Refractory alloys based on Niobium and Chromium cast with addition of various elements for promoting MC carbides

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Introduction

Niobium alloys are among the refractory alloys of interest for applications at very high temperatures. Many of them are niobium silicides or niobium aluminides, containing significant contents of silicon and aluminium respectively. Si and Al are with Cr elements of high importance for the oxidation resistance at high temperature. However chromium is seemingly not frequently introduced in niobium alloys. In another way, niobium alloys are often strengthened by intermetallic precipitates against high temperature creep deformation, and rarely – and maybe never – by carbides.

The purpose of this communication is to present some microstructure and hardness results concerning four niobium alloys elaborated by casting and containing Cr instead Si or Al, as well as elements for promoting the formation of MC carbides: carbon and 6 wt.% Ta, 1.6 wt.% Ti, 5.8 wt.% Hf or 3 wt.%Zr.

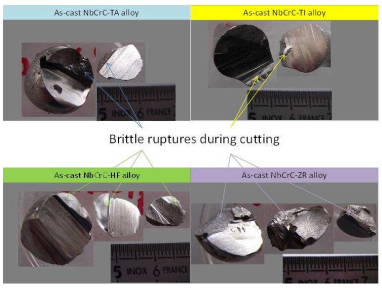
These alloys, designed to contain 33 wt.%Cr and 0.4 wt.%C, were added with one of the four MC–former metals with weight contents rated to reach the same atomic content as carbon. They were synthesized by classical foundry under inert atmosphere (pure argon). The obtained as–cast microstructures were analysed and observed using X–ray diffraction, scanning electron microscopy, energy dispersion spectrometry. Their hardness was measured by applying indentation according to the Vickers method.

Elaboration of the alloys

- Charges (40 grams) made of pure elements (> 99.9%)
- Melting using high frequency induction furnace under inert atmosphere
- Reached temperatures no far from 2000°C

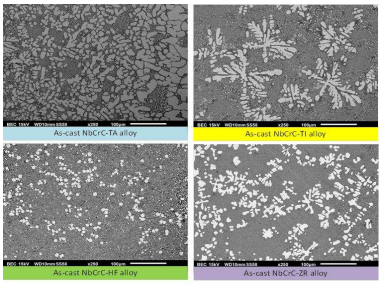
Cutting / machining

- Very hard to carry out (very slow, saw very heated)
- Brittle rupture occurring before final cutting



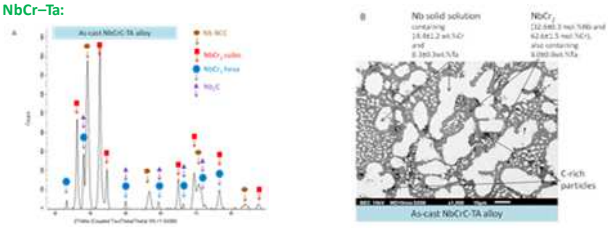
General microstructures

- Synthesis successful despite the very high refractoriness of niobium
- Totally different from the alloys with the same Cr, C and M (Ta, Ti, Hf or Zr) contents based on cobalt, nickel or iron
- Notably: no script–like MC carbides

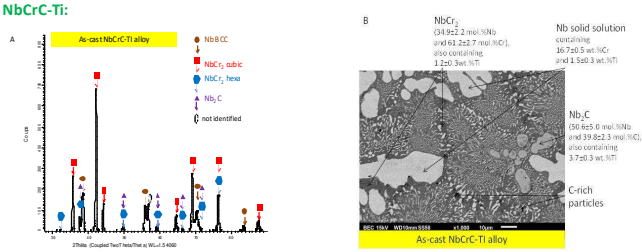


The obtained microstructures in detail

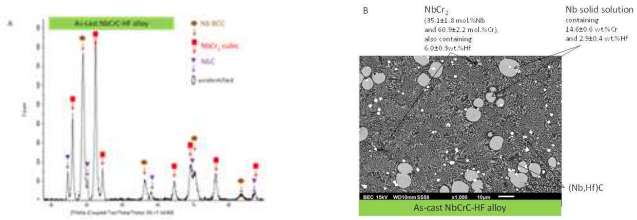
- NbCr–Ta:



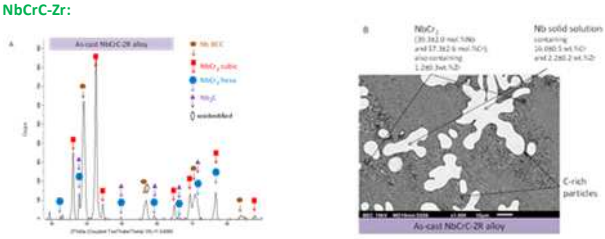
- NbCrC-Ti:



- NbCrC-Hf:

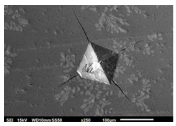


- NbCrC-Zr:



- Hardness values (and example of crack: case of NbCrC-Ti)

Alloy	Hardness (HV10kg)	AVERAGE VALUE	Standard deviation
NbCrC-Ta		1038	67
NbCrC-Ti		1005	82
NbCrC-Zr		915	28
NbCrC-Hf		886	42



Summary / Conclusion

Results show that the microstructures are, in the four alloys, made of a dendritic Nb–based solid solution and of the $NbCr_2$ Laves phase located in the interdendritic spaces. Despite the well–known high MC–forming tendency of the Ta, Ti, Hf and Zr elements (usually observed in nickel, iron or cobalt alloys), no MC carbides were observed and carbon was obviously present only as graphite flakes. All alloys are brittle at room temperature and difficult to machine. Vickers indentation led to very high values of hardness, close to 1000HV_{10kg}. The indentation runs caused cracks which propagated through the niobium phase and the Laves phase. Obviously no Nb–based alloys can be expected as microstructurally similar to the high performance MC–reinforced nickel or cobalt–based alloys. However the high temperature mechanical and oxidation behaviours of these alloys will be explored.

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