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Strengthening against creep at elevated temperature of HEA alloys of the CoNiFeMnCr type using MC-carbides

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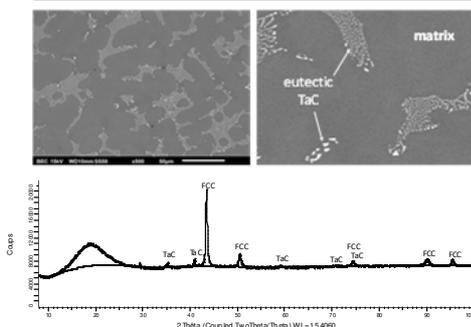
Introduction

Cast high entropy CoNiFeMnCr alloys can become alternative solutions to cast cobalt-based and nickel-based superalloys able to resist creep at 1000°C and beyond. The partial substitution of Co and Ni by Fe and Mn allow lower cost and lower dependence on the Co and Ni critical elements. However, their grain boundaries need to be strengthened. In this work equimolar CoNiFeMnCr alloys were elaborated by high frequency induction melting under inert atmosphere, after having added carbon and either Ta or Hf, in quantities rated to favor the development of an intergranular network of script-like eutectic carbides, either TaC or HfC. These carbides were successfully obtained with the required location and morphology. 3 points bending creep tests were carried out at 1100°C for an induced maximal tensile stress = 20 MPa.

Microstructures of the HEA-based TaC-alloy and HfC-alloy in their as-cast states [1, 2]

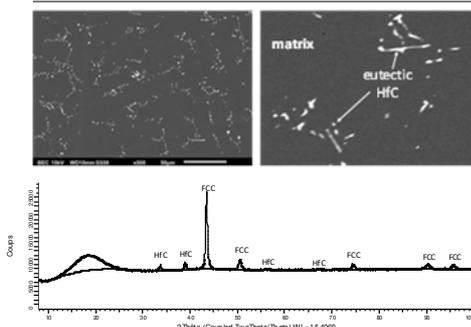
• TaC-alloy: double-phased polycrystalline alloy with a dendritic structure; matrix equivalent to the equimolar CoNiFeMnCr Cantor alloy but containing 2 wt.%Ta; interdendritic network made of script-like TaC carbides resulting from final eutectic solidification (L → matrix + TaC); presence of rare coarse TaC possibly precipitated as pre-eutectic crystals

TaC-alloy	Co	Ni	Fe	Mn	Cr	Ta
General	19.3	20.1	18.6	18.3	19.2	4.5
Wt.%	±0.2	±0.5	±0.5	±0.3	±0.3	±0.4
Matrix	20.5	20.5	20.9	16.7	19.4	2.1
Wt.%	±0.4	±0.3	±0.9	±1.4	±0.6	±0.1



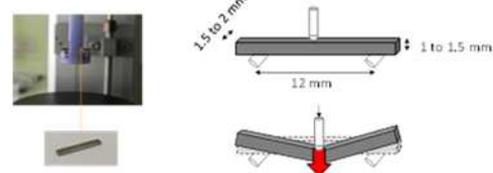
• HfC-alloy: double-phased polycrystalline alloy with a dendritic structure; matrix equivalent to the equimolar CoNiFeMnCr Cantor alloy (no Hf in matrix); interdendritic network made of script-like TaC carbides resulting from final eutectic solidification (L → matrix + HfC); presence of rare coarse HfC possibly precipitated as pre-eutectic crystals

HfC-alloy	Co	Ni	Fe	Mn	Cr	Hf
General	19.9	20.2	18.4	18.2	19.3	4
Wt.%	±0.3	±0.6	±0.4	±0.2	±0.5	±1.9
Matrix	21.1	19.7	21.6	16.8	20.7	0.1
Wt.%	±1.2	±0.7	±1.6	±1.8	±0.3	±0.1



Three points flexural creep tests at 1100°C in argon flow

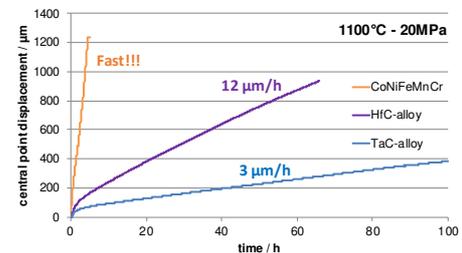
• Principle of the test and apparatus used:



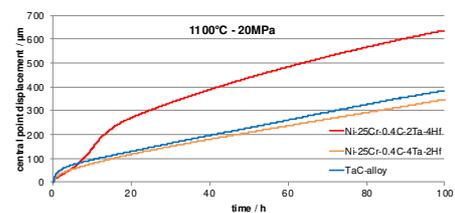
• Examples of samples after test:



• Deformation curves obtained for the three studied alloys:



• Comparison of the TaC-alloy with two nickel alloys reinforced by (Ta,Hf)C carbides:



Summary / Conclusion

The two alloys studied to which this study was devoted, the HfC alloy and the TaC alloy, result from the successful combination of an efficient interdendritic MC carbide network very stable at elevated temperature, and a matrix made of a High Entropy Alloy (CoNiFeMnCr equimolar) – case of the HfC alloy – or made of a HEA matrix with minor presence of Ta atoms in solid solution – the TaC alloy – which demonstrated here a particularly interesting creep resistance. Both can be considered as being metal matrix composites made of a HEA matrix (especially the HfC alloy) and strengthening short fibers (HfC or TaC carbides). Obtaining such microstructures was reasonably expected since they were earlier successfully obtained in alloys based on Co–Cr (HfC and TaC), Ni–Cr (HfC) or (Ni,Fe)–Cr and Fe–Cr (TaC) systems. From such Co-based, Ni-based and even (Ni,Fe)-based alloys in which the critical Co and Ni elements are present in rather high quantities, one derived thus new less (Ni and Co)-dependent alloys with more Fe and Mn substituting parts of Co and Ni with similar level of high creep-resistance for a temperature at which gamma/gamma prime single-crystalline Ni-based superalloys are significant weakened by the loss of part of their strengthening intermetallic particles.

The corresponding supplemental proceeding TMS is available; see pp.1093–1102.

Acknowledgements:

Lionel Aranda who performed the creep tests.

References:

- [1] P. Berthod: As-Cast Microstructures of High Entropy Alloys Designed to Be TaC-Strengthened. *Journal of Metallic Material Research* (2022) 5(2) 1–10. DOI: 10.30564/jmmr.v5i2.4685
- [2] P. Berthod, As-cast microstructures of HEA designed to be strengthened by HfC. *Journal of Engineering Science and Innovation* (2022) 7(3) 305–314. <https://hal.science/hal-03887727>