



**HAL**  
open science

# Thermo-mechanical Behavior of HEA Alloys Containing Interdendritic MC Carbides

Patrice Berthod, Lionel Aranda, A. Vernière

► **To cite this version:**

Patrice Berthod, Lionel Aranda, A. Vernière. Thermo-mechanical Behavior of HEA Alloys Containing Interdendritic MC Carbides. TMS 2024 153rd Annual Meeting & Exhibition, Mar 2024, Orlando (FL), United States. hal-04471716

**HAL Id: hal-04471716**

**<https://hal.science/hal-04471716>**

Submitted on 21 Feb 2024

**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.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0 International License

# Thermo-mechanical Behavior of HEA Alloys Containing Interdendritic MC Carbides

Patrice Berthod<sup>1,2</sup>, Lionel Aranda<sup>2</sup>, Anne Vernière<sup>1,2</sup>

<sup>1</sup>Faculté des Sciences et Technologies, Campus Victor Grignard, F-54500 VANOEUVRE-LES-NANCY (France)

<sup>2</sup>Institut Jean Lamour, CNRS (UMR 7198), 2 allée André Guinier, Campus Artem, F-54000 NANCY (France)

[patrice.berthod@univ-lorraine.fr](mailto:patrice.berthod@univ-lorraine.fr)



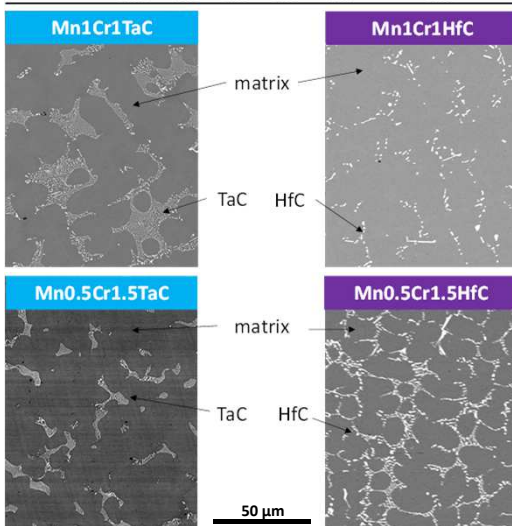
## Introduction

The casting route allows obtaining *in situ* composites which combine a HEA dendritic matrix and an interdendritic network of MC carbides. This association brings the simultaneous benefit of the intrinsic good creep resistance of the HEA matrix and of the delayed (steady state to tertiary) transition of creep regime given by the improved cohesion between neighbor dendrites resulting from script-like carbides. However, the difference in thermal expansion behavior between matrix and carbides may induce curious geometrical behavior of the whole alloy at high temperature, as earlier observed for cobalt-based [1] and (iron and/or nickel)-based alloys [2]. This work aims to investigate the dimensional behavior of MC-strengthened HEA alloys at high temperature during heating as well as during an isothermal stage at H.T., in order to observe the possible consequences of the internal interaction between matrix and carbides resulting from differential thermal expansion. Effectively, in contrast with the carbides-free quinary HEA alloys based on Co, Ni, Fe, Mn and Cr, the alloys based on these HEA and added with TaC or HfC carbides can be expected to behave similarly to the TaC-containing Co-based and Fe(Ni)-based alloys evocated above.

## Chemical compositions & as-cast microstructures of the alloys [3-5]

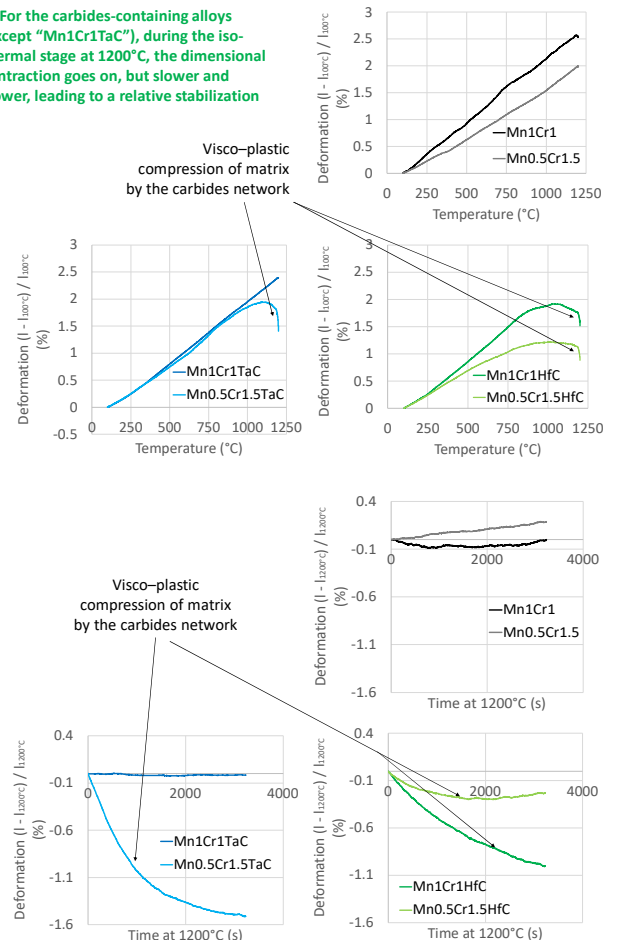
- “Mn1Cr1” is the original Cantor’s alloy (equimolar in Co, Ni, Fe, Cr and Mn) in a conventionally cast version; “Mn0.5Cr1.5” is a modified version resulting from a decrease in Mn ( $\times 0.5 \rightarrow 10$  at.%) and an increase in Cr ( $\times 1.5 \rightarrow 30$  at.%) ; both of them are single-phased
- “Mn1Cr1TaC” and “Mn0.5Cr1.5TaC” are developed from the quinary “Mn1Cr1” and “Mn0.5Cr1.5” alloys respectively; they additionally contain 4 wt.% Ta and 0.25 wt.% C; their matrices are similar to the two quinary alloys (except the additional presence of about 1 wt.% Ta in solid solution); eutectic TaC carbides, located in the interdendritic spaces, are present in their microstructures
- “Mn1Cr1HfC” and “Mn0.5Cr1.5HfC” are the “Mn1Cr1” and “Mn0.5Cr1.5” alloys modified by the addition of 4 wt.% Hf and 0.25 wt.% C; their matrices are similar to the two quinary alloys described above (notably: no Hf in solid solution); eutectic HfC carbides are present in the interdendritic spaces; some blocky HfC carbides – probably of a pre-eutectic nature – also formed, forming clusters.

Alloys ↓	Co	Ni	Fe	Mn	Cr	Ta	Hf	C
Mn1Cr1	20.0 ±0.5	21.5 ±0.5	19.5 ±0.5	19.5 ±0.5	20.5 ±0.5	/	/	/
Mn0.5Cr1.5	20.0 ±0.1	20.5 ±0.3	19.8 ±0.2	8.3 ±0.5	31.3 ±0.4	/	/	/
Mn1Cr1TaC	19.3 ±0.2	20.1 ±0.5	18.6 ±0.5	18.3 ±0.3	19.2 ±0.3	4.5 ±0.4	/	0.25
Mn0.5Cr1.5TaC	19.5 ±0.2	20 ±0.5	19.1 ±0.3	8.4 ±0.2	28.5 ±0.3	4.6 ±0.2	/	0.25
Mn1Cr1HfC	19.9 ±0.3	20.2 ±0.6	18.4 ±0.4	18.2 ±0.2	19.3 ±0.5	/	4 ±1.9	0.25
Mn0.5Cr1.5HfC	19.7 ±0.4	20.1 ±0.3	19.1 ±0.3	8.8 ±0.7	27.8 ±0.7	/	4.5 ±0.6	0.25



## Dimensional behaviors during heating up to 1200°C and during the following {1 hour}-isothermal stage

- “Mn1Cr1” and “Mn0.5Cr1.5”: linear expansion up to 1200°C
- Less Mn / more Cr seems to decrease thermal expansion ( $24 \times 10^{-6} \text{ K}^{-1}$  down to  $18 \times 10^{-6} \text{ K}^{-1}$ )
- “Mn1Cr1TaC”: linear expansion up to 1200°C
- “Mn0.5Cr1.5TaC”: linear expansion up to 950°C, then slowed expansion followed by inversion
- “Mn1Cr1HfC”: linear expansion up to 850°C, then slowed expansion followed by inversion
- “Mn0.5Cr1.5HfC”: linear expansion up to 650°C, then slowed expansion followed by inversion
- For the carbides-containing alloys (except “Mn1Cr1TaC”), during the isothermal stage at 1200°C, the dimensional contraction goes on, but slower and slower, leading to a relative stabilization



## Conclusion

The presence of carbides obviously led to the high temperature visco-plastic deformation of the matrix under the compressive stresses applied by the carbides, until the total decrease of the tensile stresses which developed in the carbide network during the first part of heating. These MC-reinforced HEA alloys are thus affected by the phenomena of matrix/carbides interactions and internal stresses development previously observed for Co, Fe or Ni-based alloys containing carbides with similar characteristics. Such behavior can cause problems of dimensional precision as well as of internal deterioration of the alloys, especially in situation of thermal cycling.

The corresponding supplemental proceeding TMS is available; see pp.679–688.

**Acknowledgements:**  
Nassima Chenikha, Corentin Gay and Pauline Spaeter for their help for synthesizing some of the alloys.

## References :

- [1] P. Berthod, C. Hell, L. Aranda: Influence of the morphologic evolution of the eutectic carbides at high temperature on the thermal expansion behavior of refractory cast alloys. *Journal of Alloys and Compounds* (2010) 504, 243–250.
- [2] P. Berthod, L. Aranda, Y. Hamini: Thermal expansion of chromium-rich iron-based or iron/nickel-based alloys reinforced by tantalum carbides. *Physicochemical Mechanics of Materials* (2011) 3, 46–52.
- [3] P. Berthod: As-cast microstructures of high entropy alloys designed to be TaC-strengthened. *Journal of Metallic Material Research* (2022) 5, 1–10.
- [4] P. Berthod: As-cast microstructures of HEA designed to be strengthened by HfC. *Journal of Engineering Science and Innovation* (2022) 7, 305–314.
- [5] N. Chenikha, P. Spaeter, C. Gay, A. Vernière, P. Berthod: Microstructures in as-cast condition of Medium Entropy Alloys designed to contain eutectic carbides TaC or HfC. *Journal of Engineering Science and Innovation* (2023) 8(2) 159–170.