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Exploration of the high temperature oxidation of the M–30Cr alloys (M = Co and/or Ni) containing tantalum in absence of carbon

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Introduction & Experimental

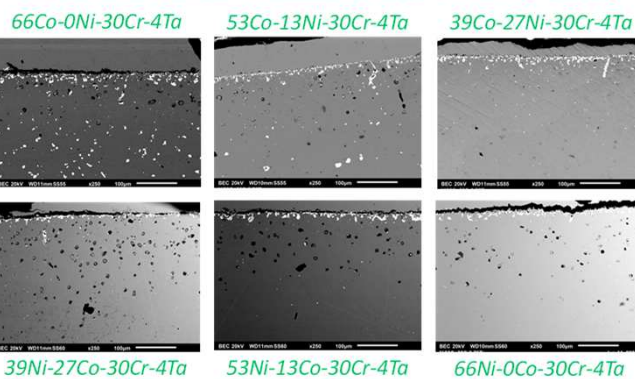
Tantalum is often present in chromia-forming polycrystalline superalloys based on cobalt or nickel. It may play a double role in their strengthening, as solid solution hardener and as a strong carbide-forming element (TaC carbides, generally). In carbon containing superalloys Ta is present in the matrix as well as in the primary carbides crystallized during solidification (and also in secondary carbides after having applied a precipitation heat treatment). Tantalum is also an element which is easy to oxidize and it generally takes part to the phenomena during the high temperature oxidation of the concerned alloys. The related phenomena may depend on the forms with which Ta is present in the alloy.

In this work, a series of $\{(66-x)\text{Co}-x\text{Ni}-30\text{Cr}-4\text{Ta}; 0 \leq x \leq 66\}$ alloys were elaborated by conventional foundry. First the obtained general chemical compositions were controlled by energy dispersive spectrometry and second the microstructures of the alloys in their as-cast states – logically carbide-free since the presence of carbon was avoided in these alloys – were explored by electron microscopy. Third, thermogravimetric tests at 1200°C were performed, followed by the exploitation of the mass gain files to access to the oxidation kinetics. Post-mortem characterization was carried out for knowing the natures and quantities of the oxides formed and the subsurface changes induced by oxidation.

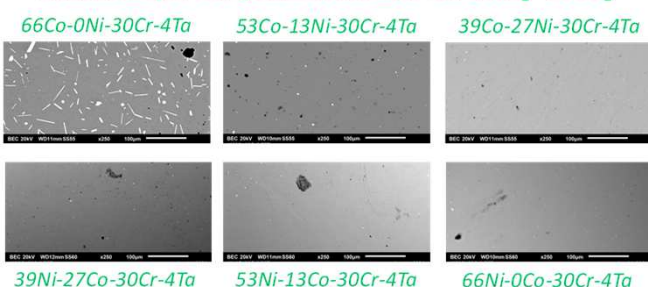
Results / Post-mortem characterization

- Surface: only small parts of external oxide (Cr_2O_3) to examine and characterize
- Sub-surface: elongated cluster of internal oxides (CrTaO_4) at low depth
- Bulk: coarsening of compounds involving tantalum (only for the cobalt-richest alloys; too fine to allow accurate analysis (possibly the Co_3Ta intermetallic; on-going checking)

Surface states after 50h of oxidation at 1200°C in 80%N₂ – 20%O₂

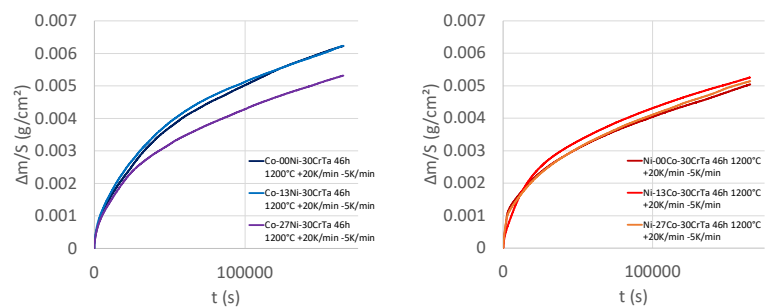


Bulk states after 50h of oxidation at 1200°C in 80%N₂ – 20%O₂



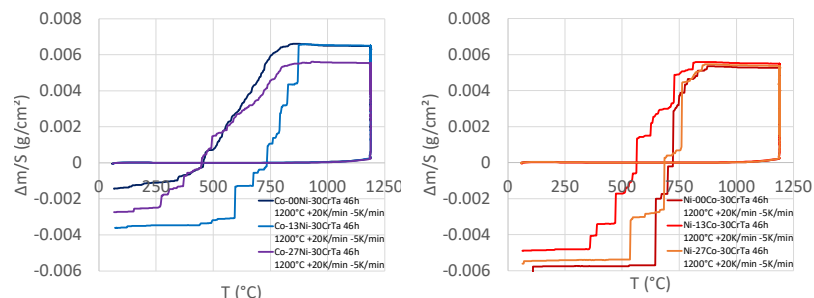
Results / Mass gain and mass loss phenomena and kinetics: isothermal

- Kinetics globally all parabolic
- Mass gain for the two cobalt-richest alloys: faster than for the four other alloys
- Order of magnitude for the parabolic constants K_p (corrected from chromia volatilization) for all alloys: $100 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$ (typical of chromia growth at this temperature in air)
- Order of magnitude for the chromia volatilization constants K_v (chromia volatilization) for all alloys: $100 \times 10^{-10} \text{ g cm}^{-2} \text{ s}^{-1}$ (typical of this temperature in air)



Results / Mass variation phenomena and kinetics: cooling

- Early starts of oxide scale spallation during cooling (at more or less 900°C, i.e. after only 300°C of cooling)
- Masses per surface unit area after test all lower than before test (negative values for total mass variations along the whole thermal cycle)
- Scale spallation phenomenon slightly sooner for the nickel-richest alloys than for the cobalt-richest alloys (tendency)



Summary / Conclusions

- Global kinetics of oxidation (chromia volatilization-corrected mass gain, chromia volatilization rate) of similar levels as for the same alloys but containing C to promote TaC
- Same early oxide scale spallation starts and associated mass losses leading to negative total mass variations
- Same differences between Co-based alloys and Ni-based alloys for the Ta stability in solid solution in the matrix (in the Co-base ones, here Ta-rich intermetallic compounds instead the TaC carbides in the carbon-containing quaternary and quinary corresponding alloys)

