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Microstructures and high temperature properties of refractory alloys designed to be TiC-reinforced

Mira Khair, Floriane Allegre, Estelle Kretz, Patrice Berthod

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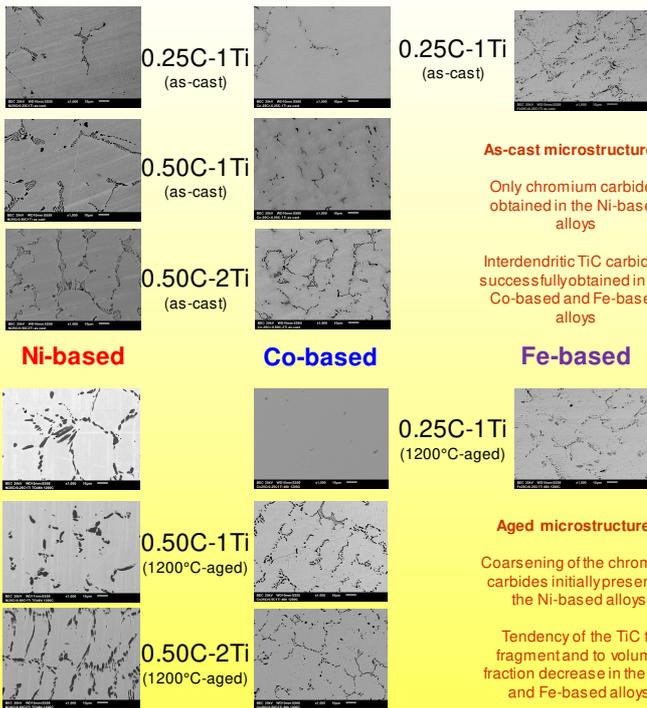
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Some polycrystalline superalloys elaborated by classical foundry can be very refractory and bring unexpectedly high properties at high temperature. This is for instance the case of some cobalt-based alloys strengthened by tantalum carbides or hafnium carbides. Cast alloys based on Ni or Co, and even Fe, 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 investigated.

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

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



As-cast microstructures:
Only chromium carbides obtained in the Ni-based alloys

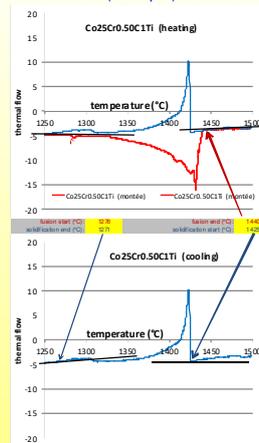
Interdendritic TiC carbides successfully obtained in the Co-based and Fe-based alloys

Aged microstructures:
Coarsening of the chromium carbides initially present in the Ni-based alloys

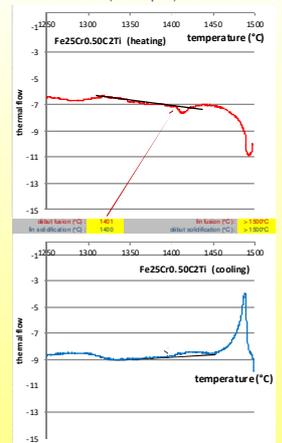
Tendency of the TiC to fragment and to volume fraction decrease in the Co- and Fe-based alloys

Mushy zone temperature range

Co-25Cr-0.50C-1Ti (example)



Fe-25Cr-0.50C-2Ti (example)



Ni-based alloys
0.25C-1Ti
Fusion over: 1310 → 1400°C
Solidif. over: 1325 ← 1350°C

0.50C-1Ti
Fusion over: 1300 → 1375°C
Solidif. over: 1275 ← 1365°C

0.50C-2Ti
Fusion over: 1300 → 1380°C
Solidif. over: 1250 ← 1365°C

Co-based alloys
0.25C-1Ti
Fusion over: 1375 → 1450°C
Solidif. over: 1355 ← 1400°C

0.50C-1Ti
Fusion over: 1280 → 1440°C
Solidif. over: 1270 ← 1425°C

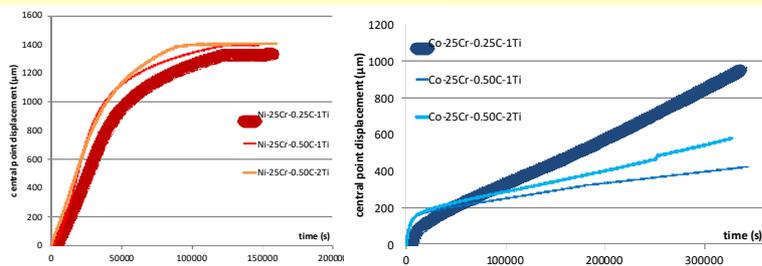
0.50C-2Ti
Fusion over: 1280 → 1450°C
Solidif. over: 1370 ← 1480°C

Fe-based alloys
0.25C-1Ti
Fusion over: 1405 → >1500°C
Solidif. over: 1405 ← >1500°C

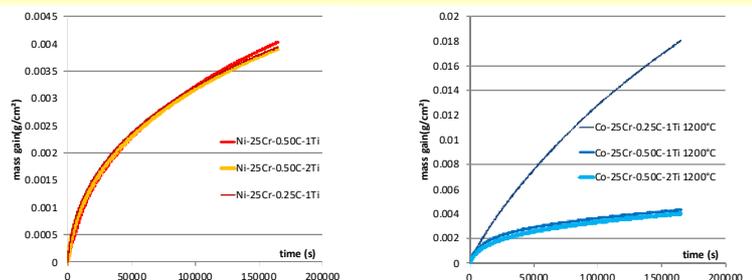
0.50C-1Ti
Fusion over: 1280 → >1500°C
Solidif. over: 1320 ← >1500°C

0.50C-2Ti
Fusion over: 1400 → >1500°C
Solidif. over: 1400 ← >1500°C

Centered 3-points flexural creep at 1200°C for 20 MPa just below the central point; Behaviour: Fe-based <<<< Ni-based << Co-based



Thermogravimetry tests at 1200°C in dry synthetic air; Behaviour: Fe-based ≈ Ni-based >> Co-based



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. Indeed, Cr₃C₂ crystallize at solidification rather than TiC, and during high temperature isothermal exposures the rare titanium carbides which precipitated among the numerous chromium carbides, completely disappear.

This is totally the contrary in chromium-rich cobalt-based and iron-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. Because of the too low strength of the ferritic matrix of the iron-based alloys, the creep behaviour of these ones did not benefit from the TiC carbides. 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 the Ni-based and Fe-based alloys were much lower than the Co-based alloys, this respecting the classical hierarchy between the three families.