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High temperature oxidation behaviour of alloys containing very high densities of carbides

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Some alloys containing both very high fractions of carbides and a high amount of chromium can potentially display a low thermal expansion and a good resistance against high temperature oxidation, simultaneously. The aim of this work is to explore the high temperature oxidation behaviour of such alloys, by studying three alloys based on nickel and one based on cobalt, all of them containing more than one weight percent of carbon to obtain very high carbides fractions and 30%wt. of chromium added to achieve a chromia-forming behaviour.

Four alloys were prepared by induction melting in a cold crucible under inert atmosphere (300mbar of pure Argon). Three are based on Ni-30%Cr with three different high carbon contents (1.2%C, 1.6%C and 2.0%C, weight percent) and a fourth one is based on Co-30%Cr with a high fraction of tantalum carbides achieved by 0.8%C and 12%Ta (for equal atomic contents between carbon and tantalum). Thermogravimetry tests were performed at 1000°C, 1100°C and 1200°C for 50 hours in dry air.

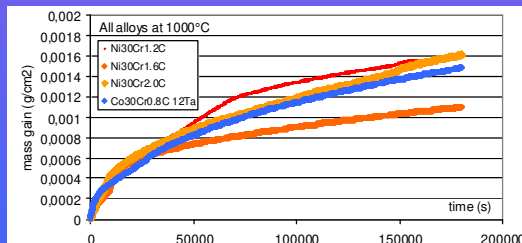
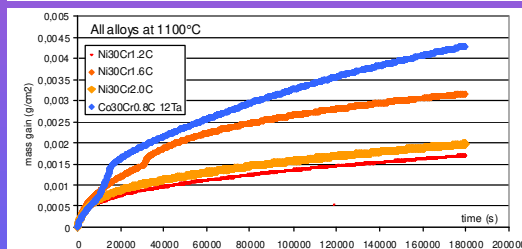
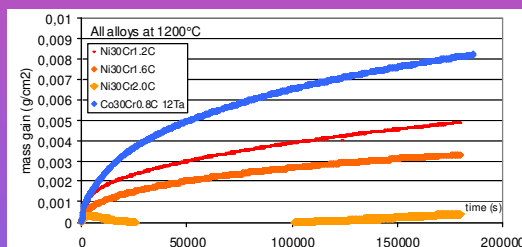
Alloy	Ni	Co	C	Cr	Ta
Ni12	Bal.	/	1.2	30	/
Ni16	Bal.	/	1.6	30	/
Ni20	Bal.	/	2.0	30	/
CoTa08	/	Bal.	0.8	30	12

Average thic kn. of the Cr oxide (µm)	temperature	Ni12 Ni30Cr 1.2%C	Ni16 Ni30Cr 1.6%C	Ni20 Ni30Cr 2.0%C	CoTa08 Co30Cr 0.8%C 12%Ta
1200°C		21 ± 1	21 ± 2	20 ± 2	30 ± 2
1100°C		7.6 ± 1.5	12 ± 2	9.2 ± 1.3	11 ± 1
1000°C		5.5 ± 1.1	9.6 ± 0.8	6.6 ± 1.3	5.1 ± 0.5

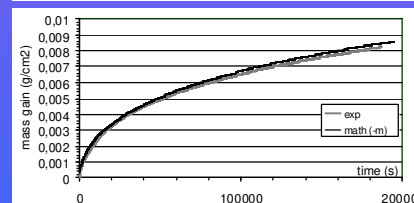
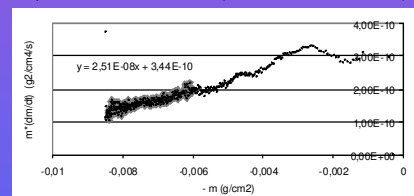
Aver. depths of the carb.-free zone (µm)	temperature	Ni12 Ni30Cr 1.2%C	Ni16 Ni30Cr 1.6%C	Ni20 Ni30Cr 2.0%C	CoTa08 Co30Cr 0.8%C 12%Ta
1200°C		84 ± 12	61 ± 6	56 ± 7	61 ± 7
1100°C		30 ± 6	44 ± 2	27 ± 2	31 ± 5
1000°C		17 ± 2	13 ± 3	12 ± 6	5.3 ± 2.3

CoTa08 after 50h at 1200°C (top), 1100°C and 1000°C (bottom)

Mass gain curves obtained for all the alloys when oxidized at 1200°C (top), 1100°C (middle) and 1000°C (bottom)



($dm/dt = K_p - K_v \cdot m$)-type treatment of mass gain results and validation of the obtained K_p and K_v by comparison between experimental curve and the mathematical curve plotted with these values (here: CoTa08 at 1200°C)



Values of K_p and K_v issued from the ($dm/dt = K_p - K_v \cdot m$) treatment of the thermogravimetry results for all alloys at the three temperatures

K_p ($\times 10^{-12}$ $g^2 \cdot cm^{-2} \cdot s^{-1}$)	temperature	Ni12 Ni30Cr 1.2%C	Ni16 Ni30Cr 1.6%C	Ni20 Ni30Cr 2.0%C	CoTa08 Co30Cr 0.8%C 12%Ta
	1200°C	103	65	/	344
	1100°C	15	48	25	67
1000°C	9.6	4.8	7.6	9.4	

K_v ($\times 10^{-10}$ $g \cdot cm^{-2} \cdot s^{-1}$)	temperature	Ni12	Ni16	Ni20	CoTa08
	1200°C	102	117	/	251
	1100°C	59	85	94	45
1000°C	27	24	7.6	26	

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

The studied alloys are almost all sufficiently resistant against oxidation for this exposure duration. The parabolic constant K_p and the constant of chromia volatilization K_v for the nickel alloys do not follow a systematic law of variation versus the carbon content. However the depth of the carbide-free zone clearly decreases when the carbon content increases. It is possible that the impoverishment of the matrix for very high fractions of chromium carbides (which then contain a great part of chromium), can lead to local losses of the chromia-forming behaviour. In the case of the cobalt alloy the presence of tantalum obviously leads to fast mass gain kinetics but delays catastrophic oxidation.