



# Oxidation at high temperature of chromium-rich Co, Ni and Fe-based alloys very rich in tantalum carbides

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Chromium-rich alloys, based on cobalt for example, can be met in many various applications, from prosthetic dentistry<sup>1</sup> to turbine blades of aero-engines<sup>2</sup> and hot tools used in industrial processes<sup>3</sup>. Many of these alloys also contain carbon – and then carbides – to achieve good mechanical resistance at high temperature<sup>4</sup>. Versions containing a lot of carbon as well as of carbides-former elements can be used for cutting tools<sup>5</sup> and for Co-W<sub>2</sub>C coatings for improving the wear resistance of metallic substrates<sup>6</sup>, by taking advantage from the high hardness of cobalt and of carbides<sup>7</sup>.

High densities of chromium carbides can be obtained in alloys based on cobalt<sup>8</sup>, nickel<sup>9</sup> and on iron<sup>10</sup> elaborated by casting. But this implies that such alloys contain high carbon quantities which may lead to problematic decrease in refractoriness. Similar volume fractions can be also achieved after selection of other carbides-forming elements, such as the MC-formers ones: Ta, Hf, Zr... With 1wt.%C only, it is possible to develop a dense interdendritic carbides network in Co-based, Ni-based and Fe-based alloys rich in chromium, by adding about 15wt.%Ta. Furthermore, the carbides which developed in such alloys, essentially tantalum monocarbides, well behave at high temperature on long times. This is due to their thermal stability which is greater than the chromium carbides ones. In contrast the behavior of such alloys in oxidation at high temperature needs to be better known. Indeed the presence of a so oxidable element as tantalum may lead to particular oxidation phenomena.

In the present study three types of alloys rich in chromium and containing very high TaC fractions, a Co-based one, a Ni-based one and a Fe-based one, were subjected to oxidation at high temperature in air, to get answers to the previous questions.

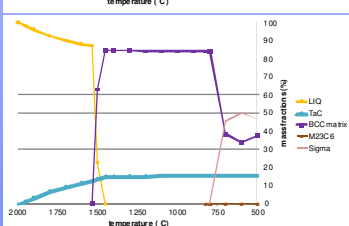
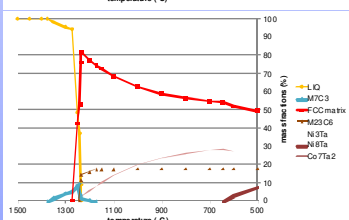
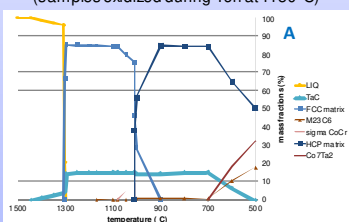
Theoretic solidification sequences according to

Thermo-Calc calculations for a better understanding of the obtained microstructures (notably: eutectic TaC carbides and pro-eutectic TaC appearing even before matrix)

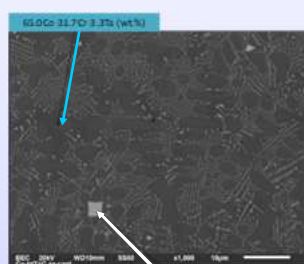
Scanning Electron Microscope (SEM) micrographs taken in Back Scattered Electrons mode (BSE) illustrating the obtained as-cast microstructures

Energy Dispersion Spectrometry (EDS) results for the general, matrix and particle's chemical compositions

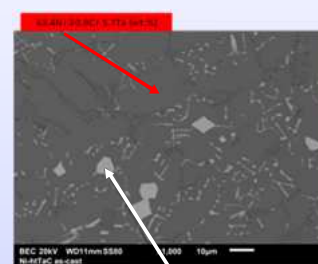
SEBSE micrographs of the oxidized surface and deteriorated sub-surfaces, with EDS identification of the external and internal oxides and measurements of the chromium content in extreme surface (samples oxidized during 46h at 1150°C)



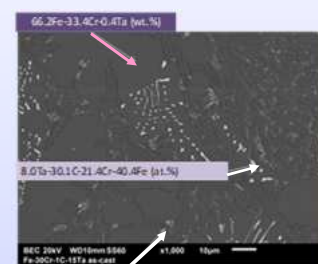
## as-cast microstructures



General composition:  
55.5Co-32.1Cr-12.5Ta-C (wt.%)

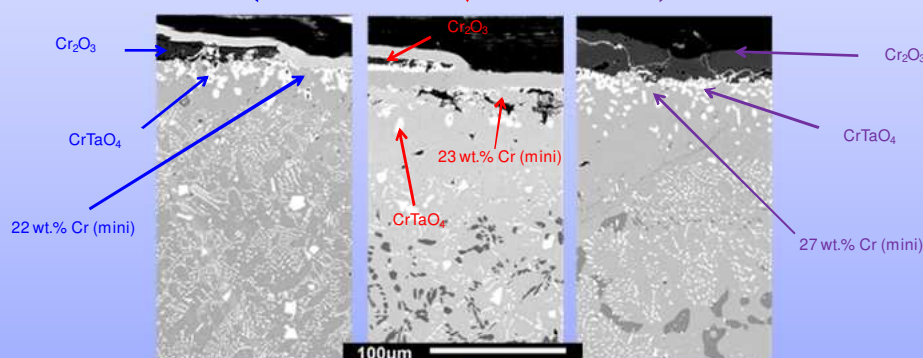


General composition:  
55.7Ni-32.1Cr-12.2Ta-C (wt.%)

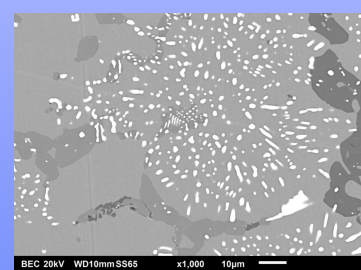
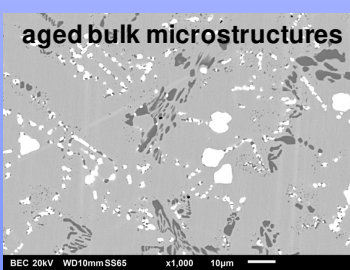
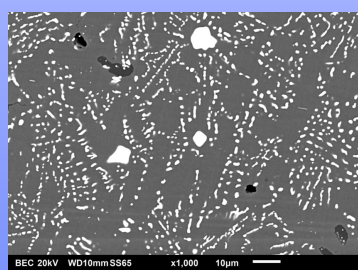


General composition:  
60.2Fe-34.1Cr-5.7Ta-C (wt.%)

## surface and sub-surface states



## aged bulk microstructures



By targeting 1 wt.%C and 15wt.%Ta, the cobalt alloy well contained only TaC carbides in great quantities. In contrast the nickel and iron alloys did not contain tantalum carbide as single carbide phase (presence of chromium carbides). Despite the rather high temperature of test for such alloys, the behaviors of the three alloys in oxidation at 1150°C for 46 hours was rather good since they were obviously all covered by a continuous protective chromia scale and, by considering the rather still high chromium contents in extreme surface determined after test, this chromia-forming behavior will probably continue for additional tens hours. However, the bulk underwent a fragmentation of the TaC carbides and morphology changes for the chromium carbides when they are present (nickel and iron alloys). Consequently the alloys may have become not sufficient enough to really resist wear in hot conditions (elevated temperatures due to friction for example). The problem becomes serious in sub-surface, because of the loss of the carbides due to high temperature oxidation in sub-surface. This carbide-free zone is unfortunately the zone which is the most concerned by wear solicitations.

## References

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