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Patrice Berthod, Assane Kane, Safa Tlili. Partial or total substitution of Cobalt by Nickel, and of Hf by Ta or Zr, in cast polycrystalline chromium-rich superalloys strengthened by HfC or TaC for high temperature applications. TechConnect WORLD INNOVATION Conference & Expo, Jun 2022, Washington DC, United States. hal-03702728

HAL Id: hal-03702728

<https://hal.science/hal-03702728>

Submitted on 23 Jun 2022

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Partial or total substitution of Cobalt by Nickel, and of Hf by Ta or Zr, in cast polycrystalline chromium-rich superalloys strengthened by HfC or TaC for high temperature applications

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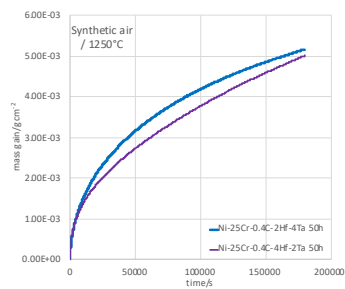
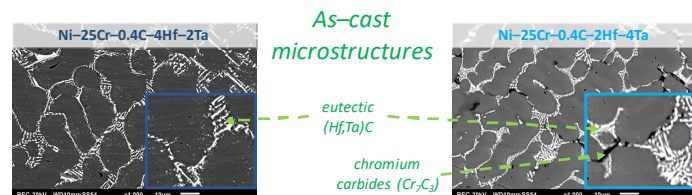
Despite their classical way of elaboration, the family of the polycrystalline superalloys conventionally cast is still of interest for high temperature service [1]. Some of these superalloys are resistant against both hot oxidation and hot corrosion thanks to their high contents in chromium [2]. Furthermore, some new versions allow uses at temperatures higher than 1100°C under moderate stresses. In contrast with γ/γ' single crystalline superalloys – which are usually chosen for the hottest turbine blades, such alloys may be shaped with complex geometries (allowed by classical foundry) and they do not require neither thermal barrier for protecting their external surfaces, nor internal cooling by air flow.

Among these recent superalloys, there are the chromia-forming HfC-strengthened cobalt-based superalloys, containing 25–33 wt.% Cr for the hot oxidation and corrosion resistance [3, 4]. Such alloys contain script-like eutectic carbides in the grain boundaries and in the interdendritic boundaries. These carbides allow long-lasting cohesion between grains and between dendrites, and they significantly delay the (secondary stage of creep → ternary stage of creep) – transition. Unfortunately, such alloys involve great quantities elements which are rather expensive or very expensive, and which may be affected of strategic problem of available quantities: cobalt (from 60 to 70 wt.% of the whole alloy) and hafnium (from 4 to 7 wt.%).

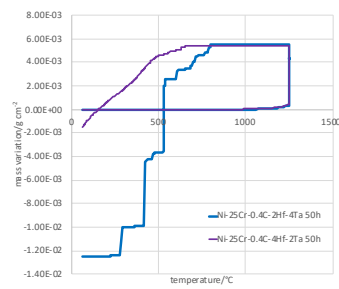
The purpose of the present paper is to share some results about several new superalloys with promising properties of chemical resistance (against oxidation) and of mechanical strength (against creep deformation):

- All resulting from the total substitution of Co by Ni as base element from reference alloys [5]
- Some of them resulting from the substitution, in resistant Ni-based superalloys reinforced by HfC [6], of a part of Hf by Ta, without loss of the high temperature stability of the MC-carbides (problem earlier met for TaC in (Ni,Cr)-based alloys [7])
- The other alloys resulting from the total replacement by Zr of the expensive and rare Hf element.

Partial substitution of Hf by Ta in Ni-based Cr-rich cast superalloys reinforced by HfC carbides [8]

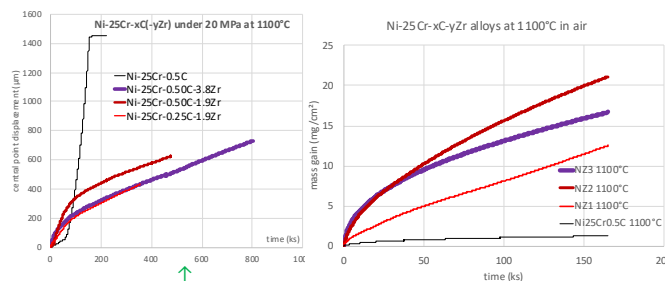
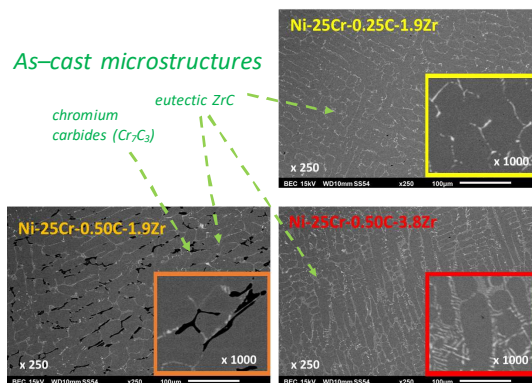


Oxidation rate kept at the same level

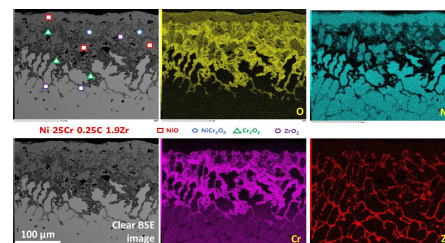


... but deleterious effect on scale adherence

Total substitutions of Co by Ni and of Hf by Zr in Co-based Cr-rich cast superalloys reinforced by HfC carbides [9]



Very creep-resistant ... but low resistance to oxidation



The cobalt-based superalloys resistant, at elevated temperature, to oxidation thanks to the presence of 25 wt.% or more of Cr, and to creep deformation thanks to HfC carbides, can be advantageously replaced by nickel-based alloys containing the same Cr quantities and MC carbides with other compositions. Interesting high temperature properties were earlier noticed for (Ni,Cr)-based alloys containing HfC [6] (resulting from the total replacement of Co by Ni). In the work presented here, one saw that replacing a part of Hf by Ta may be done by keeping, in such Ni-based alloys, a carbide network still exclusively made of MC (if Hf remains higher than Ta), and that Hf can be totally replaced by Zr, also by keeping a 100% MC carbide network (ZrC). The creep resistance can be maintained, but the oxidation behavior seems to be significantly deteriorated, in both cases, unfortunately. Thus, to allow these new alloys to be much less dependent on the critical Co and Hf elements, ways of improvement needs to be found and tests. This can be simply done by increasing the Cr content, for example, hoping that chromium will remain less critical than cobalt and hafnium.

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