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Corrosion behaviours in acidic solution of spheroidal cast irons highly alloyed with nickel or cobalt. Part 1: Elaboration and microstructures of the alloys

Kamel Meridja, Patrice Berthod

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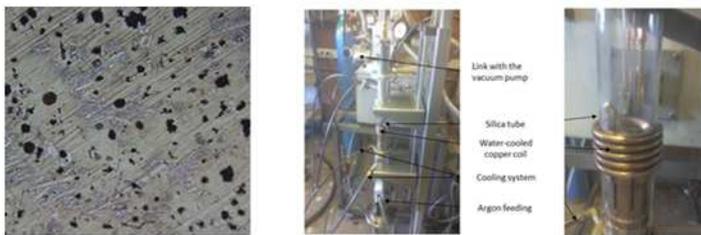
Certainly the most used metallic alloys are the ferrous ones. Initially issued in the liquid state from the reduction of iron ore, at the exit of blast furnaces [1] the liquid cast iron, mainly constituted of Fe but containing also significant amounts in carbon (coke) and in silicon (gangue), may be directly driven to the foundry workshop to be treated then poured in moulds to solidify with the shape wished for the wished pieces [2] or driven to the oxygen converter to lose the main parts of their carbon and silicon to become liquid steel [3]. In both cases they can be enriched with supplementary elements to obtain more or less highly alloyed cast irons or steels for achieving special microstructures and properties [5]. This can be useful to achieve new mechanical behaviours as well as improved corrosion resistance.

Alloying cast irons with new elements, foreign to the composition at the exit of blast furnace often supposes that new liquid metal treatments must be done after the addition (inoculation for help graphite nucleation, desulphurization then magnesium treatment for promoting the spheroidal growth of graphite...). But it was also demonstrated that it is possible to take a spheroidal graphite cast iron (SG cast iron), rapidly remelting it, adding the new element, homogenizing a short time the liquid alloy before quickly solidifying it [5].

This was attempted here to obtain SG cast irons highly alloyed to either nickel or cobalt, in order to study the properties that they are able to bring.

Elaboration of the Ni- and Co-alloyed cast irons

Several parts were preliminarily cut in a spheroidal graphite cast iron ingot of industrial origin, the composition of which is about 3.5 wt.%C and 2.5 wt.%Si (rest: Fe). Three 30g-weighing, three 20g-weighing and three 10g-weighing parts of industrial SG cast irons were available after cutting. In parallel three charges (10, 20 and 30g) of mixture of pure elements were prepared and melted together in a High Frequency induction furnace under an inert atmosphere (pure argon).

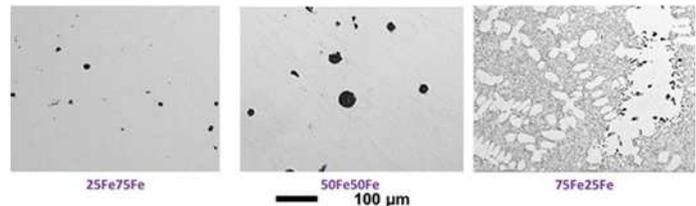


Microstructure of the industrial SG cast iron devoted to be alloyed with the mother alloys

Photographs of the high frequency induction furnace

This led to mother alloys the chemical compositions of which were either Co-3.5C-2.5Si, or Ni-3.5C-2.5Si or Fe-3.5C-2.5Si (all contents in weight percent). The three 30g-weighing part of industrial cast iron were thereafter remelted together with the 10g-weighing ingot of M-rich mother alloy (M=Co, Ni or Fe), this leading to three 25M75Fe-based alloys. The three 20g-weighing part of industrial cast iron were remelted together with the 20g-weighing ingot of M-rich mother alloy (M=Co, Ni or Fe), this leading to three 50M50Fe-based alloys. The three 10g-weighing part of industrial cast iron were remelted together with the 30g-weighing ingot of M-rich mother alloy (M=Co, Ni or Fe), this leading to three 75M25Fe-based alloys. The same furnace as for preliminarily preparing the mother alloys was used for that.

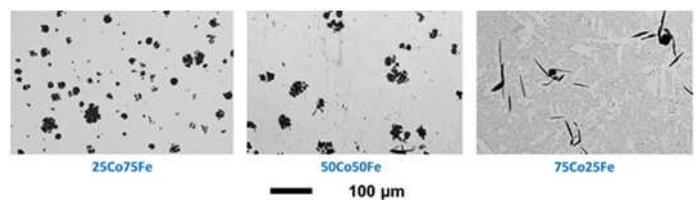
The remelting was carefully done: fast heating, short stage (30 seconds) in liquid state but at a not to high temperature (in order to avoid the most possible losing the benefit of the initial inoculation and spheroidization treatments of the liquid metal industrially done at the origin), fast decrease in injected power for rapid solidification.



Microstructures of the xFe-(50-x)Fe cast irons



Microstructures of the xNi-(50-x)Fe cast irons



Microstructures of the xCo-(50-x)Fe cast irons

The EDS control of the chemical compositions of the obtained alloys showed that the targeted contents in Ni or Co, Fe and Si were really obtained (carbon cannot be analysed with this technique).

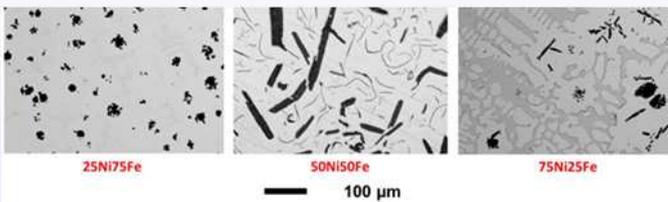
The conservation of the initial spheroidal type of graphite of the industrial SG cast iron was rather successful in the case of the 25Ni75Fe cast iron. The graphite nodules are only a little irregular.

This is not the same case for the 50Ni50Fe cast iron in which one can see coarse graphite plates together with thin graphite lamellae. Several types of graphite are present in the 75Ni25Fe cast iron: degenerated spheroids, rather coarse plates and extra-thin lamellae.

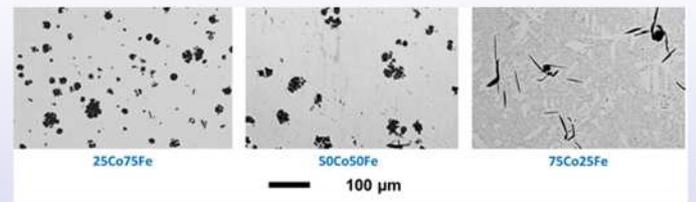
The initial graphite spheroids were also kept in the 25Co75Fe and 50Co50Fe cast irons. Contrariwise the 75Co25Fe cast iron looks like the 75Ni25Fe one. The 25Fe75Fe and 50Fe50Fe cast irons seem to be perfectly spheroidal graphite cast irons, but with an rather low apparent volume fraction of graphite. In contrast the 75Fe25Fe is totally different: dendrites and graphite present as very thin lamellae and small compact particles.

Responses of the microstructures to contact with Nital 4 (96% ethanol, 4% HNO₃)

Several cm³ of fresh "Nital4" etchant (96% ethanol + 4% of pure nitric acid HNO₃ in volume) were prepared. This solution is famous for revealing the microstructures of not alloyed ferrous alloys. The metallographic samples were thereafter immersed during 10 seconds in this solution in order to observe the response of the obtained alloys to this oxidant solution. After this immersion at room temperature the metallographic samples were quickly rinsed with tap water, ethanol and dried with a hair-drier. They were observed again using this time a simple optical microscope (Olympus BX51) equipped with a camera (ToupCam). Visualization and photography were carried out using a computer and the ToupView software.



The microstructures of the three xNi-(1-x)Fe cast irons are not modified after 10 seconds of immersion in the Nital4 solution. This is not the case of the 25Co75Fe and 50Co50Fe cast alloys which display a "bull's eyes" microstructure as classical ferritic-pearlitic SG cast irons. Only the most cobalt-alloyed cast iron (75Co25Fe) seems being only slightly etched. The 25Fe75Fe and 50Fe50Fe cast irons are significantly etched by Nital, with as result the appearance of the nature of the matrix: ledeburite (white austenite-cementite eutectic) together with grey dendrites (austenite at solidification, converted in pearlite during the cooling); this is a consequence of the rather fast cooling in the liquid state and thereafter in the solid state.



It appears thus possible to obtain, from parts of industrial SG cast iron, spheroidal graphite cast iron highly alloyed with nickel (at least until 25 wt.% Ni) and with cobalt (at least until 50 wt.% Co), following the procedure applied here. This was also observed (at least until 50% of SG industrial cast iron) with the reference xFe(1-x)Fe alloys were also produced in parallel in order to eventually distinguish a specific role of nickel or of cobalt, farer than the simple dilution of the origin nuclei for graphite (inoculation of the initial industrial cast iron). The corrosion properties, which now remain to extensively specify (Part 2 of this work [6]), were already partly observed here, not in an aqueous solution, but in contact with nitric acid diluted in ethanol. In this way these are the Ni-alloyed cast irons which appeared the most resistant (no visible attack after 10 seconds), followed by the cobalt-richest cast iron. This will be deeper investigated later, in acidic solutions, by long immersions and/or by using electrochemical techniques.