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Behavior in oxidation at high temperature of three chromium-rich refractory alloys highly strengthened by TaC carbides

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► **To cite this version:**

Laura Corona, Patrice Berthod. Behavior in oxidation at high temperature of three chromium-rich refractory alloys highly strengthened by TaC carbides. Eurocorr 2013, Sep 2013, Estoril, Portugal. hal-03598463

HAL Id: hal-03598463

<https://hal.science/hal-03598463>

Submitted on 5 Mar 2022

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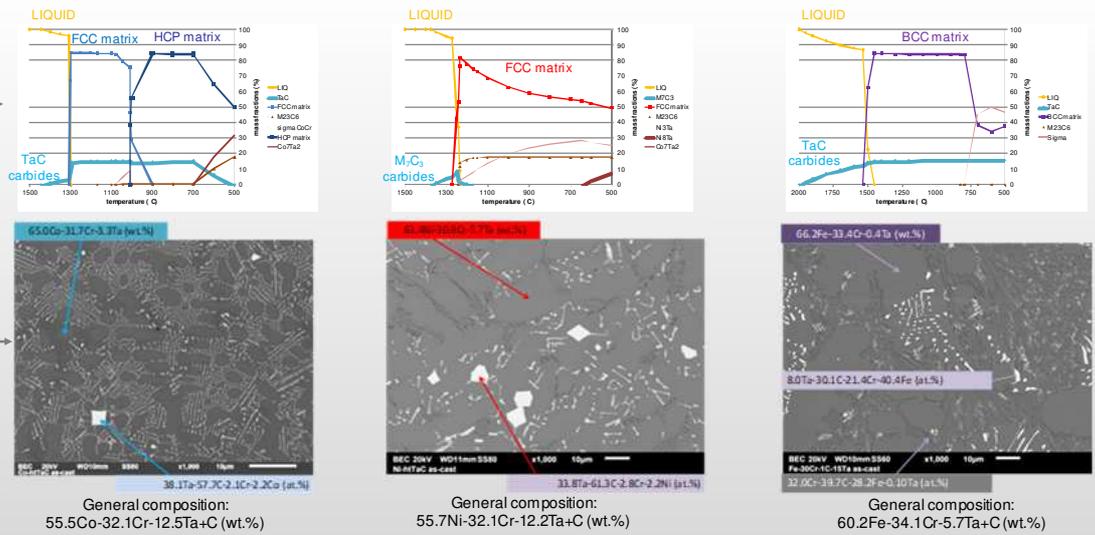
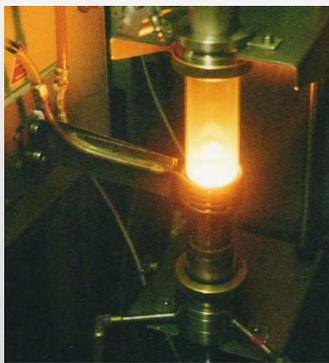
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Chromium-rich cobalt-based alloys can be involved in many applications as diversified as prosthetic dentistry [1], aero-engines [2] and industrial processes [3]. This is also the case of Cr-rich nickel-based alloys which can work at body-temperature in dentistry again [4, 5] or in hot condition [2]. When such corrosion-resistant alloys also contain high carbides fractions they can be in addition wear-resistant as bulk materials (cobalt-based [6]) or coating ones (cobalt-based [7]). This is also true for nickel-based alloys [7-10]. Iron-based rich in chromium and in carbon simultaneously can be also very hard thanks to the presence of many chromium carbides [11]. Such alloys are often particularly rich in carbon and this may threaten their refractoriness, which can be not acceptable if grinding induces significant heating when the alloy is used in some wear applications. Fortunately there are elements which are strong carbides-former and which allow maintaining a high solidus temperature. This is the case of tantalum which can lead to higher carbide fractions - than chromium for example - for a given temperature.

In the present work three alloys based on cobalt, on nickel and on iron, all containing 30wt.% of chromium, 1 wt.% of carbon and 15 wt.% of tantalum (targeted content values), were elaborated by classical foundry for obtaining materials with high hardness (obtained compositions: Co-32Cr-13Ta-xC, Ni-32Cr-12Ta-yC and Fe-34Cr-6Ta-zC in wt.%, with x=y=z=1wt.%, as determined by Energy Dispersion Spectrometry), then studied in oxidation at high temperature (46 hours at 1150°C) to better know the behavior of such hard alloys especially rich in a highly oxidable element: tantalum.

Elaboration and microstructure examination of the alloys:

Fusion and solidification under 300mbar Ar in a High Frequency induction furnace (pure elements → ingots of 40g)

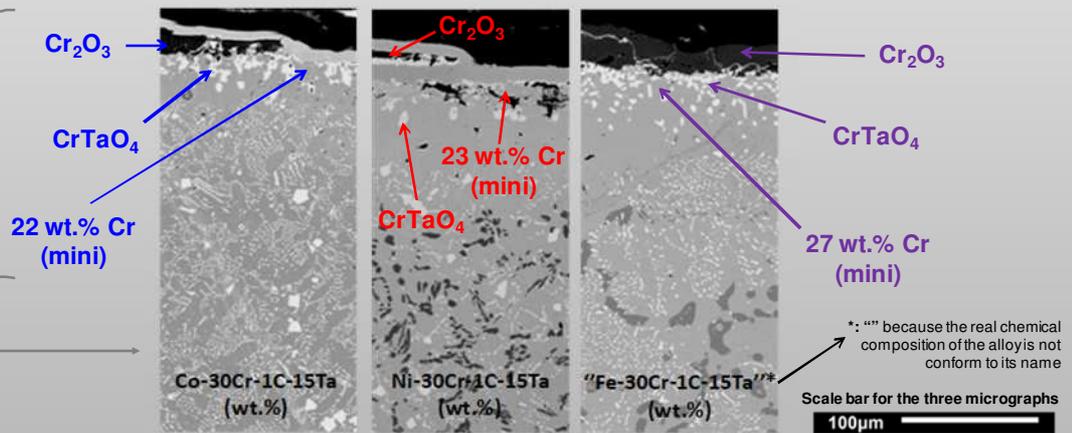


Theoretic solidification sequences according to Thermo-Calc calculations for a better understanding of the obtained microstructures (notably: eutectic TaC carbides and pro-eutectic TaC appearing even before matrix)

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)



The three alloys are obviously all resistant against oxidation by air at this so high temperature of 1150°C. After almost 50 hours of exposure none of them suffered catastrophic oxidation. On the contrary they obviously benefited of a chromia-forming behavior, favored by first a high chromium content but probably also by the presence of many carbides, of tantalum and/or of chromium, known to facilitate diffusion of chromium towards the oxidation front and then the supplying of this one in chromium. By considering the chromium content in extreme surface one can guess that this good behavior will probably continue after the 46 hours tested here. In oxidation behavior these alloys are better than the Co-30Cr-2.5 to 5wt.%C cobalt alloys highly hardened by chromium carbides earlier studied [12], but similar to Ni-30Cr-2.5 to 5 wt.%C nickel alloys [13] and to Fe-30Cr-2.5 to 5 wt.% iron alloys [14]. However, as for these latter ternary alloys previously studied, the development of a carbide-free zone should diminish the wear resistance of these Ta-rich Co-based, Ni-based and Fe-based alloys.

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