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Manale Belhabib, Patrice Berthod. Effect of the carbon content and of the hardened state on the corrosion behaviour of cast carbon steels in an acidic aqueous milieu. Part1: Study of the possible carbon content influence on the obtaining conditions and on the stability of the passive state. Eurocorr 2016, Sep 2016, Montpellier, France. hal-03283828

## HAL Id: hal-03283828 https://hal.science/hal-03283828

Submitted on 12 Jul 2021

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Faculté des Sciences et Technologies

### Effect of the carbon content and of the hardened state on the corrosion behaviour of cast carbon steels in an acidic aqueous milieu. Part1: Study of the possible carbon content influence on the obtaining conditions and on the stability of the passive state



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Carbon steels are among the cheapest metallic materials able to serve as structural materials. Initially issued from the reduction of ferrous ore in blast furnace [1,2] they may be submitted to incomplete or total decarburization and removing of silicon, by treatment of the obtained cast iron in blast furnace [3,4] or after in a converter [5-7]. From the molten state their solidification leads to various microstructures depending on their final carbon content [8, 9]: wholly ferritic (no remaining carbon), ferritic-pearlitic (carbon existing, with content lower than 0.8 wt.%), pearlitic (carbon close to 0.8 wt.%) or hyper-eutectoid (higher than 0.8 wt.%) [10-12]. In contrast with their chromium-containing versions such Fe-C are easily threatened by corrosion, especially in acidic milieu. However this degradation may be limited by cathodic polarization [13-15] by applying a low potential carrying them in their immunity domain. This energy costly technique can be replaced by anodic polarization since it is possible for iron to be maintained in its passive state, even in acidic solutions, with lower electrical energy consumption than for the cathodic polarization. In order to precise some operating

parameters it is necessary to know the behaviour in passivation of the steels considered to precise some operating in this work the focus is done on the possible variability of the passivation behaviour of cast steels versus the car bon amount they contain. A series of binary Fe-C steels was elaborated by classical foundry with carbon contents dispersed over the whole possible range of carbon weight content [0; 2 wt.%]. These steels were mounted as electrodes and submitted to a cyclic polarization (anodic  $\leftrightarrow$ cathodic) in order to better know the dependence of the obtaining conditions and the of the stability of the passive state, on the carbon content of steels issued from such an elaboration route.

#### Elaboration of the alloys and microstructures' observations

Five synthetic cabon Fe-xC steels (x=0, 0.4, 0.8, 1.2 and 1.6 wt.%) were elaborated by fusion and solidification. This was done using a Hgh Frequency induction fumace (CELS), by melting together pure iron and graphite. Each charge was placed in the water-cooled cucidle of the fumace. It was isolated from ambient air by a slica tube. Three cydes (7 × 10-2 mbar-vacuum; incorporation of 600 mbars of agon) were applied, before finally establishing an internal atmosphere of 300 mbars of pure Ar. Melting and chemical homogenization of the liquid were achieved by tespecing an isothermal stage of three minutes at 4 kV. By progressively decreasing the injected power, the melt cooled and solidified to become a compact ingotof about40g. Each ingot was cut for obtaining different types of samples. Two about (7 mm × 4 mm × 3 mm)-parallelepipeds were prepared from each of these ingots. One of the two parts was destined to metallographic characterization and the second one was devoted compression runs which will be presented in the second one was devoted compression runs which will be presented in the second part of this work[16].

The parts kept for metallography investigations were initially embedded in a cold resin mixture (82% of CY230 resin and 18% of HY253 hardener, liquid products from ESCIL®). They were ground with SIC papers from 120-git up to 2400-grit. After intermediate ultrasonic deaning these embedded samples were polished with texitel disk enriched with tyruh hard parides in order to obtain a mirror-like surface. After Ntal etching (5 seconds of immersion in a [ethanol-4%HVO3), except for the ferritic one: 15 seconds), the metallography samples were observed using an optical microscope: Ofympus, model BX51, equipped with a Toupcam camera driven by the Toupview software.

The ascast microstructures of the obtained steels are illustrated by optical micrographs taken after Ntal etching, in Figure 1 for the two hypo-eutectoid steels (ferritic Fe-0C and ferritic-pearitic Fe-0.4C) and for the euterdoid one (pearlific Fe-0.8C), and in Figure 2 for the two hyper-eutectoid steels (Fe-1.2C and Fe-1.6C, both containing pearlife and pre-eutectoid cementite). Their microstructures are polycrystalline and equi-axed in all cases.



as-cast Fe-0.8C

litine surrent density is 0 /124/um/th



#### Electrochemical tests

The parts of steel devoted to the electrochemical measurements were connected to the denuded end of a copper electrical The plan or back defined or the same cold restandant du matathemento were constructed in a una dotted of the oral dotted or the were constructed in the same cold restandant matathemento were constructed in a set of the same cold restandant in a site metallography samples. The junction was carefully covered by this restant in order to have only the plastic-covered copper vire in contact with the electrolyte. Each working electrode was associated with a platition maximized calomel one (SCE), inside a three-electrode cell.



parcent donaity in \$ /(1A/cm\*)0



General aspect of the cyclic polarisation curves in all cases one can see that the first cathodic part of the polarization curve is globally linear in this semi-logarthmic plot cathodic Tarl est aspity line), at least before appreaching the Ecorr potertial. The first part of the anode part is also rather linear (anodic Tarl estraight line) before reaching a globally stationary anode dersity of currert. Passivation finishes to happen, with as result a potual tail in current density. For higher patertial after a patertial increase in currert dhe set of the contex a loss of passivation occurs. I revealed by a drastic increase in oncide currert density. The potential goes on decreasing and become lower than the polarization curve.

General aspect of the cyclic polarisation

Data concerning the conditions of obtaining the

Data concerning the conditions of obtaining the passive state One can see that the critical current density of passivation ( $l_{e_0}$ ) is in all cases of around 200 mArcm<sup>2</sup>. The potential at which passivation occurs (E pass) is of about 550 mV by regards to the dydrogen onmal electrode (550mV /HKE, after correction from the 242mV/HKE of the Saturated for the current density just after passivation (pass mini) are rather scattered since t varies between 40 µA/cm<sup>2</sup> and 1 mA / cm<sup>2</sup> among the steels. The potential of transpassivation current (I transpass) varies of a (2004)-magnitude. Thus, except log and to the pass which are alittle variable, it seems that [pass maxi) varies of a 2004)-magnitude. Thus, except log and the pass which is the mating large space of the site for the large space of the site for the large space. E pass which are a little variable, it seems that lpa mini, E transpass maxi and I transpass maxi increase when the carbon content in the st

#### Data corresponding to the stability of the obtained passive state

They are more incomplete than the data concerning the obtaining of the passive state since it was not possible in some cases to measure the current densities and potential values corresponding to the loss of the passive state. The minimal current toss of the passive state. The minimal current density of corrosion in the passive state (1 pass mini) just before losing it is a little lower than 10 µJkcm<sup>2</sup>. The potential at which the passive state is sudderly lost is around 650 mV / HNE and the transient current density obtained at the loss of the passive state is of about 300 m Arcm<sup>2</sup>. Since seve and values are lacking it is not possible to verify whether they show a clear dependence on the carbon content in the steel.

as-cast Fe-1	.6C	2900
	-	3000
R		1500
1	E.N.	1000
	0	Sco. Sco.
 	1.006-01	4
		-500

densities and of potential ing parts of the cyclic pola 0 0.4

They were immersed in a molar sulphuric solution (H<sub>2</sub>SO<sub>4</sub>, 1M) then stay 5 minutes before applying the cyclic polarization. This

The proof influence in a mature toppoint solution (pack), implicit and of influence depropring it or yot potentiation mature one consisted in measuring it or yot potential articles are in potential at +1mill Not per second was then applied until leaching an anodic potential of 1.9 Nots. This was immediately followed by a decrease in potential at +1mill Not per second until reaching and and per 2500.

Values of current densities and of potential on interest in the potential-decreasing parts of the cyclic polarization curves								
wt.%C	0	0.4	0.8	1.2	1.6	unit		
Ipascolist	7.25	9A3	6.37	1	1	μA / cm <sup>2</sup>		
Epacehoes	608	704	666	1	582	V / HNE		
Ipecteconat	375	313	1	1	237	mA / cm²		

0.8

Thus all the studied carbon steels get passivated by anodic polarization, passivation state that they can keep if the potential is maintained at a level high enough. There was obviously no dependence of the conditions of passivation and of passivation keeping on the carbon content. If in the passivation state the anodic current density is unsurprisingly lower than in the active state but not much lower. Additional tests may be required to verify the sustainability on long time of the passive state with constant polarization at fixed potential. The tendency to have transpassivation phenomenon delayed to higher potential when the carbon content on the steel increases remains to be verified and explained.

# These results concerning only cast carbon steels, the case of plastically deformed carbon steels remains to be examined since many steels are hardened by cold or hot rolling before use. This is the purpose of the second party of this work [16].

#### P59112 (full paper available in the Eurocorr 2016 CDROM)

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