Acta Microscopica, Vol. 25 Supp. A., 2016

4° Congreso de la Asociación Argentina de Microscopía (SAMIC 2016)

BAINITE CHARACTERIZATION IN LOW CARBON MICROALLOYED STEEL

Elena Brandaleze (1), Edgardo Benavidez (1), Raúl Bolmaro (2), Martina Avalos (2).

(1) UTN. Facultad Regional San Nicolás. San Nicolás. Argentina. (2) CONICET-IFIR- UNR. Rosario.
Email: avalos@ifir-conicet.gov.ar

The characterization of the microstructure developed in ultralow and low carbon steels during continuous cooling treatment is important because of the occurrence of transformations such as bainitic or martensitic, that improve the strength and enhance the ductility of these alloys. The quantification of the different micro-constituents in steels is not an easy task, since the microstructures are extremely complex and usually consist of different types of ferrite such as polygonal ferrite and bainite [1]. The standard method to identify and quantify constituent phases in steels are optical microscopy combined with selective metallographic etchants and X-ray diffraction. However, the identification of bainitic microstructures is very difficult because many morphologies have the same composition and crystallographic structure. Electron Backscatter Diffraction (EBSD) has been demonstrated to be useful for microstructural analyses of steels [2]. In particular, to identify bainitic-ferritic microstructures, in addition to the crystallographic information and parameters like IQ and CI [2], some authors have employed microstructural criteria such as misorientation or grain size. The purpose of this paper is to analyze the bainitic-ferritic microstructure developed in a low carbon steel during continuum cooling treatment, combining optical microscopy, X-ray diffraction and EBSD, to compare and contrast the advantages and limitations of each technique. The material investigated in the present study was a low carbon microalloyed steel containing 0.06 wt % C, 0.04 wt % Ti and 0.1 wt % Nb. Samples of 4 mm x 4 mm x 25 mm were tested in a Theta Dilatronic II chamber up to Tmax=900^{o}C, with a heating rate of 10^{o} C/min and soaking time of 5 minutes. The tests were done in air and the cooling rates were 0.03 ºC/s, 0.3 ºC/s and 8.2 ºC/s. Each sample was sectioned and mechanically polished with 9 µm, 6 µm, 3µm and 1µm diamond suspensions, finishing with 0.05 µm colloidal silica. The EBSD maps were collected using a FEI Quanta 200 FEG SEM equipped with a TSL EBSD system. Two types of maps were obtained: general scans of representative areas, to quantify and characterize polygonal ferrite phases (step size 0.1 µm - 0.15 µm), and detail scans, to analyze details related with bainite (step size 0.07 µm - 0.05 µm). Figure 1 shows a section of the Continuous Cooling Transformation (CCT) curve for the steel correlated with the theoretical transformation temperatures obtained by the usual empirical expression [3]. At 0.03 ºC/s cooling rate the CCT curves are in the field of the polygonal ferrite and only at the 8.2 ºC/s cooling rate the initial and final experimental transformation temperatures are on the calculated bainitic transformation temperature range. For determining the phases and their percentages, the IQ parameter was used to compare with the results obtained by optical microscopy. Fig. 2a shows the optical microscopy and Fig. 2b shows an IQ map of the steel cooled at 8.2 ºC/s where the ferrite and the bainite phases are evident. The corresponding IQ chart is reported in Figure 3 and was used to identify the bainite since it has worse diffraction patterns than the ferritic matrix. Table 1 reports the proportion of phases detected by this methodology, similar to the values detected by optical microscopy, together with ~~an~~other microstructural parameters obtained from the map. Although no bainite was detected by the IQ parameter in the sample cooled at 0.03 ºC/s, their detailed analysis maps show~~s~~ that, in addition to polygonal ferrite, a minority phase compatible with columnar bainite is observed (Fig. 4). The structure seems to be free of defects and the cementite particles are too small to distort the ferrite and thus be detected by X-ray diffraction. The structure shows no differences in grain size, boundaries, misorientations or other microstrutural aspects allowing the differentiation via the conventional structural parameters. The columnar bainite, associated to the phase detected by IQ, is also detected in samples at intermediate and high cooling rates (Fig. 5). This work describes the microstructures formed by austenitic transformation in continuously cooled low carbon steel. Combining X-ray diffraction, optical metallography and EBSD techniques permitted an exhaustive characterization of the microstructure. The development of different types of bainite, depending on the cooling rate, is reported and questions related with characterization of the observed microstructures will be addresses in future research.

REFERENCES

[1] Krauss G. and Thompson S.W., "Ferritic microstructures in continuously cooled low and ultralow-carbon steels", *ISIJ International*, 38: 8 (1995) 937-945.

[2] Sachin L. Shrestha et al. "An automated method of quantifying ferrite microstructures using electron backscatter diffraction (EBSD) data". *Ultramicroscopy*. 137 (2014) 40 – 47.

[3] Ramazani A., Pinard P.T., Richter S. Schwedt A., Prahl U., "Characterization of microstructure and modelling of flow behaviour of bainite-aided dual phase steel", *Computational Materials Science*, 80 (2013)134-141.

ACKNOLEDGEMENTS

The authors acknowledge the facilities of the Laboratorio de Microscopía Electrónica CCT Rosario. The authors thank Vanina Tartalini and Pablo Risso for the sample preparation and equipment operation.

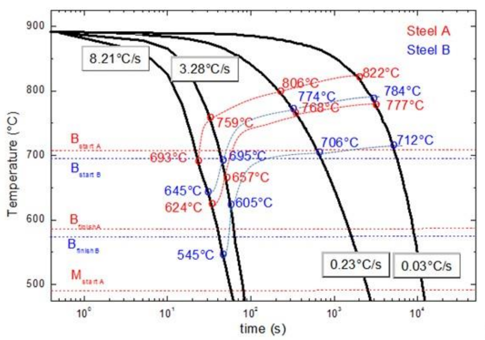

Figure 1. Correlation between the empirical transformation temperatures and the CCT curves obtained.

	0.03 ºC/s	0.3 ºC/s	8.2 ºC/s
% bainite	0	6	3,4
∅ poligonal ferrite [µm]	5,3±4	6,3±4	7,5±4
Aspect ratio	0.3 - 0.6	0.3 - 0.6	0.3 - 0.6

Table 1. Phases and other microstructural characteristic detected in the sample at different cooling rates.

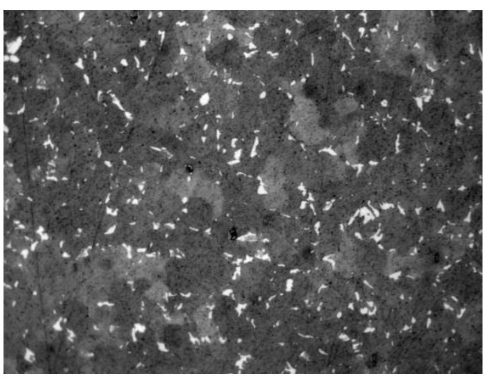

Figure 2a) Structural aspect of the steel cooled at 8.2 ºC/s observed by Optical Microscopy.

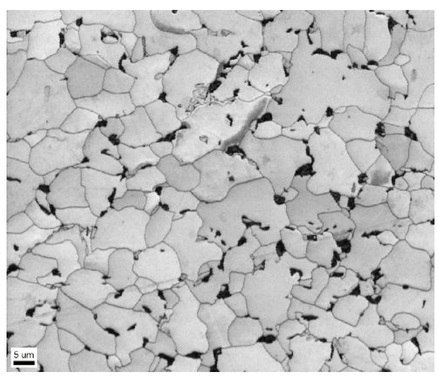

Figure 2b) IQ map of the steel cooled at 8.2 ºC/s observed by EBSD.

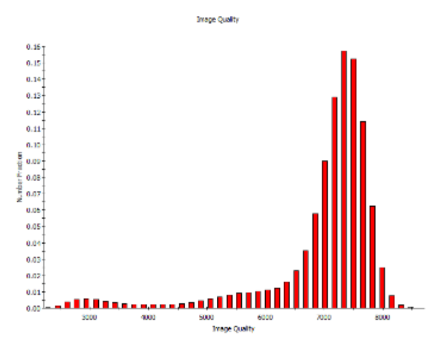

Figure 3. IQ distribution obtained from the map of Figure 2b

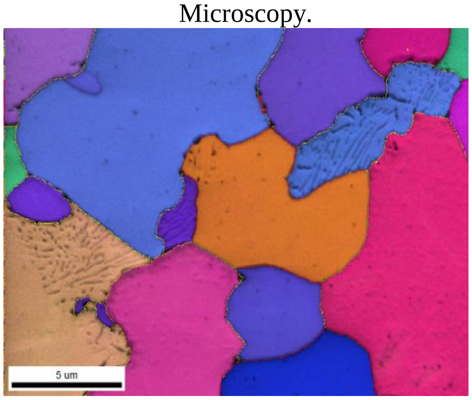

Fig. 4. Sample cooled at 0.03 ºC/s. Columnar Bainite in IQ + Inverse Pole Figure map.

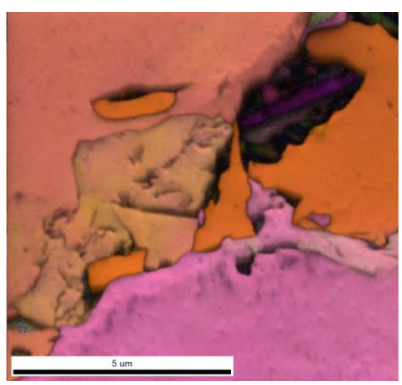

Fig. 5. Sample cooled at 8.2 ºC/s. Columnar Bainite and Bainite in IQ + Inverse Pole Figure map.