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High temperature properties of several families of TiC-reinforced cast superalloys

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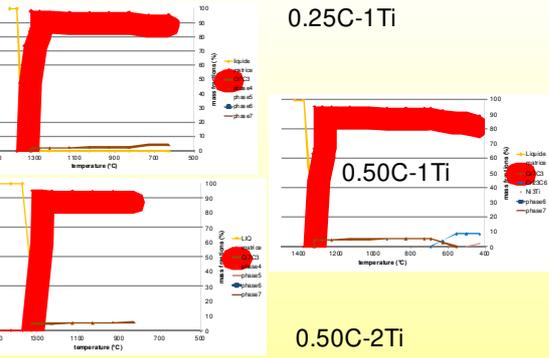
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Some poly-crystalline superalloys synthesized by classical foundry can be very refractory and offer unexpectedly high properties at elevated temperature. This is for example the case of some cobalt-based alloys strengthened by tantalum carbides or hafnium carbides. Besides, cast alloys based on Ni or Co, and containing other types of MC carbides may be also envisaged for high temperature applications. In this study this is the titanium carbide phase which is under consideration.

Several Ni-based and Co-based alloys of the [M-25Cr-xC-yTi]-type (x=0.25 or 0.50, y=1 or 2, in wt.%) were synthesized by casting using a high frequency induction furnace under pure argon. Metallographic samples were prepared to allow characterizing their microstructures by electron microscopy and energy dispersion spectrometry. Especially prepared samples were destined to DTA control of the melting range, to oxidation in synthetic air at 1200°C, and to {1200°C, 20MPa}-flexural creep tests, in order to start exploring the chemical and mechanical resistances of such alloys at elevated temperatures.

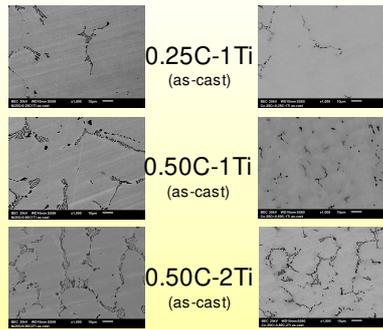
Preliminary thermodynamic calculations



Ni-based alloys

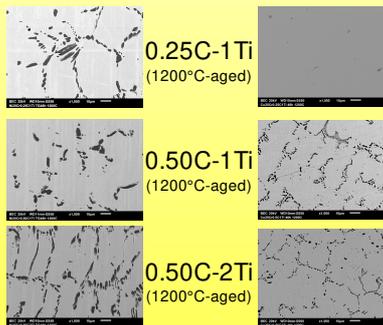
Co-based alloys

As-cast and {46h, 1200°C}-aged microstructures

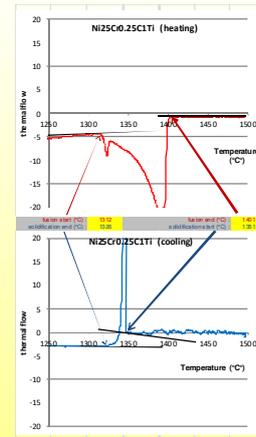


Ni-based

Co-based



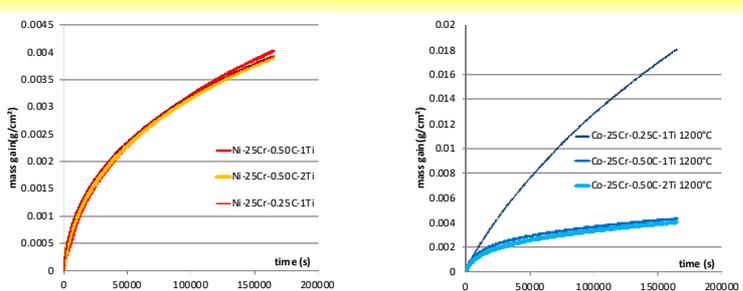
Mushy zone temperature range



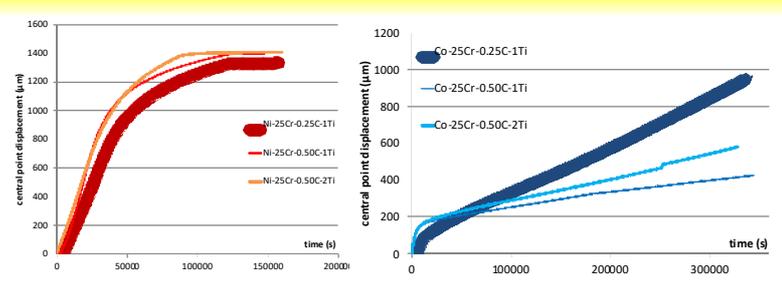
Ni-25Cr0.25C-1Ti (example)

Alloy	Fusion over (°C)	Solidification over (°C)
Ni-based alloys 0.25C-1Ti	1310 → 1400°C	1325 ← 1350°C
Co-based alloys 0.25C-1Ti	1375 → 1450°C	1355 ← 1400°C
Ni-based alloys 0.50C-1Ti	1300 → 1375°C	1275 ← 1365°C
Co-based alloys 0.50C-1Ti	1280 → 1440°C	1270 ← 1425°C
Ni-based alloys 0.50C-2Ti	1300 → 1380°C	1250 ← 1365°C
Co-based alloys 0.50C-2Ti	1280 → 1450°C	1370 ← 1480°C

Thermogravimetry tests at 1200°C in dry synthetic air (parallelepiped samples: about 10 mm length × 8 mm width × 3 mm thickness)



Centered 3-points flexural creep at 1200°C, for 20 MPa just below the central point (parallelepiped samples: 12 mm length × 2 mm width × 1 mm thickness)



Titanium carbides, which are of the MC type as TaC more commonly encountered in superalloys, may be obtained at solidification in chromium-rich cast alloys. However this depends on the base element. In nickel-based alloys the titanium carbides seem being less stable than chromium carbides since, as this was here anticipated by preliminary thermodynamic calculations, Cr₇C₃ crystallize at solidification rather than TiC, and during high temperature isothermal exposures the rare titanium carbides which precipitated besides the numerous chromium carbides, completely disappear.

This is totally the contrary in chromium-rich cobalt-based alloys: the TiC carbides were successfully obtained and remain stable during long high temperature exposure. They were obtained as script-like eutectic carbides imbricated with matrix in the interdendritic spaces. Associated to an intrinsic mechanically resistant cobalt-based matrix they allowed the studied cobalt-alloys demonstrating interesting creep resistance. The nickel-based alloys, combining – it is true – a much weak nickel-based matrix, and interdendritic chromium carbides, rapidly deformed and came in touch with the apparatus basis after only about 25 hours. In contrast the oxidation kinetics of these Ni-based alloys were much lower than the Co-based alloys the general oxidation behaviour of which is classically much worse than the Ni-based alloys' one.