



HAL
open science

An example of thermodynamical calculations applied to the study of the high temperature behaviour of Co-base superalloys strengthened by tantalum carbides

Sylvain Michon, Patrice Berthod, Lionel Aranda, Christophe Rapin, Renaud Podor, Pierre Steinmetz

► To cite this version:

Sylvain Michon, Patrice Berthod, Lionel Aranda, Christophe Rapin, Renaud Podor, et al.. An example of thermodynamical calculations applied to the study of the high temperature behaviour of Co-base superalloys strengthened by tantalum carbides. *Calphad* XXXII, May 2003, La Malbaie, Canada. hal-04079345

HAL Id: hal-04079345

<https://hal.science/hal-04079345>

Submitted on 24 Apr 2023

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

S.MICHON, P.BERTHOD, L.ARANDA, C.RAPIN, R.PODOR, P.STEINMETZ

Laboratoire de Chimie du Solide Minéral – (UMR 7555), Université Henri Poincaré
Boulevard des aiguillettes, BP 239 - 54506 Vandoeuvre cedex, France

Cobalt-base superalloys are currently used as bulk materials for parts of aeronautic turbines. These latter support mechanical and thermal constraints. As the lifetime of these parts is limited, the aim of this work is to elaborate new alloys with higher solidus temperature and mechanical resistance. The best way to speed up development of new materials is thanks to thermodynamic simulations (Thermo-Calc), which will propose solutions to choose the microstructure and the alloy elaboration process.

Database constitution

The following tables summarize the binary and ternary systems added to SSOLSGTE solutions database to build our own database :

Co-C	Ni-C	Cr-C	Ta-C	Co-Ni	Co-Ni-Cr	Co-Cr-Ta	Co-Ta-C	Co-Ni-Ta	Co-Cr-C
ssol (SGTE)	ssol (SGTE)	ssol (SGTE)	(1)	ssol (SGTE)	ssol (SGTE)	not added	(5)	not added	ssol (SGTE)
Co-Ta	Ni-Ta	Cr-Ta	Co-Cr	Ni-Cr	Co-Ni-C	Ni-Cr-C	Ni-Cr-Ta	Ni-Ta-C	Cr-Ta-C
(2)	(3)	(4)	ssol (SGTE)	ssol (SGTE)	ssol (SGTE)	ssol (SGTE)	(6)	not added	not added

- (1) K. Frisk, A. Fernandez Guillermet, *Journal of Alloys and Compounds*, 238 (1996) 167-179.
- (2) Zi-Kui Liu, Y. Austin Chang, *Calphad*, Vol. 23, No 3-4, pp. 339-356, 1999.
- (3) I. Ansara, M. Selleby, *Calphad*, Vol. 18, No. 1, pp. 99-107, 1994.
- (4) N. Dupin, I. Ansara, *Journal of Phase Equilibria*, Vol. 14, No.4, pp. 451-456, 1993.
- (5) L. Dumitrescu, M. Ekroth, B. Jansson, *Metallurgical and Materials Transactions A*, Vol. 32A, pp. 2167-2174, 2001.
- (6) N. Dupin, I. Ansara, *Z. Metallkd.*, Vol. 87, pp. 555-561, 1996.

Prediction of phases equilibrium versus temperature and composition: Influence of C content on the Co-base superalloy microstructure.

In the cobalt-base superalloys reinforced by TaC, the best mechanical properties are related with :

- a high solidus temperature
- the absence of chromium carbides

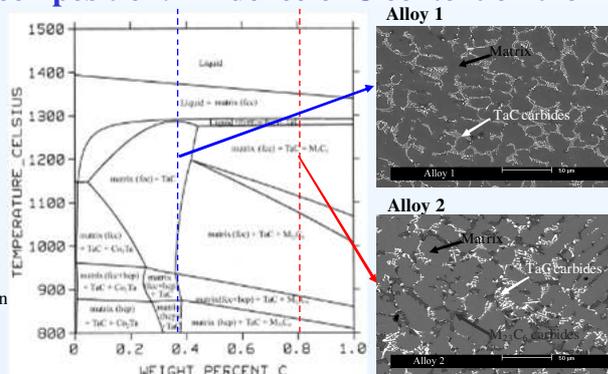
□ As a consequence, the optimum carbon content predicted by the phase diagram (on the right) is 0,38%w.

The microstructures obtained (alloys 1 & 2) are in good agreement with the phase diagram calculation.

Alloys compositions

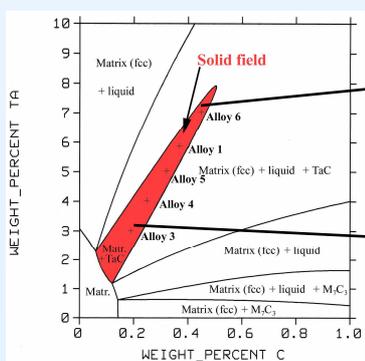
wt %	Co	Ni	Cr	Ta	C
Alloy 1	bal	8.7	28.4	5.8	0.37
Alloy 2	bal	8.7	28.4	5.8	0.80
Alloy 3	bal	8.7	28.4	3	0.19
Alloy 4	bal	8.7	28.4	4	0.25
Alloy 5	bal	8.7	28.4	5	0.33
Alloy 6	bal	8.7	28.4	7	0.44

These alloys were synthesized by induction heating and aged for 100 hrs at 1200°C

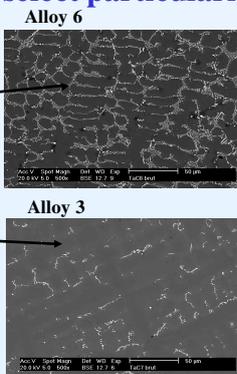


Influence of C content on alloy 1 (Thermo-Calc calculation)

Use of isothermal sections to select particularly high refractory materials



Isothermal section at 1285°C calculated by Thermo-Calc



	Solidus temperature °C (Thermo-Calc)	Experimental (DTA) melting temperature °C	ΔT °C
Alloy 3	1290	1348	58
Alloy 4	1289	1336	47
Alloy 5	1288	1337	49
Alloy 1	1287	1338	51
Alloy 6	1286	1338	52

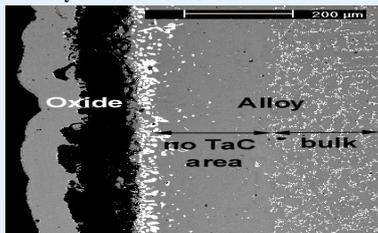
The comparison between the melting temperature predicted by Thermo-Calc with those determined by Differential Thermal Analysis shows a constant difference of about 50°C.

The absolute melting temperature can not be reached by Thermo-Calc calculations. Nevertheless, these results obtained thanks to this software allow the alloys classification according to their solidus temperature.

The solid domain predicted by Thermo-Calc is precise enough to elaborate alloys with the desired microstructure (TaC precipitated in the matrix).

Evaluation of local melting temperature : Case of the skin of Co base alloy during air oxidation at 1300°C

Alloy 1 oxidized for 100 hrs at 1300°C

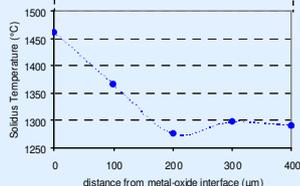


Alloy composition versus surface distance obtained by Electron Probe Microanalysis.

d (um)	Co	Ni	Cr	Ta	C*
0	bal	11.40	12.97	0	0
100	bal	11.20	17.33	0.69	0.13
200	bal	10.07	19.89	1.05	0.25
300	bal	9.65	23.77	5.80	0.37
400	bal	9.42	26.59	5.80	0.37

*: By hypothesis, carbon content decreases linearly from the bulk to the oxide scale

□ Prediction of an eventual solidus temperature diminution near the metal-oxide interface due to a variation of the alloy composition.



Conclusions

In our research fields, thermodynamic simulations allow:

- the prediction of the equilibrium phases
 - to better select the chemical composition in order to obtained the desired phases (natures and quantities)
 - to prevent the risk of apparition of undesirable phases (σ phase, TCP phases....)
- the selection of highest refractory materials
 - to select an alloy with the solidus temperature as far as possible of the working temperature.
- the evaluation of local melting temperature
 - to predict a possible minimizing of surface mechanical properties induced by the oxidation phenomena.