In situ dynamic study of phase transformation and structural changes in nanostructured "superbainitic" steel

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Carbide-free bainitic steels are representatives of a wide class of alloys in which interesting mechanical properties are obtained from relatively simple and cheap heat treatments. [1]. The final phase mixture consists of bainitic ferrite and thin film of retined austenite (Fig.1).

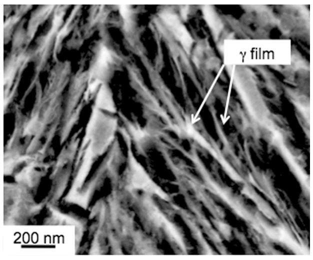

Fig.1. SEM micrograph of high carbon-high silicon superbainitic steel.

There are circumstances in which the steel is subjected temporarily to elevated temperatures in excess of 400°C; for example is the galvanizing treatment where the steel passes through a bath of a molten zinc-rich alloy or in aero-engine shafts in order to apply corrosion-resistant coatings. It is possible that the thermal stability of the austenite would not in these case be sufficient, leading to its decomposition into a thermodynamically more stable mixture of ferrite and cementite. Detailed examinations of the microstructure during heating and holding at high temperature is essential in order to understand how is possible to design a more stable steel.

Cylindrical samples of 2 mm diameter and 10 mm length were machined from the isothermally transformed material (two bainitic steels alloy 1 and alloy 2, with chemical composition that is Fe-0.9C-2.2Mn-1.8Si-1.1Co and Fe-1.1C-2.3Mn-3.0Si respectively) for the in situ continuous heating and high temperature isothermal experiments (450°C-550°C). During heating (5°C/min) from RT to 650°C using a hot air blower, the samples were exposed to an X-ray beam of monochromatic wavelength (λ=0.20812 Å).

Fig. 2, shows the experimental 2D plots describing the evolution of {111} and {200} austenite peaks and {110} ferrite peak for both steels, during in-situ heating experiments. Note the changes in the position of the {111} and {200} austenite peaks around 400°C for alloy 1 and 520°C for alloy 2, with a significant reduction of the lattice parameter up to 650°C. The residual austenite peaks are affected by a strong asymmetry due to the gradient of the carbon content in retained austenite network. The film austenite network varies between 10 and 150 nm (Fig. 1) with a consequent broad distribution of the carbon content as measured in recent a work by using atom probe tomography [2]. The changes in quantities for both alloys, as well as the lattice parameters during the heating experiment are reported in Fig 3a, b and c. From a quantitative point of view, the austenite starts to decompose above 400°C for alloy 1 and above 580°C for alloy 2. In the case of alloy 1, the change in lattice parameter is concomitant to the loss of austenite and formation of cementite. For alloy 2, the behavior is completely different: The lattice cell of austenite starts to change around 530°C and between 530°C and 580°C there is a sort of incubation period in which the carbides are not detectable and no decomposition of retained austenite is observed.

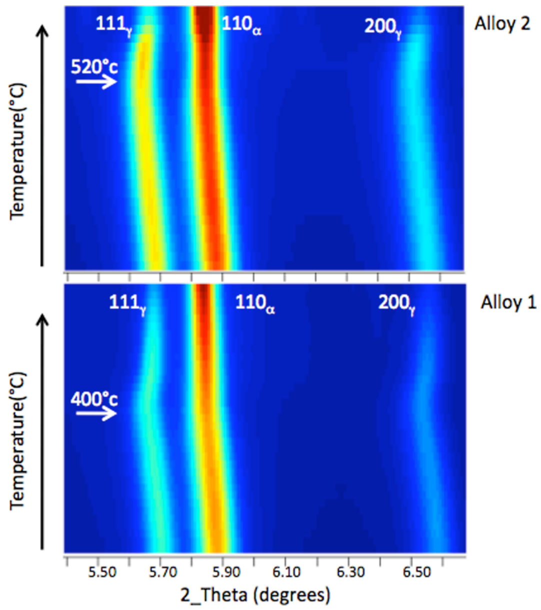

Fig.2. Experimental 2D plots show the qualitative evolution of retained austenite and bainitic ferrite during continuous heating for alloy 1 and alloy 2.

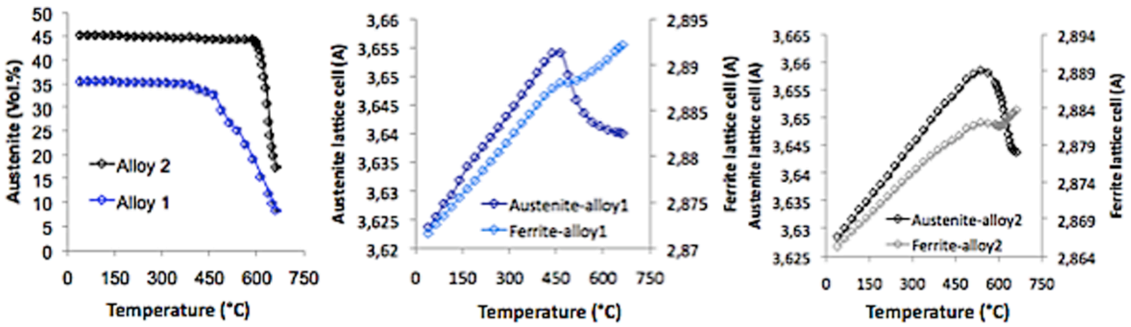

Fig. 3. Quantitative evolution of retained austenite during heating (a). Lattice parameters changes during heating for alloy 1 (b) and alloy 2 (c)

The super-saturated ferrite lattice starts to deviate from the linear thermal expansion between 400°C and 420°C for alloy 1, and around 480°C-500°C for alloy 2. For both alloys the loss of carbon in austenite and supersaturated ferrite is clearly evident. Particularly, the amount of carbon in both supersaturated ferrites appears to decrease substantially during heating above 420°C for alloy 1 and 500°C for alloy 2, in contrast to a recent work in which the carbon in a superbainitic steel, was measured with atom probe tomography where the amount of material that can be examined is much more limited [2]. During continuous heating, no further enrichment of carbon from supersaturated ferrite into austenite was observed. However, during isothermal holding at 520°C for 2h, alloy 2 displays an unexpected behavior in which the lattice parameter of ferritic bainite starts to increase after the first hour of tempering (Fig 5a and b). The origin of this carbon enrichment in bainitic ferrite during tempering is currently under study but we believe that is possible to associate this fluctuation to the density of defects changes during tempering.

References

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