

CREEP BEHAVIOR AT ELEVATED TEMPERATURES OF SEVERAL POLYCRISTALLINE NI-BASED SUPERALLOYS STRENGTHENED BY MC-CARBIDES

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About the Presenter

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CV highlights and research interests:

- **Mech. Eng. Ecole Centrale de Lille, PhD Mater. Sci., HDR Chemistry**
- **Foundry, metallurgy, corrosion, microstructures and properties of superalloys at high temperature**

“Surface & Interfaces: Chemical Reactivity of Materials” research group

Work achieved without funding sources

No conflict of interest

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Outlines

- **Introduction**
- **Choosing Zr and Hf+Ta as MC – former elements for Ni(Cr) alloys**
- **Elaboration of the alloys (some details)**
- **Obtained microstructures and chemical compositions for the alloys**
- **Creep tests (technical details)**
- **Creep tests (results)**
 - Ni(Cr)–ZrC alloys
 - Ni(Cr)–(Hf,Ta)C alloys
- **Conclusions**
- **Outlooks**



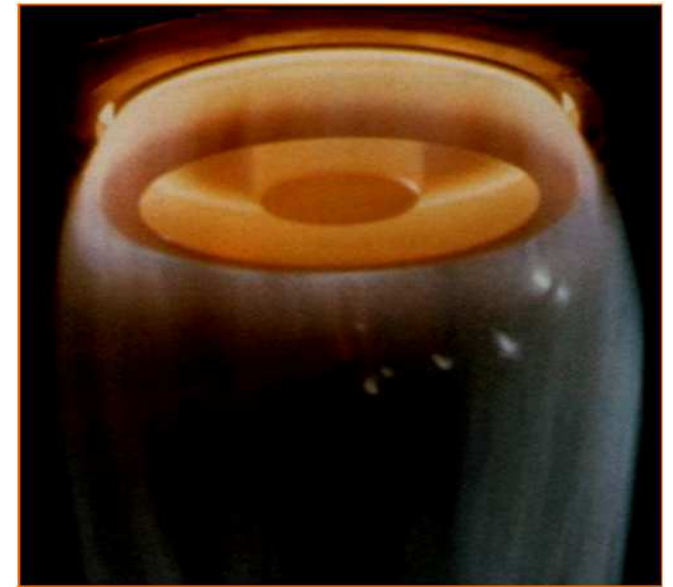
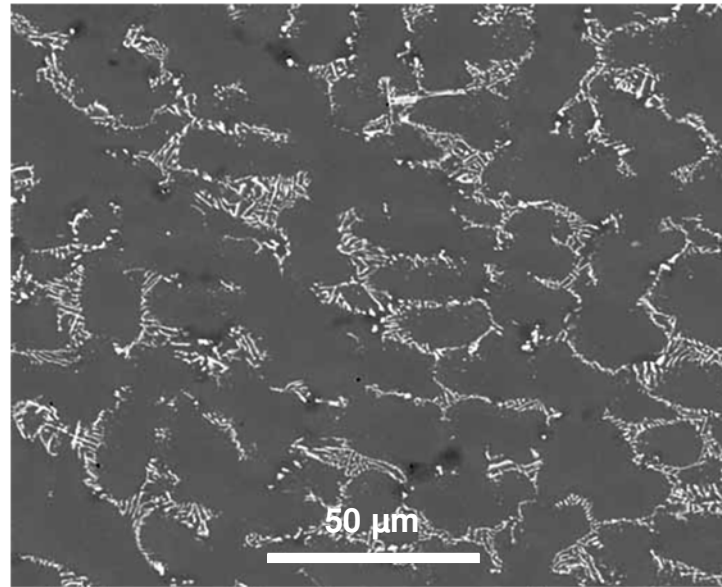
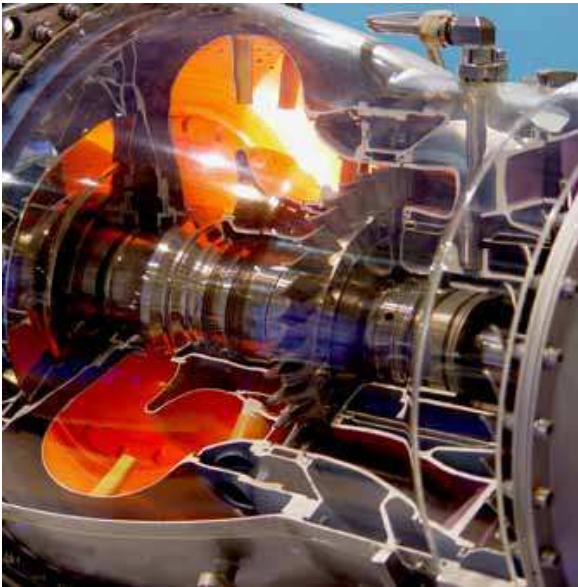
Introduction

- **Coarse–grained polycrystalline superalloy’s family: still a solution for components with complex shapes and destined to high temperature work under significant stresses**
- **Chromia–forming behavior compulsory for good resistance against hot corrosion by melts**
- **Eutectic carbides useful for the reinforcement of grain boundaries (GB) and interdendritic spaces (IS)**
- **Monocarbides from Ta, Hf, Zr... often particularly efficient at $T > 1000^{\circ}\text{C}$:**
 - **If eutectic origin: script morphologies allowing good interdendrites cohesion**
 - **Some of them: stable at H.T. in term of volume fraction and of morphology**

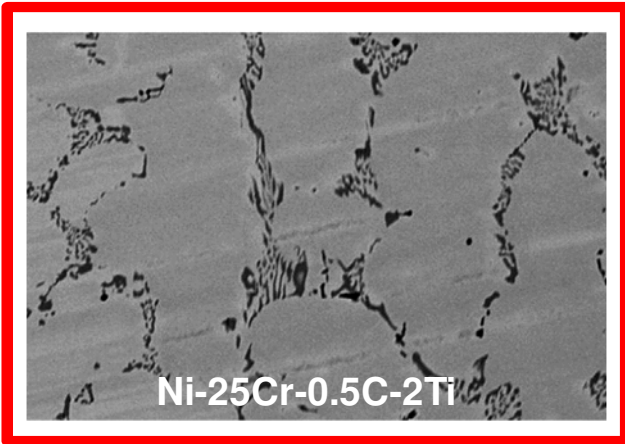


The example of TaC–reinforced Co superalloys

Pre–industrial and industrial alloys for turbine blades, glass–shaping tools...



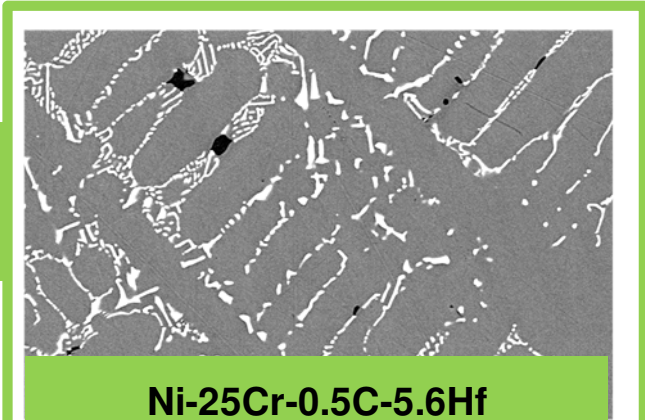
Examples of MC-containing Ni model alloys



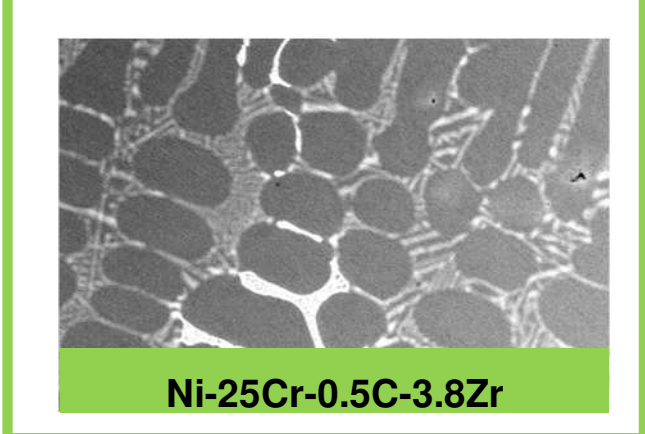
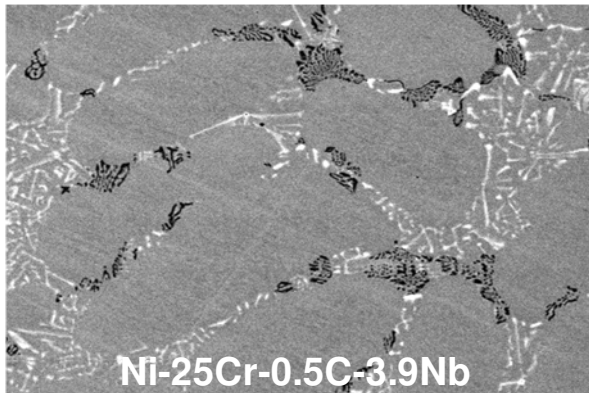
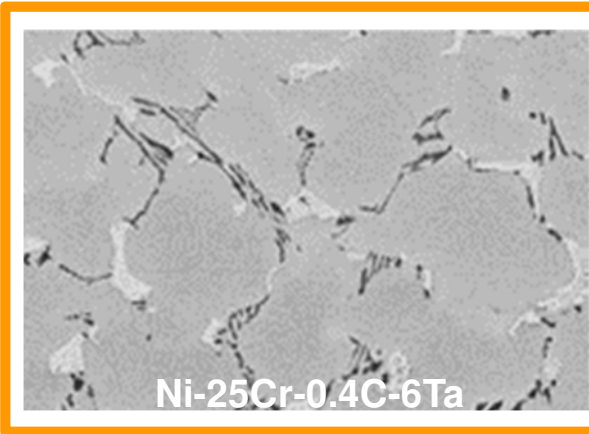
Cr_xC_y

Model alloys
25 μ m

MC only!



MC and Cr_xC_y



Journal of Metallic Material Research (2019) 2(01) pp.10–18.

Strengthening by MC carbides: Co-based or Ni-based superalloys?

- Strength at elevated temperature of chromia-forming alloys:
a priori Co-based matrix intrinsically better than Ni-based matrix
- Exclusive presence of MC carbides: Co matrix in case of M = Ta, Ti and Nb
- Crystalline stability during thermal cycling: Ni matrix (stays FCC \forall T)
- Chromia-forming behavior: Ni matrix (easier Cr volume diffusion)

For applications inducing serious H.T. oxidation and corrosion problems for bulk alloys → Ni-based superalloys
What MC carbide to choose?



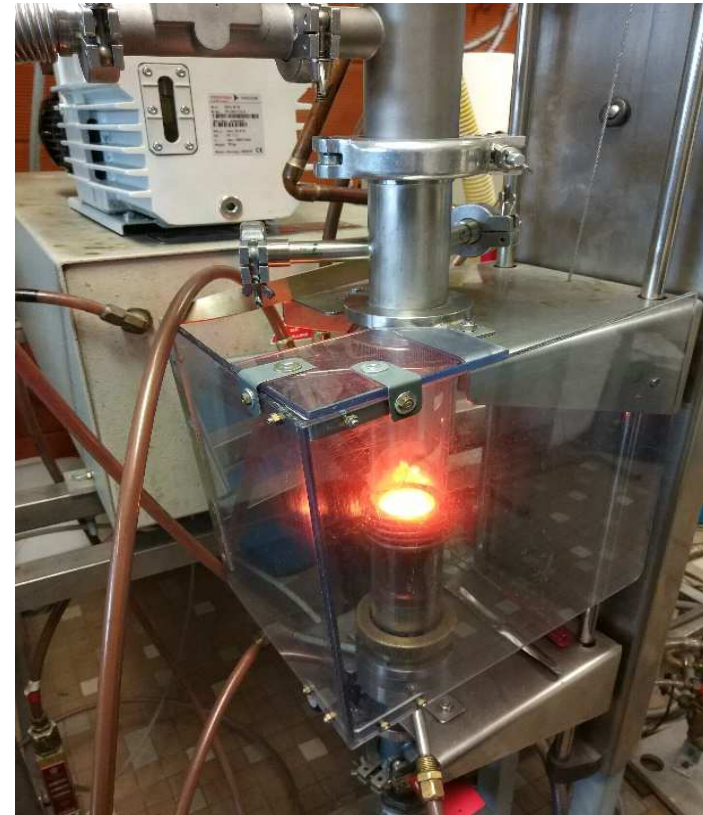
Choose MC-former elements for chromia-forming Ni-based alloys:

- To maintain MC high volume fractions and script shape at H.T.: Hf or Zr
- Ni(Cr)–HfC alloys recently investigated:
 - Good oxidation and creep resistances at 1100°C (*Materials and Design* (2016) 104 pp.27–36.)
 - Good oxidation resistance at 1200°C (*Oxidation of Metals* (2014) 81 pp.393–405.)
 - But Hf is a too critical element to introduce by targeting > 5 wt.% Hf in bulk alloys
- In this work too ways were explored:
 - Ni(Cr)–ZrC alloys
 - Ni(Cr)–(Hf,Ta)C alloys

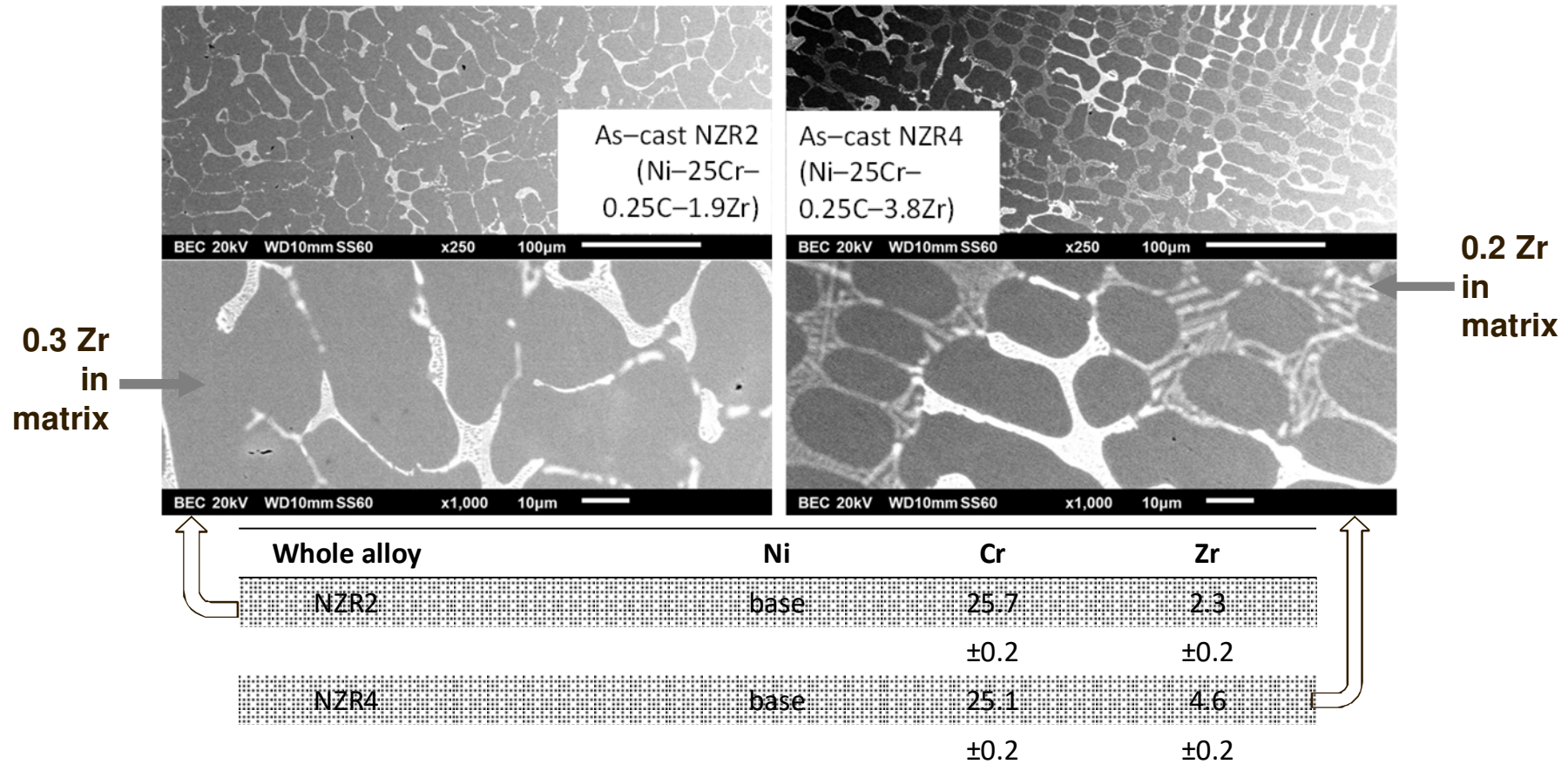


Elaboration of the alloys for the study

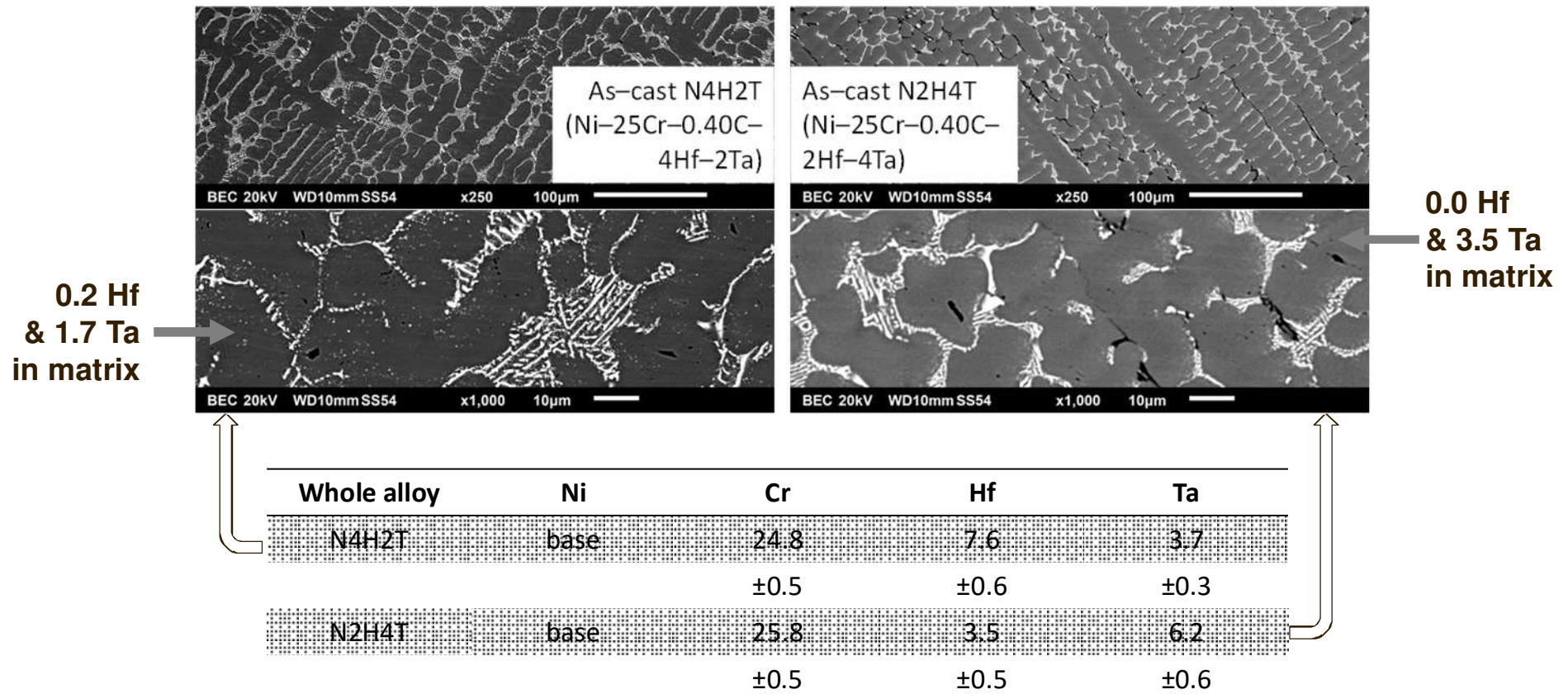
- **Chemical compositions (wt.%):**
 - “ZrC” way: Ni-25Cr-0.25C-1.9Zr and Ni-25Cr-0.25C-3.8Zr
 - “(Hf, Ta)C” way: Ni-25Cr-0.4C-4Hf-2Ta and Ni-25Cr-0.4C-2Hf-4Ta
- **40g of mix of pure elements (>99.9%)**
- **High frequency induction furnace**
- **300 millibars pure Argon**
- **10 minutes of homogenization in the liquid state ($\approx 1700^{\circ}\text{C}$)**



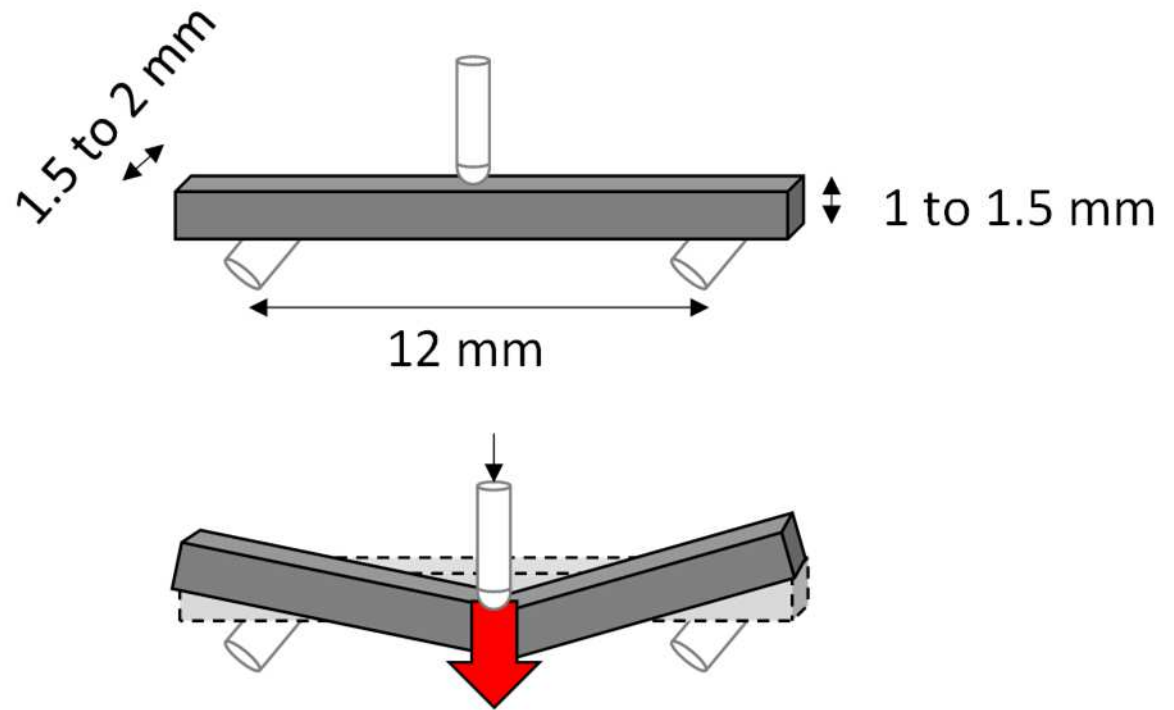
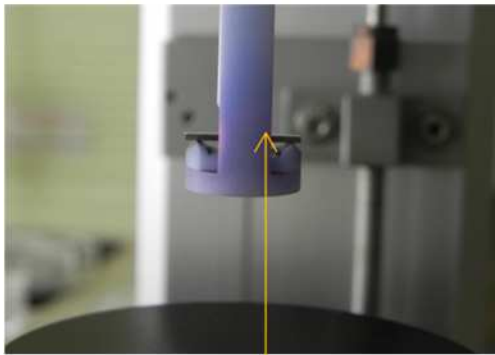
Obtained chemical compositions (wt.%) and as-cast microstructures (“ZrC”)



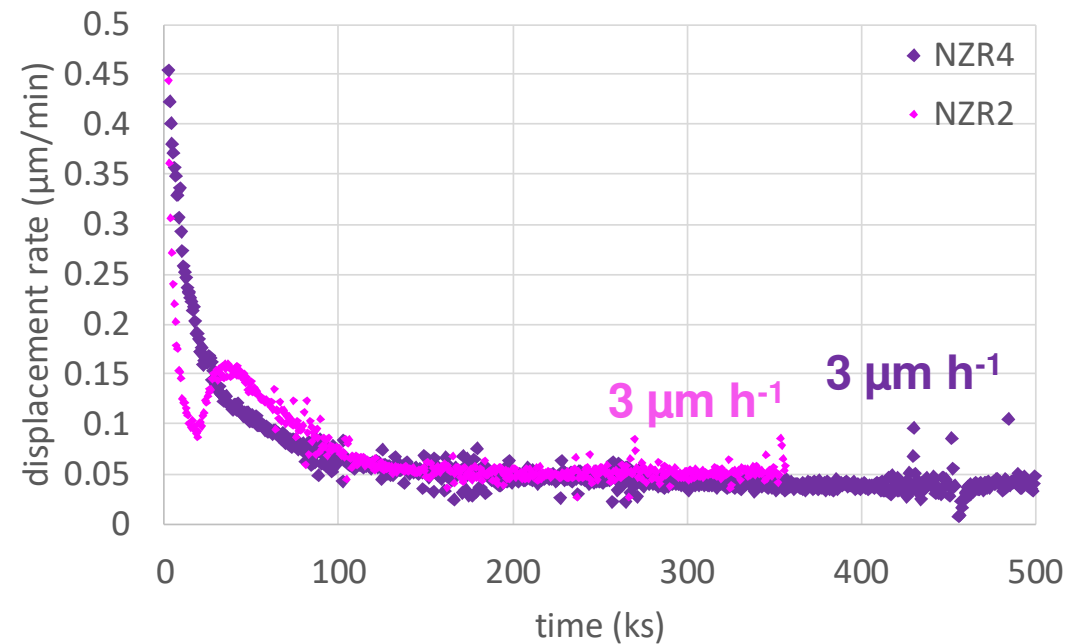
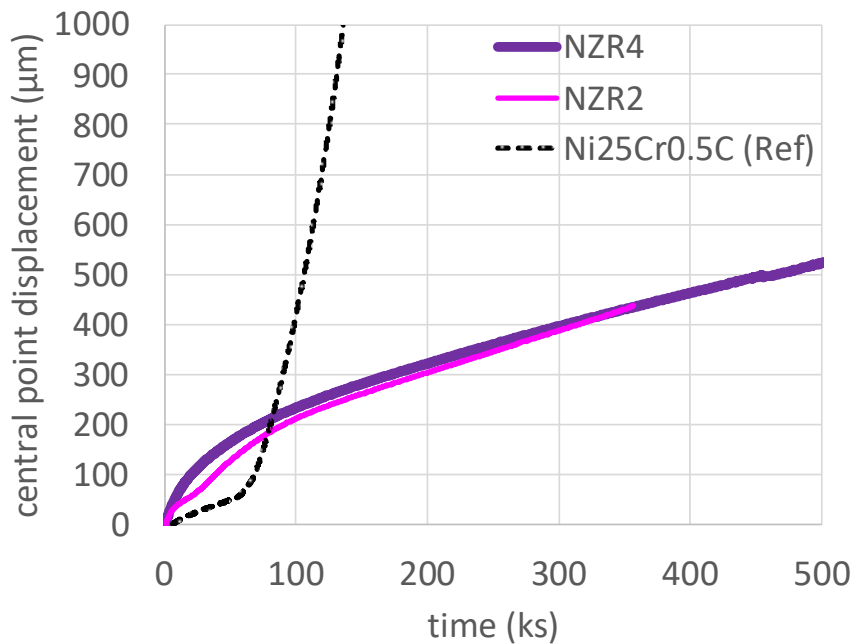
Obtained chemical compositions (wt.%) and as-cast microstructures (“(Hf,Ta)C”)



Three points – flexural creep tests at 1100°C under a load inducing 20 MPa / technical details

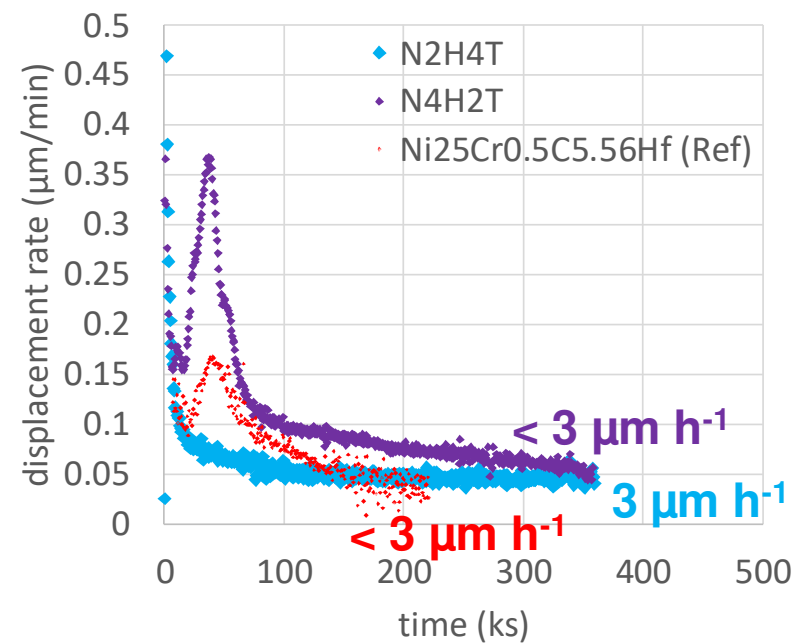
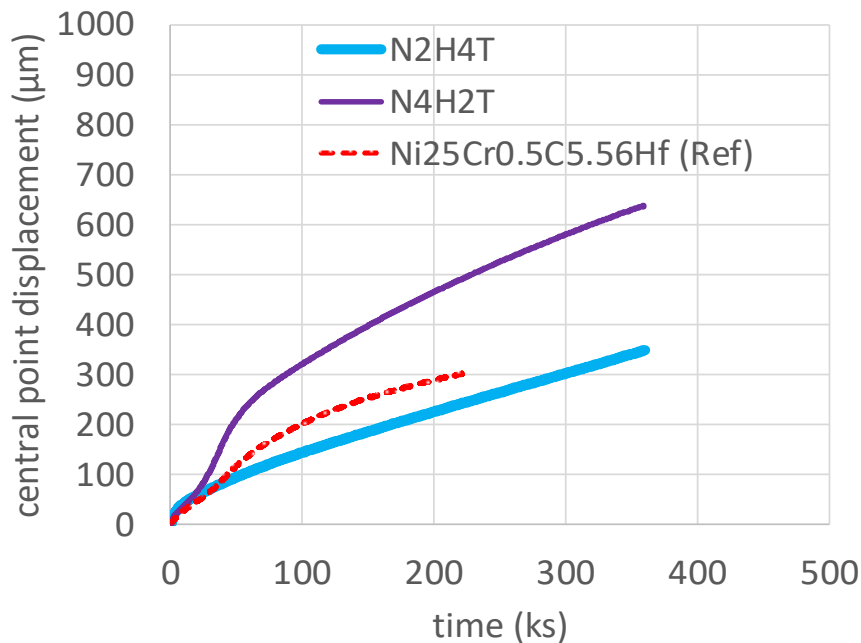


Three points – flexural creep tests at 1100°C under a load inducing 20 MPa max / “ZrC”



**Ni(Cr)–ZrC alloys both more creep-resistant than Ni(Cr)–Cr₇C₃
Still secondary creep steady state not finished after 200 hours**

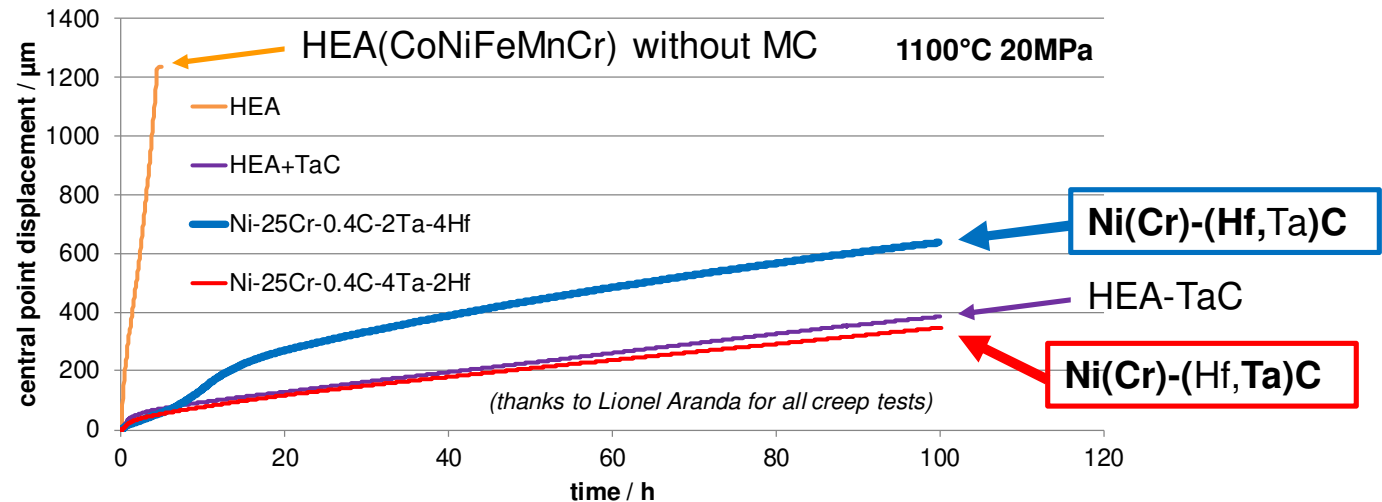
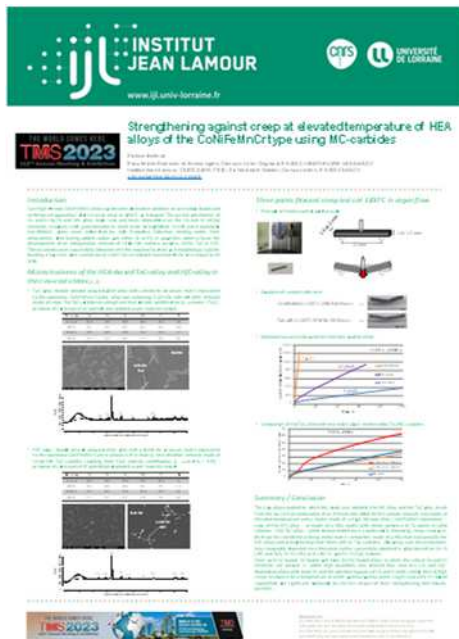
Three points – flexural creep tests at 1100°C under a load inducing 20 MPa max / “(Hf,Ta)C”



Ni(Cr)–(Hf,Ta)C more or less equivalent to Ni(Cr)–HfC
Still primary creep not finished after 100 hours

Comparison with other MC-reinforced alloys

Resistance similar to MC-strengthened HEAs



Poster presented here (TMS2023) "Strengthening Against Creep at Elevated Temperature of HEA Alloys of the CoNiFeMnCr Type Using MC-Carbides" & Supplemental proceeding: pp.1103–1111.



Conclusions

- The presence of MC as single carbide in Ni(Cr) alloys allows obtaining high creep resistance (close to some MC–reinforced HEA alloys)
- Their beneficial effects seem concerning the {II → III}–creep state transition (delayed) as well as the steady state deformation rate
- For a same base, creep resistance increases if: no carbides → Cr_7C_3 → MC
- Ni(Cr)–based alloys containing MC as single carbides are not as creep – resistant as similar alloys based on Co, but their behaviors are of interest.



Outlooks

- Longer creep tests (e.g. 1000 hours) to observe more {II → III}–creep state transition for the present alloys and the present {T, σ } conditions
- Creep tests at various {T, σ }: currently in progress
- Specifying the parameters involved in the {steady state deformation rate = $f(T)$ } and {steady state deformation rate = $f(\sigma)$ } dependence laws





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



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