



Behavior in High Temperature Oxidation of Cast Chromium-rich Co-based, Ni-based and Fe-based Alloys containing Very High Fractions in Tantalum Carbides

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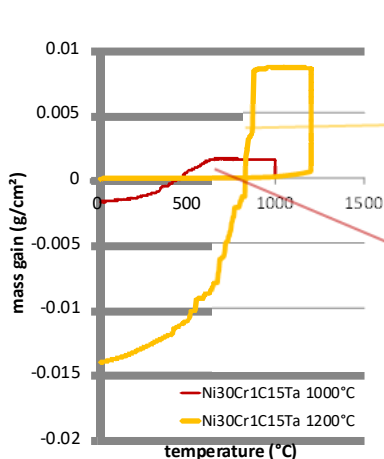
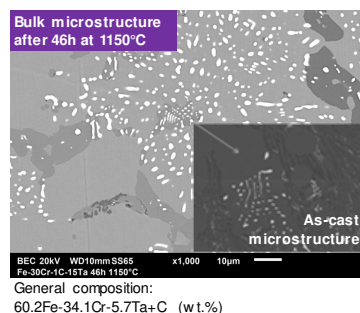
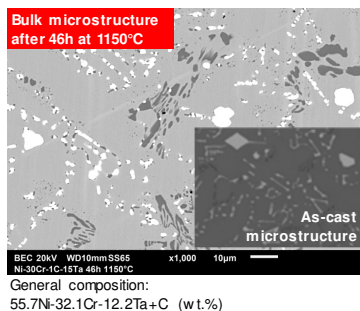
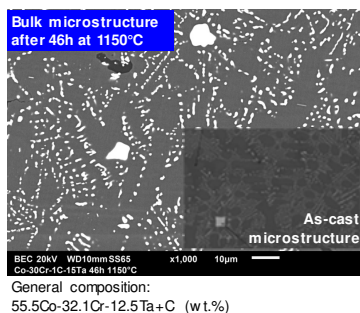
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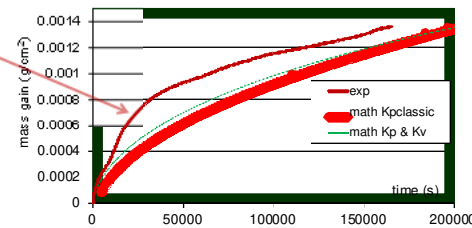
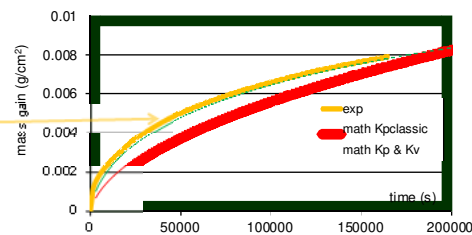
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Chromium-rich cobalt-based, nickel-based or iron-based alloys are used at cryogenic/ambient/body temperatures (as for prosthetic dentistry [1]) or at medium, high or very high temperatures (as in aero-engines [2] or industrial processes [3]). Their high Cr contents allow them resisting corrosion in corrosive aqueous milieus or high temperature corrosion by gases or by molten aggressive substances [4]. Many of these alloys also contain carbon which allows the development of carbides aiming to high mechanical resistance at high temperature [5]. Some versions very rich in carbon and in carbides-former elements are devoted to applications exploiting the intrinsically high ductility of the matrix and hardness of the carbides. An example is the cases of cobalt alloys for cutting tools [6] made of a Co-based matrix and hardened with high fractions in tungsten carbides or of Co-W₂C coatings [7], for which high wear resistance, and also resistance against high temperature oxidation, are required.

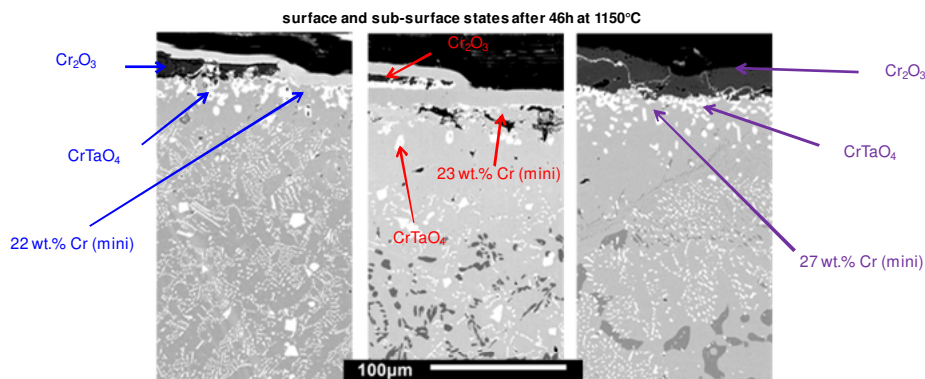
Besides Cr or W other elements can be chosen to obtain great quantities of hard carbides, with maybe a better efficiency in resistance against wear. Among them one can find the MC-formers ones: Ta, Hf, Zr... In this study it the case of tantalum which was selected, this for a cobalt base, a nickel base and an iron-base. To favor this single type of carbides, first helped by the fact that tantalum is a stronger carbide-former element than chromium (which was kept at a high level for high temperature oxidation resistance), it was decided to take the same atomic content in Ta as the one in C to avoid the formation of chromium carbides. With this choice, to 1 wt.% of carbon corresponds 15 wt.% of tantalum, a very high content in such element. It was then chosen to limit the C content to 1 wt.% and then the Ta one to 15 wt.%. So, a Co(bal.)-30Cr-1C-15Ta, a Ni(bal.)-30Cr-1C-15Ta and a Fe(bal.)-30Cr-1C-15Ta were elaborated by foundry. Then, they were characterized in terms of microstructure and oxidation behavior at high temperature (1000 < T < 1200°C).



Severe oxide scale spallation at cooling revealed by plotting the mass gain versus temperature



Mass gain curves of the Ni-30Cr-1C-15Ta oxidized at 1200°C (top) and 1000°C (bottom); thick curves: experimental curves, thin curves: mathematical curves for constants' validation, the red ones plotted with the Kp values classically determined (5.3 and $203 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$ at 1000 and 1200°C respectively) and the green ones plotted with the Kp and Kv values issued from the $(m \times dm/dt = Kp - Kv \times m)$ method [8] (6.9 and $391 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$ for Kp, 18 and $298 \times 10^{-10} \text{ g cm}^{-2} \text{ s}^{-1}$ for Kv at resp. 1000 and 1200°C)



The presence in very high contents in Ta and C in these alloys obviously led to microstructures different from what is commonly found in cast cobalt-based, nickel-based or iron-based alloys or superalloys with no so high carbon content and with equivalent atomic percentage in tantalum. The most noticeable difference, presence of pre-eutectic TaC carbides, caused problems during the elaboration of the iron-based alloy only (outward migration of many pre-eutectic carbides in the liquid under the effect of the electromagnetic stirring).

Concerning especially the behaviors in high temperature oxidation of these alloys, they all showed a very good resistance, as clearly shown by first slow parabolic mass gain rates, presence of a continuous external chromia scale (even spallation obviously occurred during cooling) and chromium contents in subsurface still high close to the alloy/oxide interface.

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