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# Thermal and mechanical properties at high temperature of Co-based superalloys strengthened by MC Carbides with M=Ta or Nb



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## Introduction

- Polycrystalline Co-based superalloys strengthened by carbides can be used at high temperature above 1100°C.
- These alloys are the most often mechanically reinforced by TaC carbides [1-2].
- But versions involving MC carbides can be strengthened by other carbides as Nb, Ti, Zr or Hf carbides [3].
- In this work, the effects of the presence of niobium carbides in a Co-based superalloy on its thermal and mechanical properties were studied.
- The results are compared with those of a more classical Co-based superalloy reinforced by tantalum carbides.
- The influence of aging was also studied for the two alloys (strengthened by NbC and by TaC).

## Synthesis

- Chemical composition:

wt. %	Co	Cr	C*	Ta*	Nb*
CoTa	Bal.	25	0.5	7.5	/
CoNb	Bal.	25	0.5	/	3.9

\* the same molar concentrations for forming only MC-type carbides

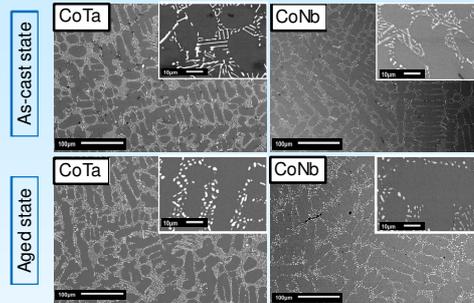
- Elaboration: from solid parts of pure elements (>99.9%), melting using a high frequency induction furnace under argon
- Rather fast solidification since achieved in a water-cooled copper crucible

## Annealing

- Heat treated at 1200°C during 100h in tubular furnace
- For simulating an aging in service [4]

## Microstructure: morphology of the obtained carbides

- Microstructures of both alloys in the as-cast state and after aging (SEM images in BSE mode):



- Polycrystalline, equiaxed microstructures obtained for both alloy
- Presence of TaC carbides in the CoTa alloy and of NbC carbides in the CoNb alloy for both states
- Aging: shape change for the carbides, from script-like to circular, for decreasing the matrix/carbides interfacial energy  
⇒ **Fragmentation of carbides** [5]

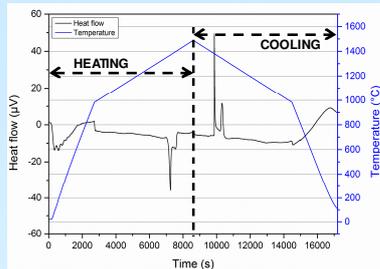
## Microstructure: carbide's quantity

- Image analysis: determination of the surface fraction of TaC and of NbC (this value considered equal to the volume fraction)
- With the phase's densities: determination of the weight fraction of TaC and of NbC
- Aging: decrease of the mass fraction of TaC and NbC  
⇒ **Consequently: enrichment in Ta and Nb in the matrix**

Alloy	State	wt. % of MC carbide
CoTa	As-cast	13.1
	Aged	12.2
CoNb	As-cast	7.0
	Aged	4.9

## Differential thermal analysis (DTA)

- Principle: measurement of a heat flow versus the temperature all along a thermal cycle



- Two pics for the melting and for the solidification: the first peak corresponds to the melting of the {matrix-carbide} eutectic and the second to the melting of the matrix

Alloy	State	Fusion		Solidification	
		Start	End	End	Start
CoTa	As-cast	1347°C	1398°C	1316°C	1378°C
	Aged	1355°C	1422°C	1333°C	1387°C
CoNb	As-cast	1335°C	1414°C	1315°C	1384°C
	Aged	1344°C	1447°C	1296°C	1390°C

- Aging: decrease of all temperatures (solidus and liquidus) except the temperature of solidification's end of the CoNb alloy

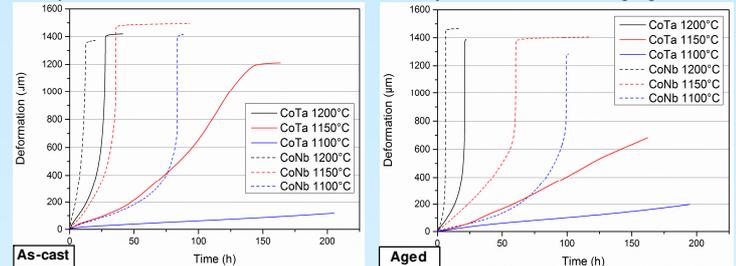
⇒ **Homogenization of the alloys during the aging: the probability to have an area which melts at lower temperature decreases thus temperatures at aged state higher than the temperatures for the as-cast state**

- Comparison between the two alloys: the solidus temperature is lower and the liquidus temperature is higher for the CoNb alloy than for the CoTa alloy

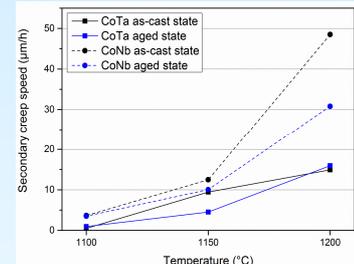
⇒ **The mushy domain where the liquid phase and solid phases coexist is greater for the CoNb alloy**

## 3 points flexural creep

- Creep test at 1000°C under 20MPa for both alloys before and after aging:



- Secondary creep speed for each test:



- Aging: no influence on the mechanical properties

⇒ **Two effects** [6]:

- **Fragmentation of carbides: carbide network more discontinuous therefore decrease of the interdendritic cohesion (accelerated tertiary creep)**
- **Enrichment in Ta and Nb in the matrix: mechanical reinforcement of alloy by solid solution strengthening (limitation of the secondary creep)**
- **Two opposite effects: aging no impact on the mechanical resistance of alloys**

- Alloy reinforced by TaC more resistant than the same alloy strengthened by NbC, at all temperatures, before and after aging

⇒ **Reinforcement by solid solution strengthening less effective for Nb (atom lighter than Ta): but low impact**

⇒ **Visibly TaC: better mechanical reinforcement than NbC**

## Comparison with similar superalloys based on Ni

- TaC [7]: tantalum carbide not stable in nickel-based alloys (comparison no possible)
- NbC [8]: the Co-based alloy is more mechanically resistant than the Ni-based alloy at same temperatures

## Conclusion

- TaC and NbC are stable in Co-based superalloys: it is possible to have sustainable TaC or NbC in a Co-based alloy.
- The alloy strengthened by TaC is more mechanically resistant than the CoNb alloy.
- However, these alloys are not suitable for uses at 1200°C and also 1150°C for the CoNb alloy.
- The CoNb alloy led to better properties than for the same Ni-based alloy: the Co-based alloys can be used to produce materials which must present good mechanical behaviour at high temperature (1100°C-1150°C) instead Ni-based alloys and maybe furthermore to compete with  $\gamma/\gamma'$  superalloys.

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