Summary of results obtained from the isothermal test on B1 steel

In Figure 1 it is shown a schematic diagram of the isothermal test performed at Gleeble on B1 steel sample (Table 1). The austenization cycle was the same used for the assessment of the CCT diagram (heating at 5°C/sec up to 880°C, followed by 5 minutes of holding at this temperature), then the sample was cooled at 45°C down to the transformation temperature, which was 400°C, hold at this temperature during one hour, and then cooled down to room temperature at 10°C/sec. During the test, the diameter of the sample was measured with a high resolution dilatometer and the temperature was controlled with a type K thermocouple spot welded to the middle section of the specimen.

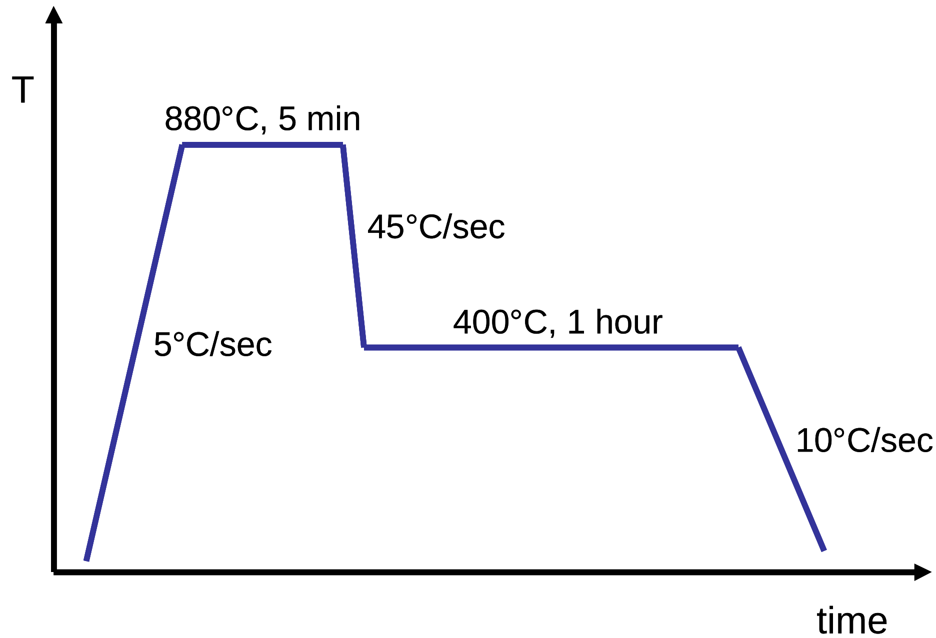

Figure 1: Schematic diagram of the isothermal test.

C	Mn	Si	Cr	Mo	Ni
0.24	0.09	1.27	1.00	0.23	3.64

S	P	Al	N (ppm)	O (ppm)
0.001	0.005	0.014	63	14

Table 2: Chemical composition of steel B1. Values in wt% except when indicated

From the change of the sample diameter (d), the diametral strain was derived as $\varepsilon = \Delta d/d0$ (d0 = 6 mm). In Figure 2, ε is plotted as a function of temperature. It can be seen that, due to the austenite decomposition reaction, there is a clear change in the diameter during the isothermal holding at 400°C. But, there is also a slight deviation from the linear behavior during cooling from the austenization temperature to 400°C. This deviation, that began at ~750°C, might be ascribed to a high temperature reaction, for example polygonal ferrite formation. Interrupted quenching tests will be performed at Gleeble in order to study this reaction. From the analysis of the dilatometric curve, the final volume fraction associated to this high temperature reaction is about 5 to 10% of that corresponding to the isothermal reaction taking place at 400°C. During cooling from the isothermal reaction temperature to room temperature, no deviation from the linear behavior was observed, then it was assumed that no transformation took place below 400°C.

In Figure 3, ε is plotted as a function of the time of holding at 400°C. The isothermal reaction started at about 20 seconds and ended after nearly 10 minutes of holding. The final microstructure was mainly a mixture of bainite and retained austenite (Figure 4 and 5). It was slightly finer than that obtained previously after a normalization treatment (same austenization cycle), see Figures 6 and 7. There were also in this case large blocks of retained austenite (up to 3 μm of size), but at the same time fine films of a second phase (possibly retained austenite) were frequently observed between sheaves of bainitic ferrite. The hardness of the sample isothermally treated was also higher than that corresponding to the normalized steel (see Table 2).

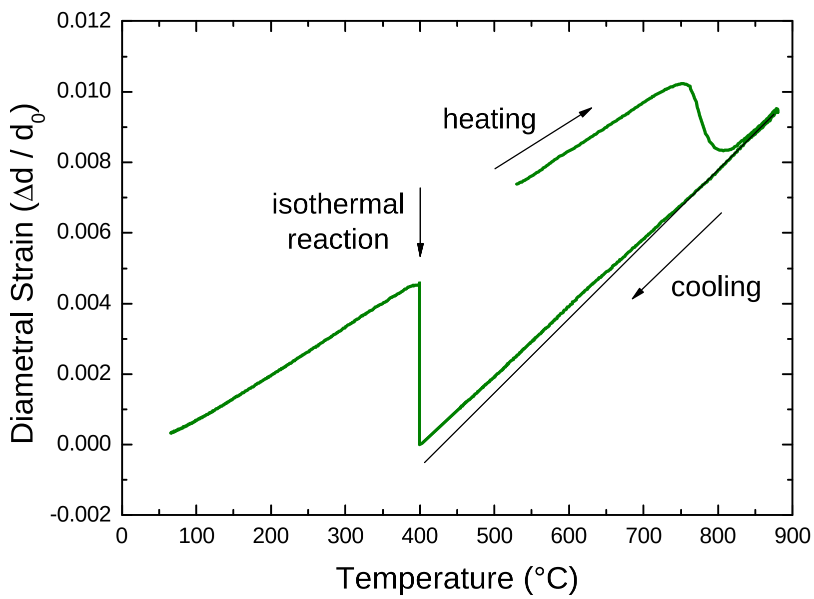

Figure 2: Diametral strain as a function of temperature.

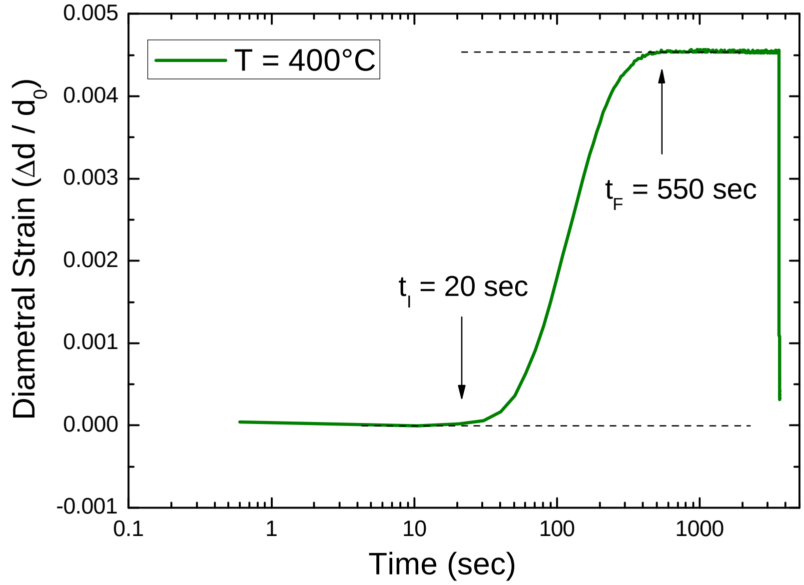

Figure 3: Diametral strain as a function of the holding time at 400°C.

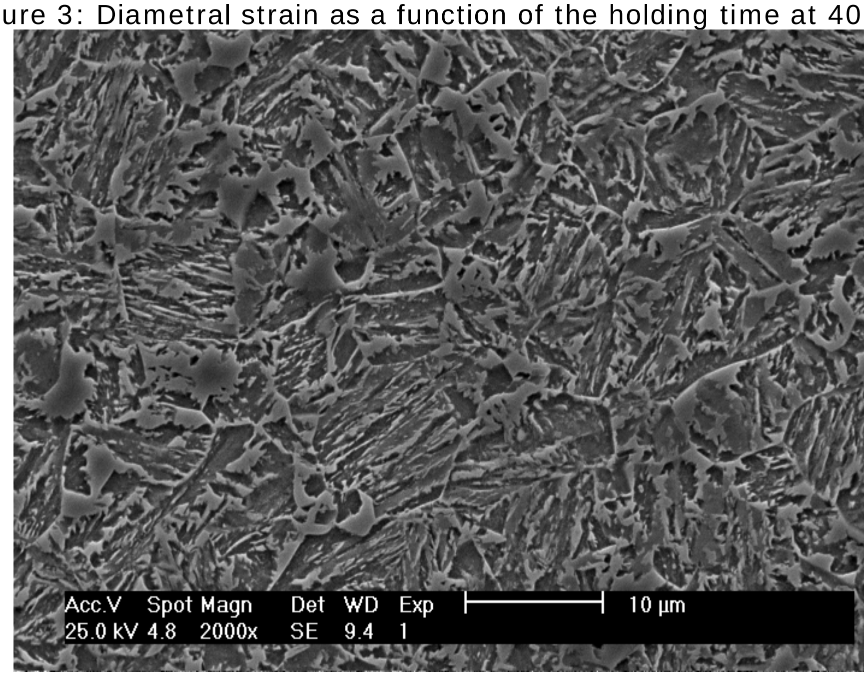

Figure 4: SEM micrograph of B1 steel transformed isothermally at 400°C during 1 hour.

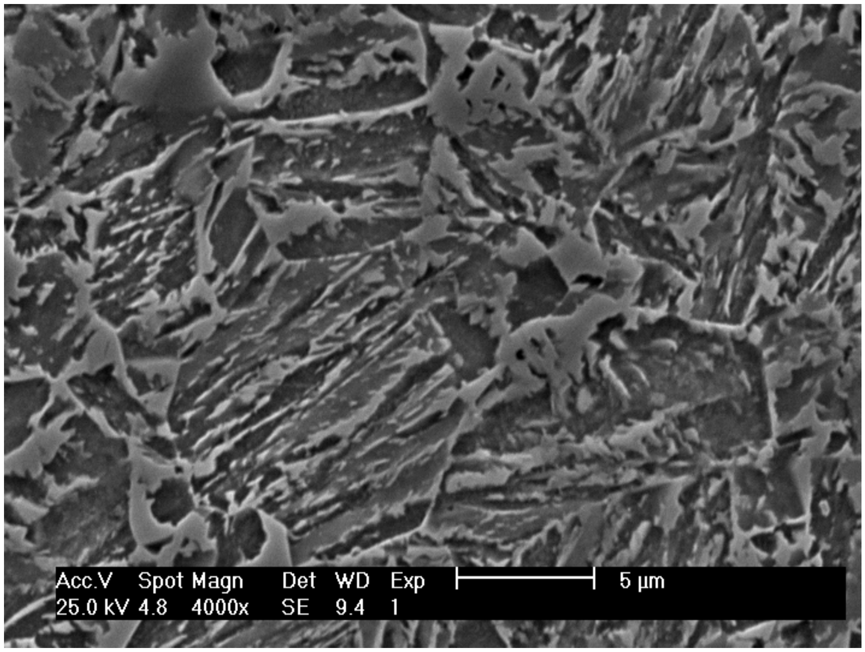

Figure 5: SEM micrograph of B1 steel transformed isothermally at 400°C during 1 hour.

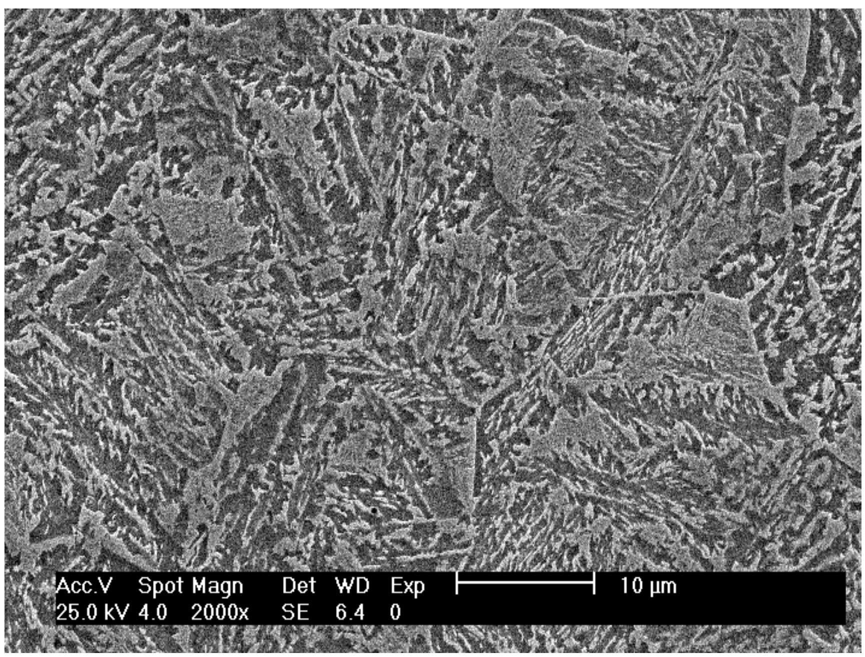

Figure 6: SEM micrograph of B1 steel after a normalization treatment.

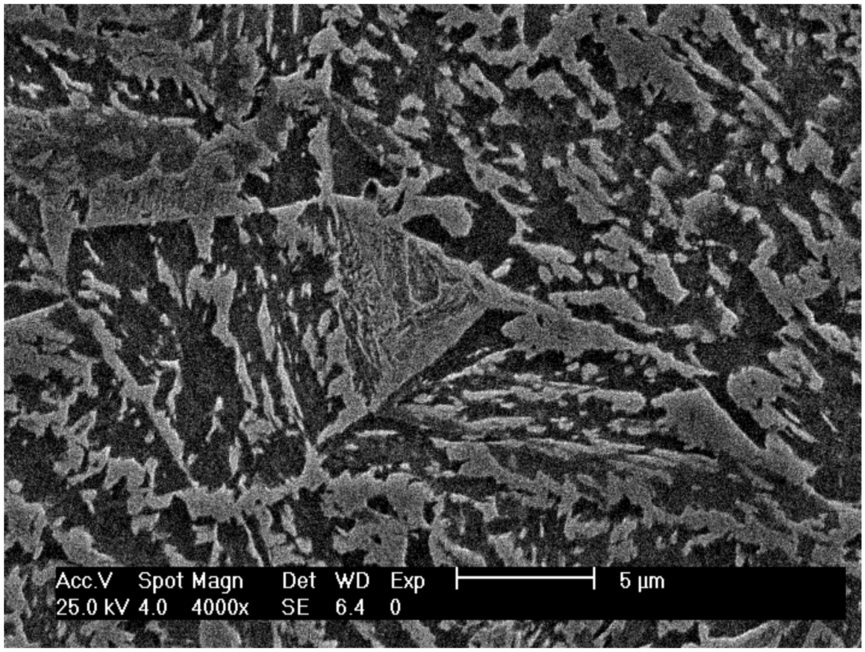

Figure 7: SEM micrograph of B1 steel after a normalization treatment.

	Hv (1Kg)
B1 isothermal transformed at 400°C	421 +/- 7
B1 normalized	367 +/- 10

Table 2: Hardness of B1 steel after different heat treatments.