cold drawn.
- Water hardening from 900°C.

C	Mn	P	S	Si	Cr	B
0.3	1.3	<0.035	<0.035	0.3	0.95	0.003

Table 1: Composition of steel (30MnB5), % by mass content.

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- Subcritical annealing at 770°C, for 15 minutes and quenching in water [2].

The metallographic preparation was done in a conventional way for the samples observed in Scanning Electron Microscopy [2] and for X-Ray Diffraction (Figure 1). The equipment used for the Scanning Electron Microscopy is a JEOL JSM 6400, operated at 20 KeV; while for the X-Ray tests a Philips diffractometer model X'PERT has been used, with $K\alpha$ of the Cu (0.15405 nm) with a voltage of 45 KV, a current intensity of 40 mA and a radius of incidence of 320, from a Cis-Extres process.

For Transmission Electron Microscopy, the preparation of the samples meant that they were thinned by electrolytic polishing, in an electrolytic polisher model LectroPol-5, applying a current of 2^a and 40v, during 12 seconds, at a temperature of 22°C. The samples were thinned by electrolytic polishing, in an electrolytic polisher model LectroPol-5, applying a current of 2^a and 40v, during 12 seconds, at a temperature of 22°C. The electropolished sample was cleaned by plasma in a Fischione model 1020 for 5 minutes. The equipment used for the Transmission Electron Microscopy is a JEOL 2000-FX equipped with Oxford Link hardware, for EDS-EDX microanalysis, and operated at 200 KeV. In addition, observations were made with a more powerful equipment model JEOL 2100-HT, equipped with an Oxford Link hardware, for EDS-EDX microanalysis, and operated at 400 KV.

Results

The steel reception structure studied in this research, 30MnB5, consists of a ferritic matrix of grains elongated in the direction of mechanical behaviour, with dispersed iron carbides of very irregular morphology. These iron carbides are associated in colonies (Figure 2).

This steel was subjected to a subcritical annealing heat treatment

at 770°C for 15 minutes and then tempered in water. The structure obtained with this treatment is dual-phase, formed by martensite and ferrite crystals (Figure 3).

A conventional heat treatment of annealing at 900°C for 30 minutes was also applied, followed by water quenching. The structure obtained with this treatment is total martensitic (Figure 4).

In this research we have tried to verify where boron is found, in the form of iron borides, and its location in the different phases of boron steel without heat treatment, with conventional heat treatment of hardening and with subcritical heat treatment of hardening. By means of Transmission Electron Microscopy in the described equipment (experimental technique section) we have not been able to observe the existence and location of iron borides (Figure 5). Possibly, this is due to their small size. So we try to detect them by X-Ray Diffraction.

The presence of boron in the form of borides is noted in X-ray diffractograms.

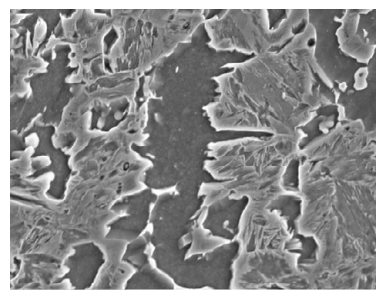


Figure 3: Microstructure of steel 30MnB5 after thermal treatment of subcritical annealing at 770°C and subsequent quenching in water. The ferrite and martensite crystals, corresponding to the dual structure, can be observed.

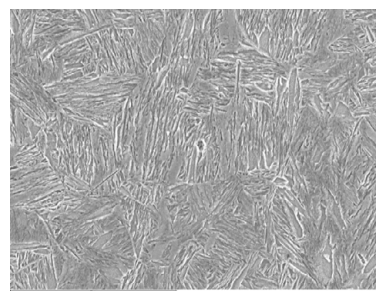


Figure 4: Martensitic microstructure of steel 30MnB5 after conventional heat treatment of annealing at 900°C followed by quenching in water.



Figure 1: Boron steel specimens 30MnB5 used.

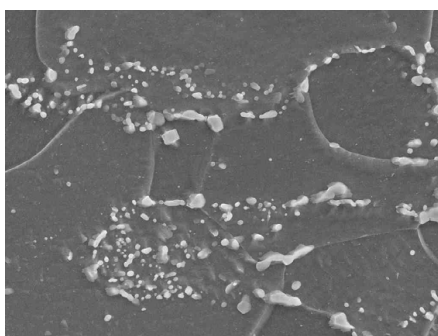


Figure 2: Microstructure of steel 30MnB5 in its receiving state. Iron carbide colonies are observed in a ferritic matrix.

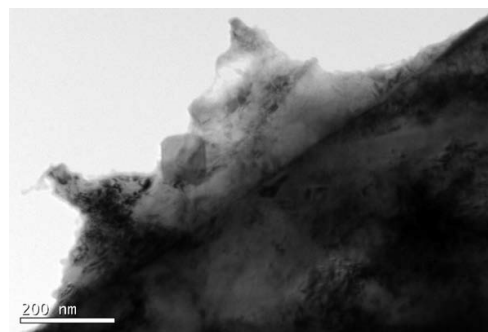


Figure 5: Microstructure of steel 30MnB5 after subcritical heat treatment at 700°C followed by water quenching. TiO crystals are observed.

In steel heated to 770°C for 15 minutes and tempered in water, iron borides are integrated and dissolved in the austenite, abandoning the ferrite, due to its gammagen character, and favouring the water quenching of the steel. Therefore, during heating, boron passes almost exclusively to austenite, remaining retained in austenite, which favours its quenching in water; iron borides appearing in the martensitic phase, as can be seen in the diffractogram in Figure 6.

If we heat the steel to 900°C for 30 minutes, the gammagen character of the boron favours its dissolution in the austenite, which this time is massive, transforming and favouring the appearance of martensite in the whole structure during water tempering, as can be seen in the diffractogram in Figure 7.

Another data that may be relevant is to check, where are the iron borides in the receiving steel. The diffractograms carried out on steel 30MnB5 show the generalized presence of these iron borides in the ferritic matrix, distributed in a regular way, as can be seen in the diffractogram in Figure 8.

The X-Ray diffraction allow to detect the presence of iron borides in the different phases of the steel 30MnB5 and, therefore, its action on the martensitic transformation in the dual phase structure.

Conclusions

Transmission Electron Microscopy has not provided us with information on the presence of iron borides in the phases of dual-phase steel 30MnB5. The use of X-Ray Diffraction has been very useful to detect this presence.

30MnB5 steel is easily heat-treated to obtain a dual-phase structure, because boron almost massively dissolves in the austenitic phase during heating to 770°C for 15 minutes and leaves the ferritic phase remaining during this subcritical annealing. Tempering from 770°C in water allows the boron's tempering action to concentrate on the austenite colonies formed and favour their transformation to martensite.

In the case of annealing at 900°C, boron is distributed throughout the austenitic structure, favouring transformation to total martensite

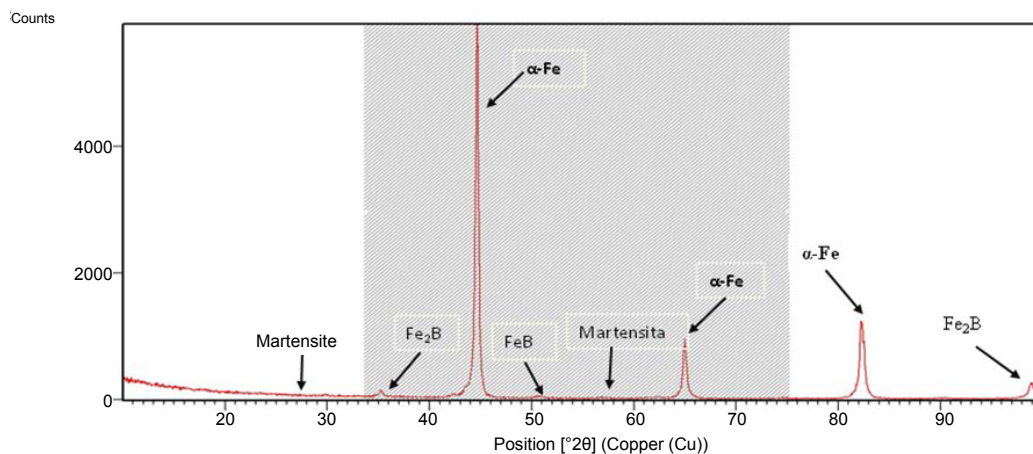


Figure 6: Diffractogram of the steel 30MnB5 in its state of reception.

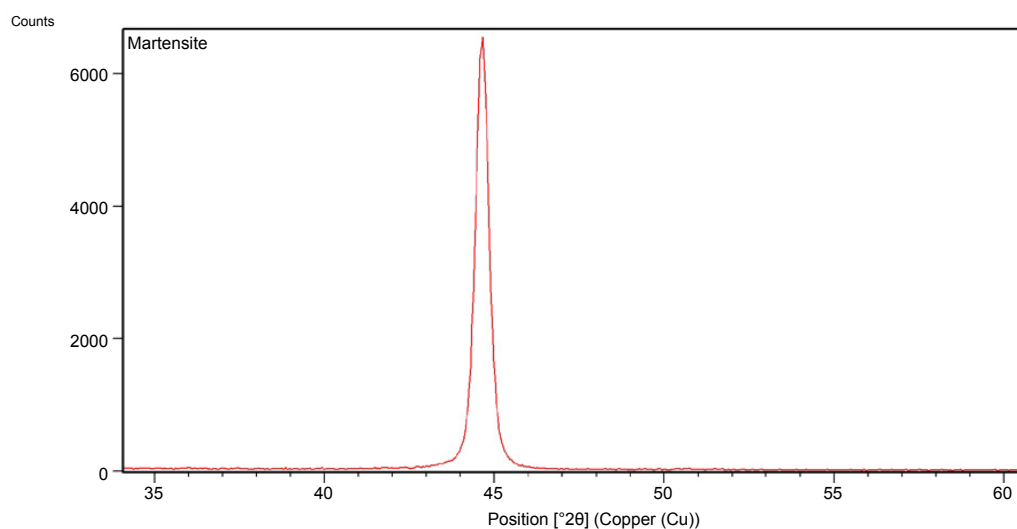


Figure 7: Diffractogram of steel 30MnB5 after conventional heat treatment of annealing at 900°C followed by quenching in water. Boron is found in the form of borides homogeneously distributed throughout the martensitic phase.

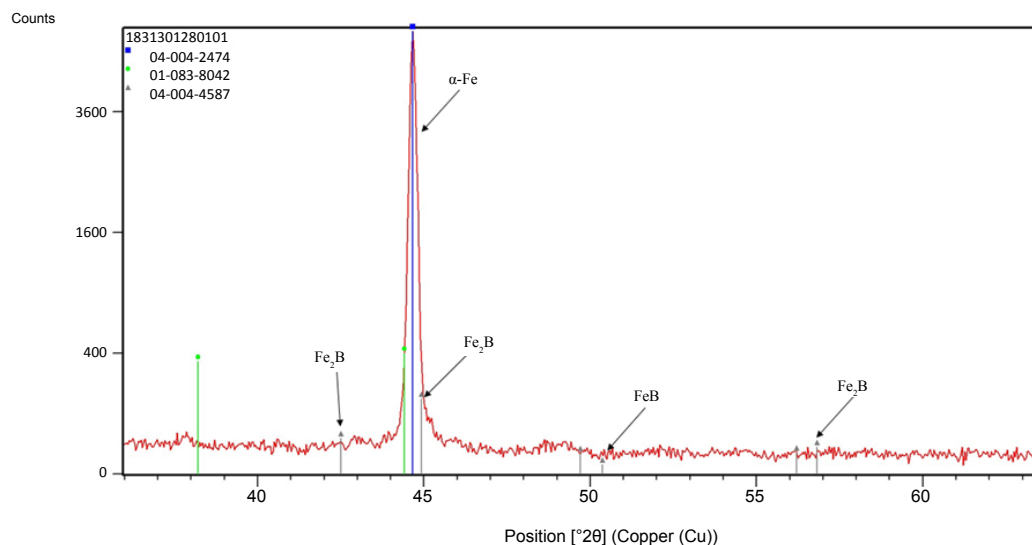


Figure 8: Diffractogram of steel 30MnB5 after subcritical heat treatment at 700°C followed by water quenching.

during water quenching. This fact is corroborated in the diffractogram carried out on steel 30MnB5, annealed at 900°C for 30 minutes and tempered in water.

It is clear from the X-Ray diffractograms that the selective preference of boron for austenite allows it to concentrate on the proportion of austenite formed during the subcritical annealing of 30MnB5 steel at 770°C for 15 minutes, favouring the presence of the dual-phase structure after it has been quenched in water.

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