High temperature behaviour of chromium-nickel alloys with Ni varying from 50 to 0 wt.%

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Introduction

- Need of metallic materials for applications at particularly elevated temperatures.
- Complex shapes of many pieces working at high temperature → foundry way
- Cobalt-based and even Nickel-based alloys not able for working at T > 1200°C [1-2].
- Chromium: one of the three well-known elements for combatting H.T. oxidation; also efficient for protecting refractory alloys from hot corrosion by molten substances [3].
- In addition Cr is a very refractory element: to be considered as bulk element [4,5].
- In this work, a series of binary Cr (50 to 100wt.%)-Ni alloys, possible bases for future more complex alloys, were cast and studied at H.T.
- The obtained microstructures issued from conventional foundry process were explored.
- The microstructures after long exposure to high temperature (1200°C) were characterized.

Thermodynamic calc. & synthesis

- Chemical compositions of the alloys:

Name of the alloys	Targeted composition (in wt.%)	
	Cr	Ni
Cr-50Ni	balance	50
Cr-40Ni		40
Cr-30Ni		30
Cr-20Ni		20
Cr-10Ni		10
Cr-7.5Ni		7.5
Cr-5Ni		5
Cr-2.5Ni		2.5
Cr		0

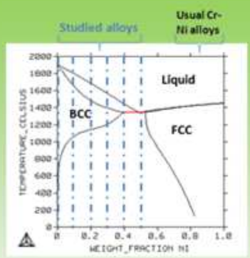
- Thermo-Calc calculations for anticipating the as-cast microstructures as well as the stable metallurgical states at high temperature
- Real elaboration using a High Frequency induction furnace (under several hundreds mbars of pure Ar)

Exposure to high temperature

- 50 hours at 1200°C in N_2-20%O_2

Preliminary thermodynamic modelling

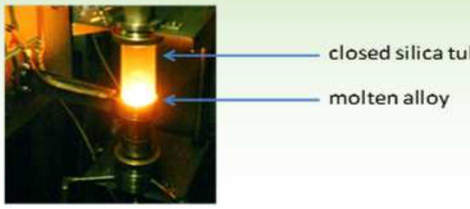
- Calculations carried out with Thermo-Calc [4] and the SSOL database [5]:



- Very liquidus temperatures: melting at about 2000°C (very high %Cr)
- But also very high solidus temperature (*idem*): favourable for high level of mechanical properties at elevated temperatures
- Solidification starting by a Chromium-based solid solution (except the Cr=Ni alloy)
- Double-phased alloys after cooling down to room temperature

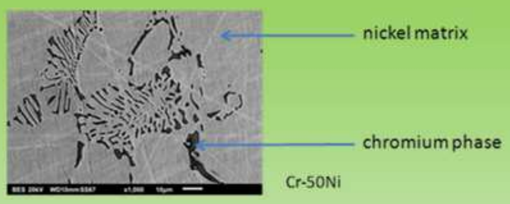
Real elaboration and samples' manufacturing

- Heating until very high temperature (typically 1200°C)
- Despite the surrounding pure Ar and the rather high pressure: significant vaporization of Cr and oxidation
- Total melting achieved
- Rather fast solidification and cooling
- Difficulty for cutting, grinding and polishing
- Problematic brittleness at room temperature

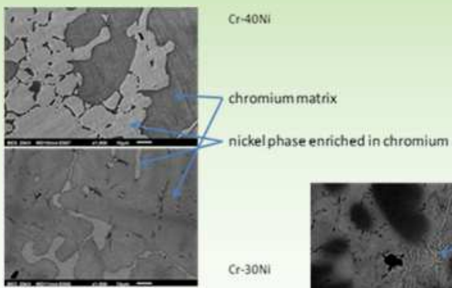


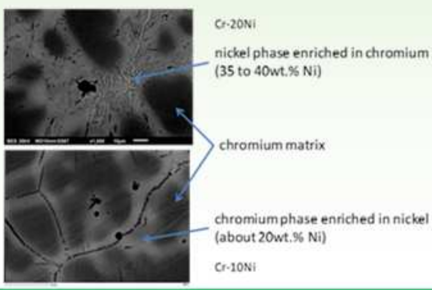
As-cast microstructures of the obtained alloys

- The hyper-eutectic alloy (solidification starting by a nickel-based solid solution): dendritic austenitic Ni-based matrix very rich in chromium and interdendritic eutectic compound (fcc Ni-phase + bcc Cr-phase)



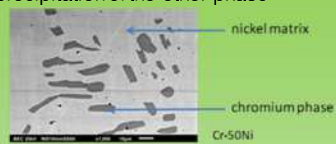
- The four hypo-eutectic binary alloys (solidification starting by the bcc chromium-based solid solution): either double-phased with a dendritic matrix of Cr-phase, or single-phased with significant chemical segregations

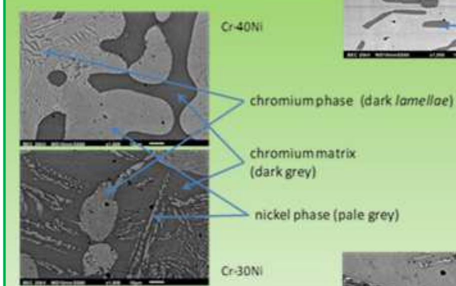


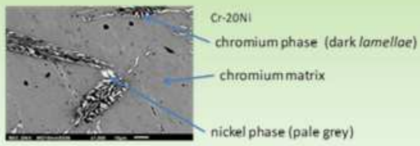


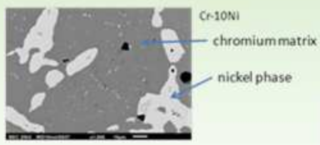
Microstructural evolution at 1200°C (during 50 hours)

- General chemical homogeneization
- Cr-phase and/or Ni-phase become rounder
- In each of the initial phase areas: precipitation of the other phase

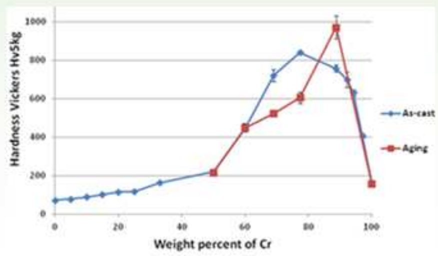








- Evolution of hardness between the as-cast state and the {1200°C – 50 h} -aged state (the highest value observed for the aged Cr-10Ni alloy is due to internal nitridation)



Discussion

- Very refractory alloys with dendritic microstructures favourable for high mechanical resistance at H.T. were obtained; they rather well resist high temperature exposures
- High hardness values can be achieved thanks to the hardening effect of the presence of Ni in Cr and of Cr in Ni

Conclusions and outlooks

- This work demonstrated the feasibility of cast Cr-based alloys by classical foundry
- Due to their dendritic microstructures and the hardening of both phases good intrinsic mechanical behaviour can be expected; the hardness evolution with their volume fractions can be modelized [8]
- The characterization of the high temperature creep and oxidation behaviours of these basis alloys are currently in progress

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