



HAL
open science

Mechanical and oxidation behaviors at high temperature of ZrC-strengthened superalloys

Valentin Kuhn, Jérémy Peultier, Safa Tlili, Patrice Berthod, Mélissa Ritouet

► To cite this version:

Valentin Kuhn, Jérémy Peultier, Safa Tlili, Patrice Berthod, Mélissa Ritouet. Mechanical and oxidation behaviors at high temperature of ZrC-strengthened superalloys. Asian Advanced Materials Congress, Mar 2017, Singapour, Singapore. hal-03235578

HAL Id: hal-03235578

<https://hal.science/hal-03235578>

Submitted on 25 May 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Valentin KUHN¹, Jérémy PEULTIER¹, Safa TLILI¹, Patrice BERTHOD^{1,2} and Mélissa RITOUET²
¹Faculty of Sciences and Technologies, ²Institut Jean Lamour
 University of Lorraine, BP 70239, Bd des Aiguillettes, 54506 Vandoeuvre-lès-Nancy, France
patrice.berthod@univ-lorraine.fr

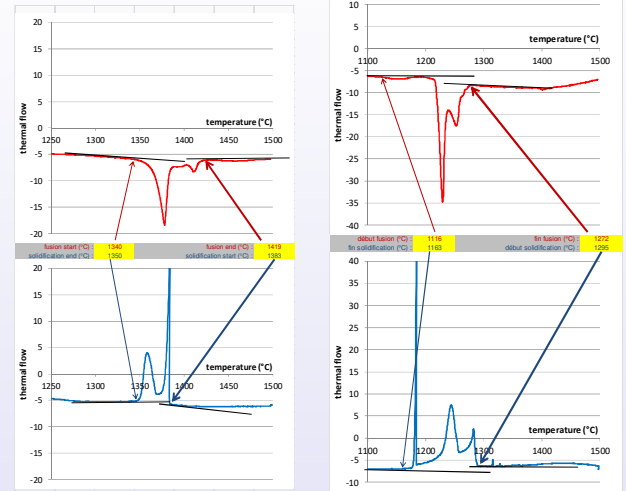
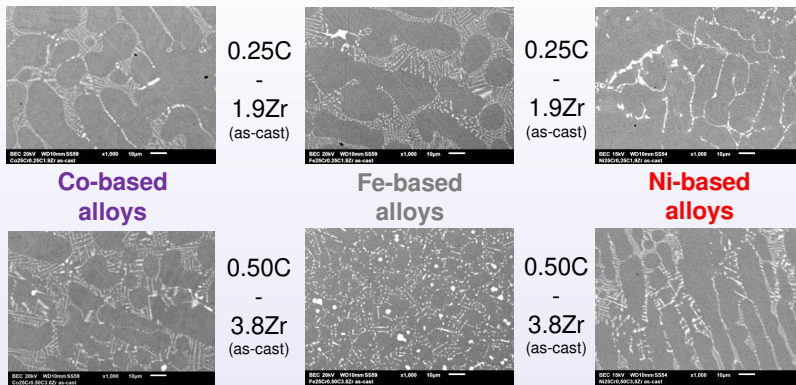
Faculté des Sciences et Technologies

Zirconium can be used as carbide-former element to promote strengthening by MC carbides in refractory alloys elaborated by casting. This type of carbides, for example represented by the TaC ones, often appears as very imbricated with matrix in an interdendritic eutectic compound. Furthermore such carbides are generally very stable at high temperature. Consequently, MC carbides may be especially efficient for the mechanical strengthening of alloys, allowing them to resist creep deformation at high temperature. Developed from an element more often introduced in alloys for trapping impurities (e.g. sulfur), ZrC are not or rarely considered for combatting high temperature creep, and the purpose of this work is to test them in refractory cobalt-based, iron-based and nickel-based alloys issued from foundry process.

Several Co-based, Fe-based and Ni-based alloys of the {M-25Cr-xC-yZr}-type (x=0.25 with y=1.9, and x=0.50 with y=3.8, in wt.%) were synthesized by high frequency induction melting under inert atmosphere. The obtained ingots were cut to obtain parts for the metallographic characterization of the as-cast microstructures, for Differential Thermal Analysis for specifying their melting range, for {1200°C, 20MPa}-flexural creep tests and for oxidation thermogravimetry tests in air at 1200°C.

As-cast microstructures and DTA results

Mushy zone temperature range



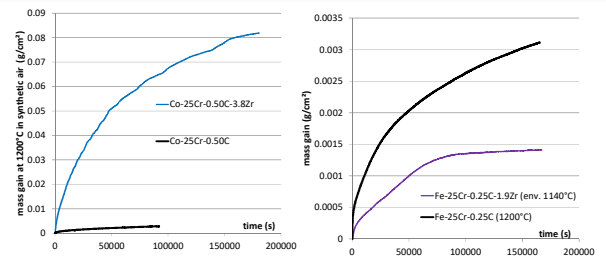
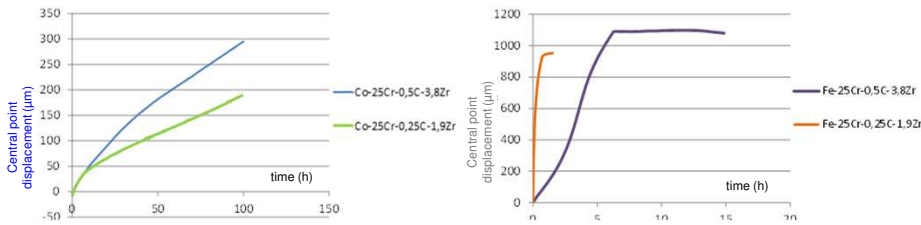
Alloy Type	Composition	Fusion over (°C)	Solidification over (°C)
Co-based alloys	0.25C-1.9Zr	1330 → 1445°C	1350 ← 1400°C
Fe-based alloys	0.25C-1.9Zr	1445 → 1500°C	1450 ← 1500°C
Ni-based alloys	0.25C-1.9Zr	1235 → 1448°C	1302 ← 1365°C
Co-based alloys	0.50C-3.8Zr	1340 → 1420°C	1350 ← 1385°C
Fe-based alloys	0.50C-3.8Zr	1445 → 1500°C	1445 ← 1500°C
Ni-based alloys	0.50C-3.8Zr	1116 → 1272°C	1163 ← 1296°C

Dendritic structure and interdendritic network of script-like eutectic ZrC carbides for all alloys

It seems that only the Co-based and Fe-based alloys are refractory enough to be tested at 1200°C → the Ni-based alloys are temporarily excluded from the following tests at 1200°C

Centered 3-points flexural creep at 1200°C for 20 MPa

Thermogravimetry tests at 1200°C in dry synthetic air



Choosing equal molar contents in carbon and zirconium led to carbides exclusively of the ZrC type, whatever the base element. The as-cast microstructures of the six alloys are thus all composed of a dendritic matrix with eutectic ZrC carbides located in the interdendritic spaces where they are mixed with matrix in a eutectic compound. The script-like shape of these carbides was successfully obtained in all cases. Other ZrC carbides, blocky-shaped are additionally present in the (Zr, C)-richest Co-based and Fe-based alloys. Avoiding the possible presence of chromium carbides allowed the Co-based and Fe-based alloys being very refractory. This was revealed by the DTA measurements which, furthermore, did not succeed in totally melting the iron-based alloys (too refractory for the used apparatus) to assess the liquidus temperature. Curiously, the nickel-based alloys started melting at rather low temperature, which did not allowed testing them at 1200°C in flexural creep and oxidation.

Concerning these tests, thus involving only the Co- and Fe-based alloys, very contrasted results were obtained. Despite their remarkably high refractoriness the two Fe-based alloys were very weak in flexural creep test, which can be explained by the not compact BCC ferritic structure of their matrixes. The two Co-based were much resistant, with rather low deformation rates for 1200°C and 20 MPa which are both particularly high for equi-axed conventionally cast superalloys. Unfortunately these were the mechanically weak Fe-based alloys which displayed the best oxidation behaviour in air at 1200°C. The two Co-based alloys, which were almost wholly destroyed by oxidation during the thermogravimetry tests, necessitate to be isolated by protective coatings from the oxidative working hot atmosphere to hope benefiting of their superior strength at high temperature.