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Original Article

Cold-rolled multiphase boron steels: microstructure and mechanical properties

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ABSTRACT

The influence of the boron concentration on phase transformation characteristics, microstructure and mechanical properties of multiphase steels was investigated using computational thermodynamics (Thermo-Calc®), dilatometry, quantitative metallography and tensile tests. Pilot scale 50 kg steel ingots were prepared in an induction furnace operating under an argon gas atmosphere with boron contents between 0 and 47 ppm. The ingots were cut into 35 mm thick blocks, which were reheated to 1250 °C for 1 h and hot rolled for seven passes to attain a thickness of 7.0 mm. The hot-rolled sheets were machined and then cold rolled to a final thickness of 1.2 mm. Continuous annealing cycles were performed in a Bähr dilatomer and in a Gleeble machine. Continuous annealing laboratory simulations showed that boron did not significantly influence the amount of austenite formed during heating and soaking steps. However, boron influenced austenite transformation during the cooling step, which reduced the amount of ferrite and increased the amount of bainite. Regarding the mechanical properties, adding boron increased strength and decreased ductility of the product. The steels with boron concentrations up to 27 ppm exhibited the greatest effect. The amount of austenite, which was calculated using Thermo-Calc®, was slightly overestimated compared with that obtained by dilatometry and metallography, particularly for soaking temperatures lower than 800 °C.

1. Introduction

Advanced high-strength steels with multiphase microstructures, which consist of ferrite, bainite, martensite and retained austenite, are being used increasingly more in many automotive applications; in particular, these steels are replacing conventional HSLA steels due to their more desirable strength–ductility ratio. These materials are characterized by an interesting combination of high strength, good ductility,

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Table 1 – Chemical composition of the multiphase steels used in the study (in weight percent).

Steel	C	Mn	Si	P	S	Al	B	Nb + Ti	N	Ti/N
B10	0.10	1.8	0.5	0.02	0.007	0.029	0.0013	>0.028	0.0052	4.4
B30	0.11	1.8	0.5	0.02	0.005	0.025	0.0027		0.0042	4.5
B50	0.09	1.8	0.5	0.02	0.007	0.034	0.0047		0.0051	4.7
Base	0.09	1.8	0.3	0.01	0.005	0.043	–	–	0.0043	–

continuous yielding, high initial work hardening rates (*n* values) and a low yield stress to tensile strength ratio (YS/TS) [1].

In the context of multiphase steels, boron is an unique alloying element in that a soluble content of 0.0010–0.0030% can provide a hardenability effect equivalent to adding approximately 0.5% of other elements, such as manganese, chromium or molybdenum [2–6]. Thus, various approaches have been attempted to produce multiphase steels with boron additions with the objective of reducing costs.

It is generally accepted that at the fully austenitized condition, boron segregation or the precipitation of fine $Fe_{23}(C,B)_6$ carbides during cooling at austenite grain boundaries retards the transformation from austenite to ferrite by impeding the nucleation of ferrite, which subsequently improves the hardenability of steel [7,8]. In the production of multiphase steels, inhibiting ferrite formation is expected to increase the amount of martensite or bainite. However, for multiphase steels, ferrite grows during cooling from the $(\alpha + \gamma)$ phase

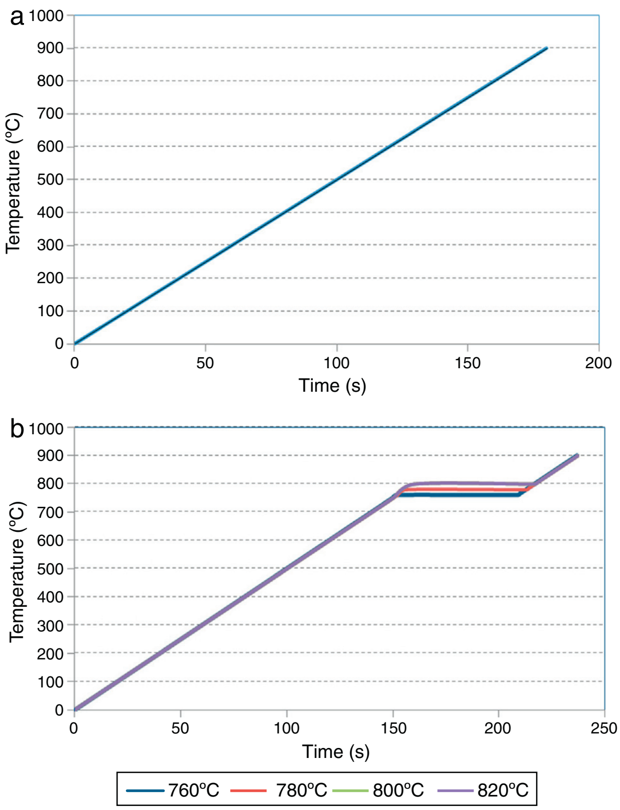

Fig. 1 – (a) Thermal cycles conducted in the Bähr dilatometer to determine the volume fraction of austenite formed with heating steps; (b) heating with the soaking steps.

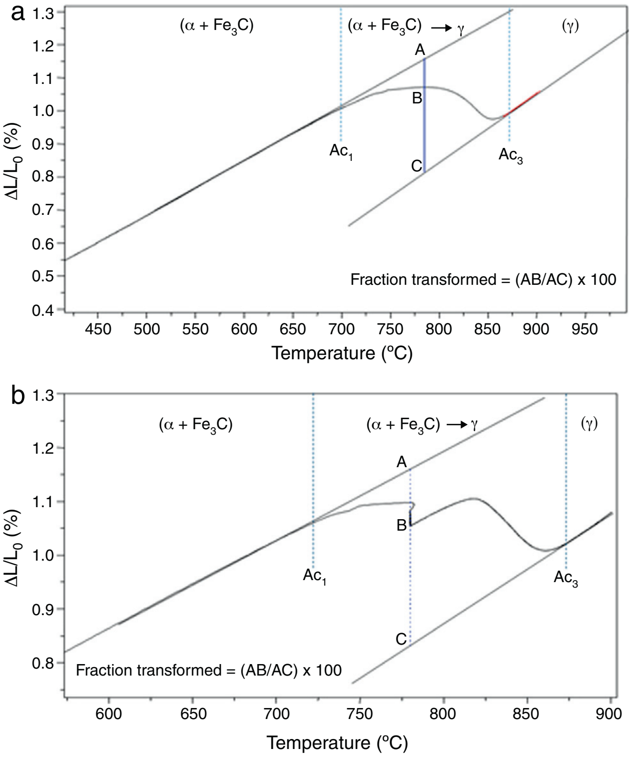

Fig. 2 – Example of application of the lever rule to determine the fraction of transformed austenite by means of dilatometry. (a) Continuous heating; (b) heating with the soaking step.

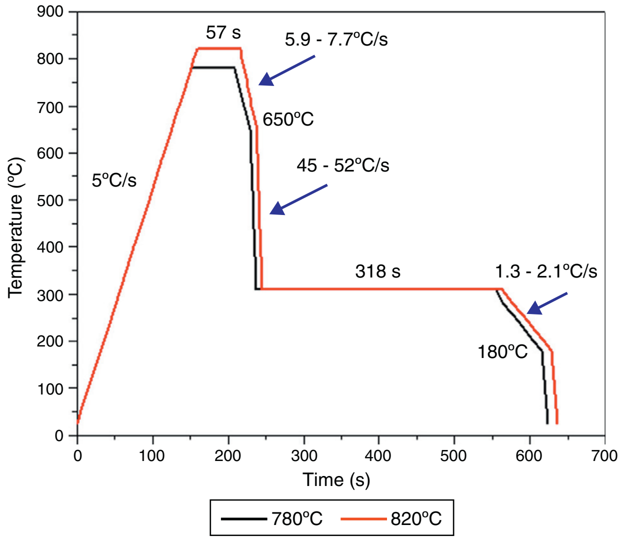

Fig. 3 – Continuous annealing cycles performed in the Gleeble simulator.