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Influence of dendrites orientation on the high-temperature oxidation behaviour of cast nickel alloys

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The local high temperature oxidation behaviour of conventionally cast metallic alloys can depend on the orientation of the dendritic structure, i.e. how grain boundaries are oriented. Such a dependence was previously observed on Co-base and Ni-base superalloys. This effect was studied here for two simple Ni-30Cr-C alloys, and two more complex Ni-30Cr-C-Ta alloys.

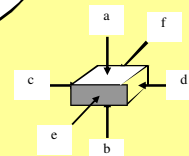
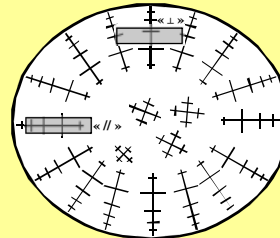
EXPERIMENTAL PROCEDURE

- Elaboration by HF induction melting of 100g ingots
- Two cutting modes to obtain a sample with an external surface
 - ▶ either parallel
 - ▶ or perpendicular

Uncoupling of the 2 global Kp to obtain local Kp_{//} et Kp_⊥

Chemical compositions for the four alloys

(%w)	Ni	Cr	Ta	C
A	Bal.	29.5	/	≅ 0.2
B	Bal.	29.2	/	≅ 0.8
C	Bal.	30.0	2.0	≅ 0.2
D	Bal.	30.0	5.4	≅ 0.4



Type of sample

	//	⊥
a	//	⊥
b	//	⊥
c	⊥	//
d	#	//
e	//	//
f	//	//

// parallel to dendrites
⊥ perpendicular to dendrites
equiaxed

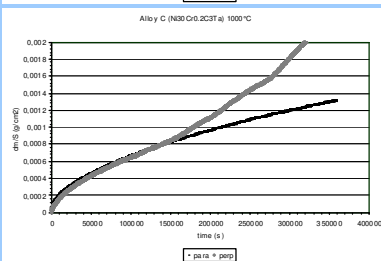
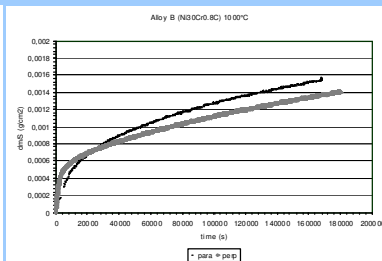
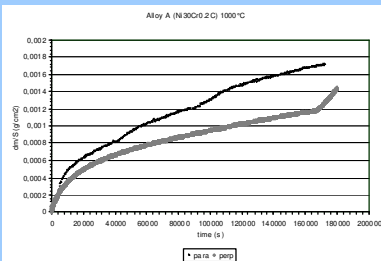
$$\frac{\Delta m_{//}}{S_{//}}(t) = \sqrt{2 \cdot K_{p//}} \cdot t^{1/2}$$

$$\frac{\Delta m_{\perp}}{S_{\perp}}(t) = \sqrt{2 \cdot K_{p\perp}} \cdot t^{1/2}$$

$$\frac{\Delta m}{S}(t) = \frac{\Delta m_{//}(t) + \Delta m_{\perp}(t)}{S_{//} + S_{\perp}} = \frac{S_{//}}{S_{//} + S_{\perp}} \sqrt{2 \cdot K_{p//}} \cdot \sqrt{t} + \frac{S_{\perp}}{S_{//} + S_{\perp}} \sqrt{2 \cdot K_{p\perp}} \cdot \sqrt{t}$$

$$\frac{S_{//}}{S} \sqrt{2 \cdot K_{p//}} + \frac{S_{\perp}}{S} \sqrt{2 \cdot K_{p\perp}} = \sqrt{2 \cdot K_p}$$

THERMOGRAVIMETRY RESULTS



Alloy	Orientation of samples	1000°C	1100°C
Alloy A (Ni-30Cr-0.2C)	mainly para	11 E-12	41 E-12
	mainly perp	6.9 E-12	36 E-12
Alloy B (Ni-30Cr-0.8C)	mainly para	9.7 E-12	50 E-12
	mainly perp	8.0 E-12	62 E-12
Alloy C (Ni-30Cr-0.2C-3Ta)	mainly para	4.2 E-12	42 E-12
	mainly perp	3.2 E-12	41 E-12
Alloy D (Ni-30Cr-0.4C-6Ta)	mainly para	2.9 E-12	30 E-12
	mainly perp	3.1 E-12	46 E-12

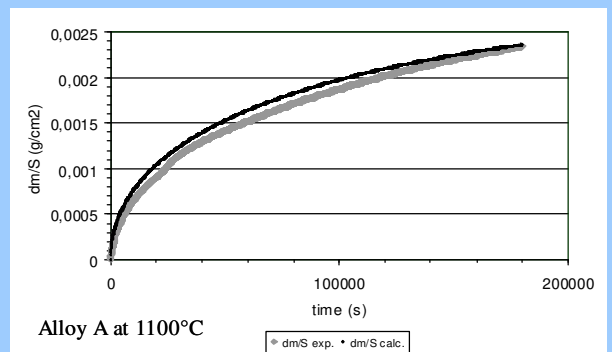
(Several mass gain curves were affected by chromia detachments; however it was always possible to estimate the parabolic constant)

Dendritic orientation may have an influence on the local oxidation rate, but depends on the chemical composition and on temperature ; for example:

- faster oxidation of Ni30CrC alloys at 1000°C for the parallel orientation but no such differences at 1100°C
- no differences for Ni30CrCTa alloys at 1000°C but faster oxidation for Alloy D (0.4C 5.4Ta) at 1100°C for the perpendicular orientation

Good fit of the real mass gain curves by model curves based on the calculated Kp_{//} et Kp_⊥

Alloy	Orientation of surfaces	1000°C	1100°C
Alloy A (Ni-30Cr-0.2C)	Kp para	12 E-12	43 E-12
	Kp perp	4.9 E-12	33 E-12
Alloy B (Ni-30Cr-0.8C)	Kp para	10 E-12	48 E-12
	Kp perp	7.4 E-12	69 E-12
Alloy C (Ni-30Cr-0.2C-3Ta)	Kp para	4.4 E-12	43 E-12
	Kp perp	3.0 E-12	40 E-12
Alloy D (Ni-30Cr-0.4C-6Ta)	Kp para	2.7 E-12	27 E-12
	Kp perp	3.6 E-12	55 E-12



The high temperature oxidation behaviour of cast alloys may depend on the average dendritic orientation, i.e. where and how pieces were machined in the castings. For the studied alloys, differences are often small but there are some cases for which dendritic orientation really influences the resistance against oxidation, It can be useful to always cut the samples following the same geometry and orientation to better compare cast alloys to each other.