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# Experimental and thermodynamic study of ternary Fe-30Cr-xC carbon-rich alloys with x varying from 2.5 to 5.0 wt.%



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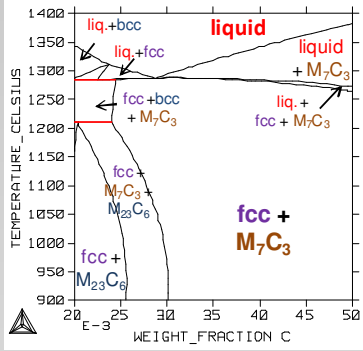
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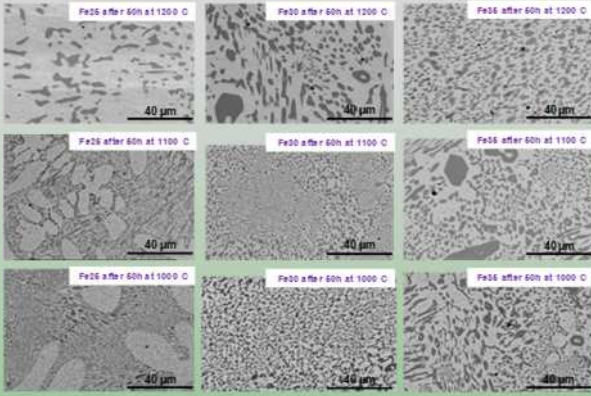
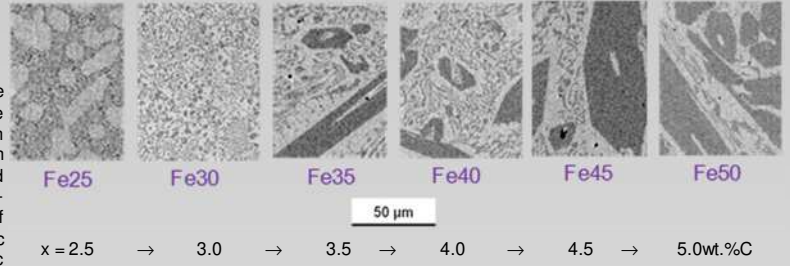
Carbon-containing iron alloys are generally known to possibly contain large quantities of hard phases or compounds able to bring high hardness to the alloys, as cementite, pearlite or martensite. If their chemical compositions also contain chromium such alloys may reach high levels of hardness, thanks to the formation of numerous interdendritic chromium carbides, as it can be met in some iron-based bulk alloys or hardfacing coatings hardened by tungsten carbides for example. Simultaneous high levels of carbon and chromium may lead to bulk alloys, easy to elaborate by casting, and which may display first high volume fractions of carbides for an enhanced hardness and wear resistance and also a good resistance to high temperature oxidation useful in case of substantial increase in temperature during service (e.g. due to friction).

The topic of this study is to elaborate by HF induction melting several alloys with very high carbon contents (from 2.5 to 5.0wt.%C), to characterize their microstructures after stabilization at different high temperatures, to assess their fusion temperature range, and finally to compare all these experimental results to predicted results issued from thermodynamic calculations.

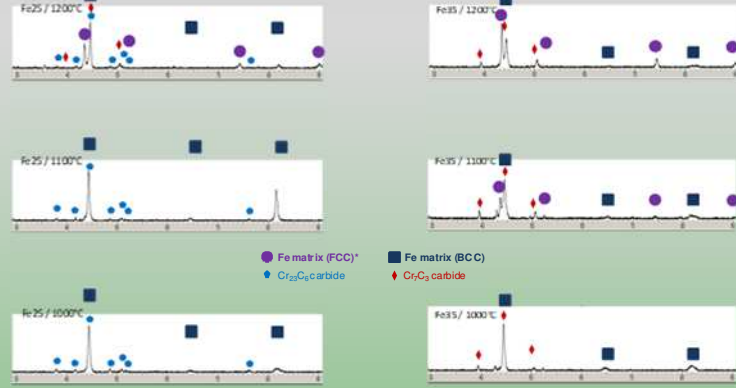


Fe-30Cr-2.5 to 5C alloys ought contain an austenitic matrix and carbides at high temperature as predicted by preliminary thermodynamic calculations.

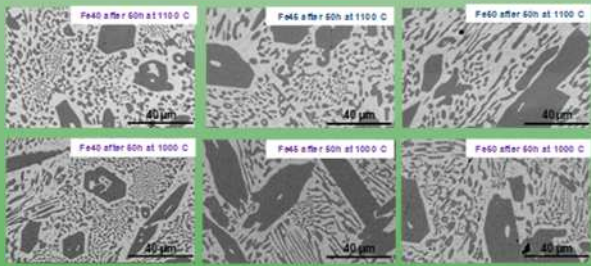
The elaboration of these alloys by melting of pure elements using a high frequency induction furnace allowed obtaining alloys the as-cast microstructures of which contain eutectic and pro-eutectic carbides (if carbon exceeds the eutectic content).



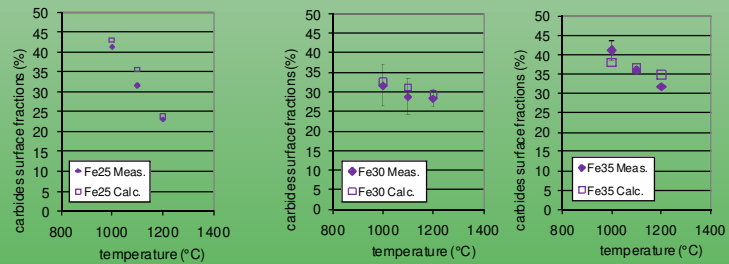
After 50 hours spent at high temperature (followed by air cooling) the carbide fractions (resp. morphologies) are slightly decreased (resp. changed), especially for 1200°C.



As revealed by X-Ray Diffraction, the carbides are  $Cr_{23}C_6$  in Fe25 and mainly  $Cr_7C_3$  in the C-richer alloys.



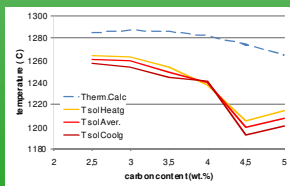
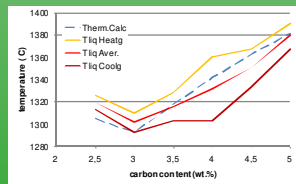
The types and carbides surface or volume fractions issued from thermodynamic calculations are consistent with XRD and image analysis results.



Good agreement was found between the fusion end/ solidification start temperatures and the calculated liquidus temperatures.

Thanks to the high intrinsic hardness of carbides (about 1650Hv for  $Cr_{23}C_6$  and 1340Hv for  $Cr_7C_3$ ), the obtained alloys logically show very high levels of hardness. It seems that, at this level of carbide fraction there is no longer an increase of the alloy's hardness with the carbon content or carbide fraction. In contrast the exposures to high temperature induce a softening, especially when it is realized at 1200°C.

	Hv30kg	1000°C	1100°C	1200°C
Fe25	833 ±33	815 ±25	416 ±35	
Fe30	721 ±34	827 ±58	489 ±8	
Fe35	728 ±31	836 ±24	511 ±32	
Fe40	770 ±37	822 ±35		
Fe45	824 ±16	707 ±31	Not done	
Fe50	824 ±32	771 ±13		



In contrast the agreement is not so good concerning the solidus temperature, but its decrease when the carbon content increases was well predicted.

The obtained microstructures are hypo-eutectic (2.5wt.%C), eutectic (3%C) and hyper-eutectic (3.5 to 5wt.%), and carbides are essentially  $Cr_7C_3$  (except for 2.5wt.%:  $Cr_{23}C_6$ ). The carbides fraction increases with the carbon content and tends to decrease with temperature. Carbides can become the main phase in the carbon-richest alloys in term of volume fraction. The results of thermodynamic calculations are consistent about the microstructures. A good agreement was also found concerning the liquidus temperatures but mismatches were noticed about the solidus temperatures. The obtained hardness are generally of very high level (more than 800Hv) but it tends to decrease when the heat-treatment temperature increases, as consequence of the decrease in carbide volume fraction when the exposure temperature increases.