Influence of tantalum on the rates of high temperature oxidation and chromia volatilization for cast (Fe and/or Ni)-base low carbon alloys

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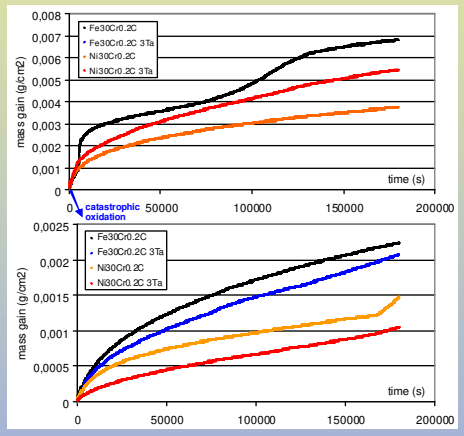
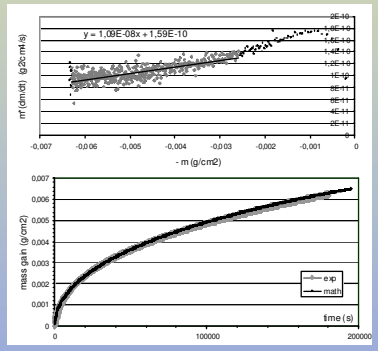
The high temperature oxidation behaviour of chromia-forming superalloys can be influenced by the presence of tantalum, an element which is often added to the alloy in order to reinforce it by solid solution strengthening or by forming refractory carbides in grain boundaries. The aim of this work is to study the oxidation kinetics of an iron-base alloy and an iron-nickel base alloy containing 0.2%C and 3%Ta at several high temperatures, with comparison with previous results obtained for more simple alloys with the same carbon content but without tantalum, and for a nickel base alloy with 0.2C and 3%Ta.

Two alloys, Fe30Cr0.2C3Ta and FeNi30Cr0.2C3Ta, were synthesized by high frequency induction melting under 300mbar of pure Ar. Thermogravimetry tests were performed at 1000°C, 1100°C and 1200°C for 50 hours under a dry industrial air flow at 1.5 L/h. The oxidation constants were determined by plotting the mass gain measures according to equation {m x dm/dt = Kp – Kv x m} and extracting the parabolic constant Kp and the volatilization constant of chromia Kv.

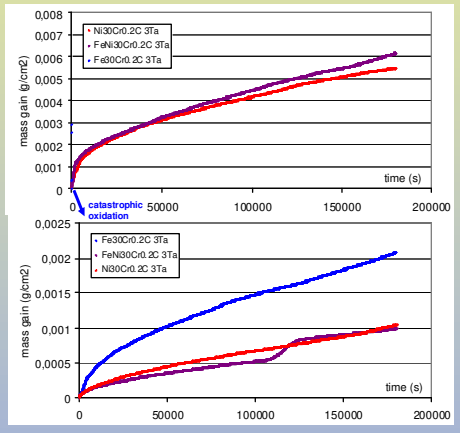


Effect of the presence of 3%Ta on the mass gain curves of Fe30Cr0.2C and Ni30Cr0.2C based alloys when oxidized at 1200°C (top) and 1000°C (bottom)

Alloy	Fe	Ni	Cr	Ta	C
Fe30Cr0.2C3Ta	Bal.	/	29.8 ± 0.7	2.1 ± 0.5	≈ 0.2
FeNi30Cr0.2C3Ta	Bal.	34.2 ± 0.5	29.6 ± 0.3	2.1 ± 0.5	≈ 0.2



{dm/dt = Kp – Kv . m}-type treatment of mass gain results and validation of the obtained Kp and Kv by comparison between real curve and the mathematical curve plotted with these values (here: Fe30Cr0.2C3Ta at 1100°C)



Effect of the base element M on the mass gain curves of the M-30Cr-0.2C-3Ta alloys when oxidized at 1200°C (top) and 1000°C (bottom)

Values of Kp and Kv issued from the {dm/dt = Kp – Kv . m} treatment of the thermogravimetry results for all alloys at the three temperatures

Kp (x 10^{-12} $g^2.cm^{-4}.s^{-1}$)	temperature	0%Ta	3%Ta
Fe30Cr0.2C	1200°C	*160*	(catastrophic oxidation)
	1100°C	98	159
	1000°C	19	8.6
FeNi30Cr0.2C	1200°C	/	*119*
	1100°C	/	23
	1000°C	/	1.4
Ni30Cr0.2C	1200°C	82	137
	1100°C	28	*42*
	1000°C	5.7	2.0

Kv (x 10^{-10} $g.cm^{-2}.s^{-1}$)	temperature	0%Ta	3%Ta
Fe30Cr0.2C	1200°C	*434*	(catastrophic oxidation)
	1100°C	204	109
	1000°C	31	-21 (?)
FeNi30Cr0.2C	1200°C	/	*112*
	1100°C	/	*52*
	1000°C	/	-2.3 (?)
Ni30Cr0.2C	1200°C	143	117
	1100°C	52	*56*
	1000°C	16	-10.6 (?)

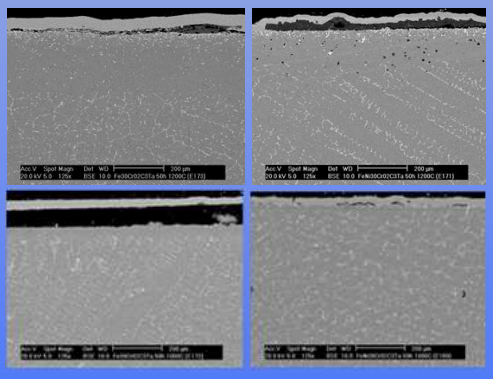
Bold characters: excellent fit between the experimental mass gain curve and the mathematical one
Normal characters: good fit between the experimental mass gain curve and the mathematical one
Italic characters: not good fit between the experimental mass gain curve and the mathematical one

SEM examinations were done on the external oxides and on the sub-surface metallurgical state of samples. Internal oxidation was characterized by measuring the surface fraction of the internal (Ta, Cr) oxides of tantalum, and by calculating the average value of an equivalent thickness (equal to micrograph length x oxide surface fraction).

Values of the average thicknesses of external chromia and of the internal (Cr,Ta) oxide

Average thickn. of the Cr oxide / Equivalent thickn. of the (Cr,Ta) oxide	temperature	0%Ta Cr_2O_3 (µm)	3%Ta Cr_2O_3 (µm)	3%Ta (Cr,Ta) oxide (µm)
Fe30Cr0.2C	1200°C	23 ± 4	36 ± 2	10 ± 0.5
	1100°C	18 ± 5	37 ± 6	4.8 ± 0.5
	1000°C	13 ± 3	**n. o. r.**	1.0 ±
FeNi30Cr0.2C	1200°C	/	29 ± 6	4.7 ± 0.5
	1100°C	/	11 ± 0.8	2.0 ± 0.3
	1000°C	/	5.7 ± 0.8	1.4 ± 0.2
Ni30Cr0.2C	1200°C	21 ± 0.4	*48 ± 8* (34*)	*2.8 ± 2.0* (2.0*)
	1100°C	8.1 ± 0.4	*12 ± 2* (8.5*)	*2.4 ± 1.1* (1.7*)
	1000°C	4.6 ± 0.7	*5.7 ± 2* (4.0*)	*1.3 ± 0.2* (0.9*)

*: values deduced from the former multiplied by 0.707 since durations were 100h instead of 50h
n. o. r. : no external oxide remained on the sample after cooling)



Surfaces of the two alloys Fe30Cr0.2C3Ta (left) and (Fe=Ni)30Cr0.2C3Ta (right) oxidized at 1200°C (top) and 1000°C (bottom)

The presence of tantalum, that can lead in Fe-base and FeNi-base carbon-containing alloys to an interdendritic carbides network exclusively constituted of TaC carbides, greatly influences the high temperature oxidation behaviour. More precisely the parabolic constant Kp and the volatilization constant Kv increases for the first one at the highest temperatures, but decreases for the second one since tantalum seems to induce a relative protection of chromia against volatilization of chromia. But such an effect only exists for low carbon alloys since tantalum should on the contrary enhance the rates of the oxidation phenomena when the carbide density is double, as observed in another study.

Eurocorr 2007 – Freiburg im Breisgau (Germany) – 9-13 September 2007