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Oxidation at high temperature of two commercial cobalt-based superalloys elaborated by casting and obtained with a fine microstructure

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Numerous superalloys exist for meeting high temperature uses' needs, with among them the cast cobalt-based ones [1,2]. Many of these Co-based superalloys present the double particularity to resist corrosion by molten aggressive substances thanks to rather high chromium quantities [3,4] and high temperature mechanical stresses (occasioning creep deformation) thanks to primary carbides present in the interdendritic boundaries and to secondary fine carbides precipitated inside the matrix [5-7]. The commercial Co-based superalloys are the most often elaborated by foundry in great quantities and their solidification is achieved in moulds with rather great size to obtain various pieces for aero-engines for instance. The microstructures which are obtained present consequently coarse grains, but smaller grain sizes may be obtained in case of fast solidification; it can be interesting to investigate the high temperature properties of alloys with the same chemical composition as well-known commercial alloys but with a finer microstructure, high temperature oxidation resistance for instance.

In this study two cobalt-based superalloys were elaborated by targeting the chemical compositions of two commercial ones. They were obtained by foundry way in conditions of rather fast cooling favoring fine microstructures [8]. They were thereafter subjected to more or less long exposures at two high temperatures in oxidizing atmosphere, principally to get some data concerning their behavior in oxidation at high temperature, but also to see how their microstructures are changing during exposure to high temperature, since these behaviors can be different by comparison to the microstructurally coarser commercial alloys.

Elaboration and microstructure examination of the alloys:

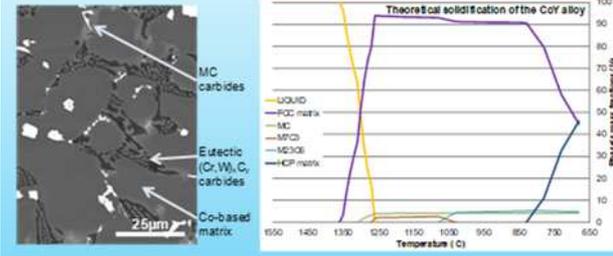
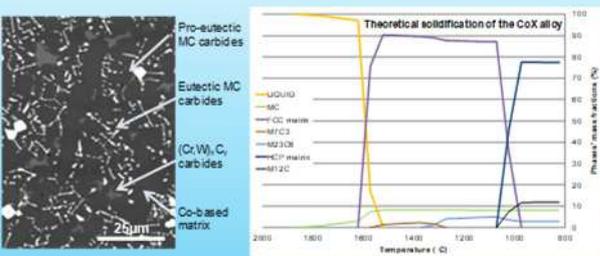
Fusion and solidification under 300mbars Ar in a High Frequency induction furnace (pure elements → ingots of 40g)

The second alloy ("CoY") elaborated in laboratory by targeting the chemical composition of a second commercial alloy; obtained comp.*: Co(bal.)-24.1Cr-10.3Ni-0.6Ti-4.0Ta-0.05Ti-7.4W-0.3Zr

** : cannot be measured (too light element), content supposed to be respected

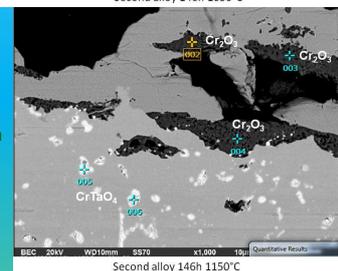
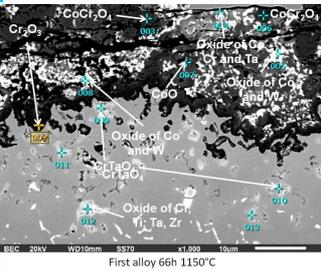
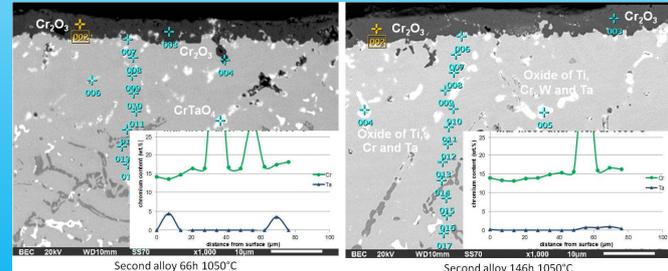
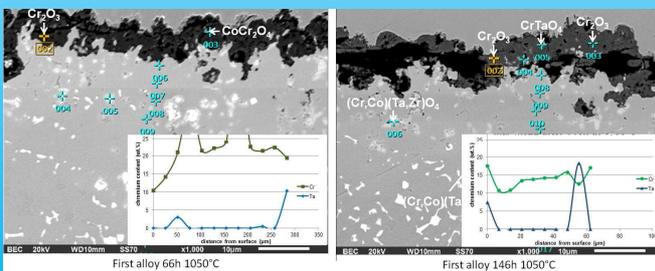
The first alloy ("CoX") elaborated in laboratory by targeting the chemical composition of a first commercial alloy; obtained composition*: Co (bal.)-22.3Cr-1**C-4.9Ta-0.7Ti-10.7W-0.7Fe-1.5Zr

* : technique used: Energy Dispersion Spectrometry



Micrograph (Scanning Electron Microscope in Back Scattered Electrons mode) of the as-cast microstructure of the CoX alloy (left side) and theoretic solidification sequences plotted from Thermo-Calc calculations' results (on the right)

Micrograph (Scanning Electron Microscope in Back Scattered Electrons mode) of the as-cast microstructure of the CoY alloy (left side) and theoretic solidification sequences plotted from Thermo-Calc calculations' results (on the right)



The microstructures of the two alloys synthesized as small ingots rapidly solidified were effectively very fine. Concerning high temperature oxidation the two alloys globally displayed a chromia-forming behavior at 1050°C, but this good behavior was lost by the first alloy before it reaches 66 hours at 1150°C. This was not surprising if one considers the rather low chromium contents measured in extreme surface after oxidation at 1050°C for 66h and 146h. A 100°C-higher temperature was sufficient to rapidly impoverish the subsurface in chromium under a critical level with consequently the start of catastrophic oxidation.

The chromia-forming behavior, also shown at 1050°C whatever the duration, was not lost by the second alloy at 1150°C, even after 146 hours (despite some locations catastrophically oxidized). This second alloy was obviously helped by the about 2wt.%Cr more than the first alloy, allowing keeping Cr contents in extreme surface 3 to 4wt.%higher than for the first alloy after 66h and 146h at 1050°C.

Thus, despite that these two cobalt-based alloys are not advantaged by first a cobalt matrix and second by rather low chromium contents by comparison with 30wt.%Cr-containing nickel-based alloys, the resistances against high temperature oxidation of these fine microstructure versions of commercial superalloys remain correct, notably for the second 24wt.%Cr-containing one.

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