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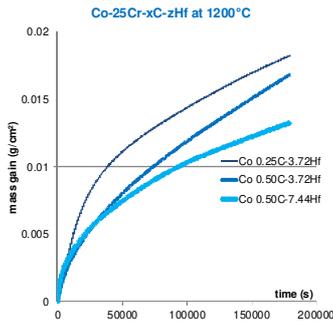
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Many cast superalloys working in hot conditions must be reinforced by interdendritic carbides. These ones must be extremely stable at high temperature when the alloys are considered for especially severe thermal applications. The volume fractions and morphologies of the most common carbides, as the chromium ones and even the TaC carbides, evolve too rapidly in such conditions [1] with consequently a loss in creep resistance. Fortunately, other interdendritic carbides – notably the HfC ones – are particularly resistant to such phenomena [2] and their script-like shape is globally maintained for longer times than for the TaC one. Hafnium, element known to significantly improve the high temperature oxidation behavior [3,4], is generally added to alloys in rather low quantities (e.g. in the 0.25 to 1.5 wt.% range) to commercial alloys. But this element is obviously rarely chosen for promoting MC carbides to resist creep. In the present work, nine 25 wt.%Cr-containing cast alloys – three Co-based, three Ni-based and three Fe-based ones – containing various amounts in carbon (0.25 and 0.50 wt.%C) and hafnium with two levels of contents (from 4-5 to 7-9 wt.%Hf), were tested in oxidation at 1200°C in air. The aim was to study how these particularly high Hf contents, necessary to develop a sufficient network of reinforcing HfC carbides, may influence the high temperature oxidation behavior of the alloys.



Co-25Cr-0.25C-3.72Hf

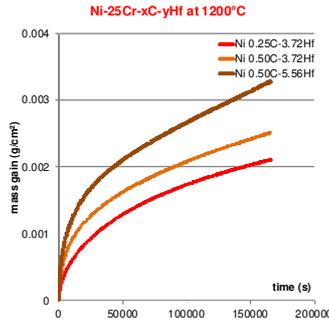
K_p values classically determined: $830 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$
 K_p and K_v values issued from the $\{m \times dm/dt = K_p - K_v \times m\}$
method [5]: $2510 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$ and $473 \times 10^{-10} \text{ g cm}^2 \text{ s}^{-1}$

Co-25Cr-0.50C-3.72Hf

K_p values classically determined: $815 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$
 K_p and K_v values issued from the $\{m \times dm/dt = K_p - K_v \times m\}$
method [5]: not applicable

Co-25Cr-0.50C-7.44Hf

K_p values classically determined: $585 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$
 K_p and K_v values issued from the $\{m \times dm/dt = K_p - K_v \times m\}$
method [5]: $1330 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$ and $530 \times 10^{-10} \text{ g cm}^2 \text{ s}^{-1}$



Ni-25Cr-0.25C-3.72Hf

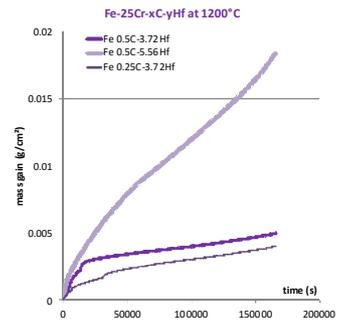
K_p values classically determined: $12 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$
 K_p and K_v values issued from the $\{m \times dm/dt = K_p - K_v \times m\}$
method [5]: $36 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$ and $126 \times 10^{-10} \text{ g cm}^2 \text{ s}^{-1}$

Ni-25Cr-0.50C-3.72Hf

K_p values classically determined: $20 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$
 K_p and K_v values issued from the $\{m \times dm/dt = K_p - K_v \times m\}$
method [5]: $42 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$ and $96 \times 10^{-10} \text{ g cm}^2 \text{ s}^{-1}$

Ni-25Cr-0.50C-5.56Hf

K_p values classically determined: $32 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$
 K_p and K_v values issued from the $\{m \times dm/dt = K_p - K_v \times m\}$
method [5]: $68 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$ and $137 \times 10^{-10} \text{ g cm}^2 \text{ s}^{-1}$



Fe-25Cr-0.25C-3.72Hf

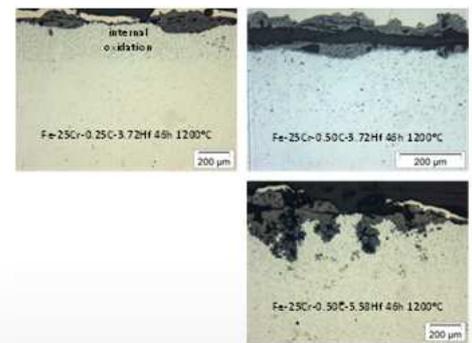
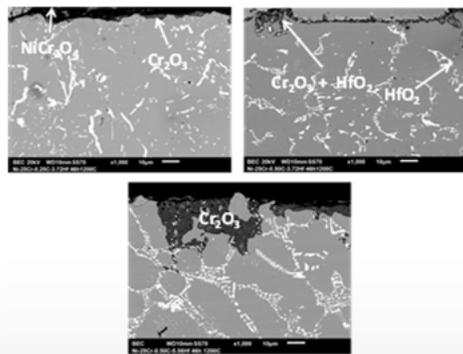
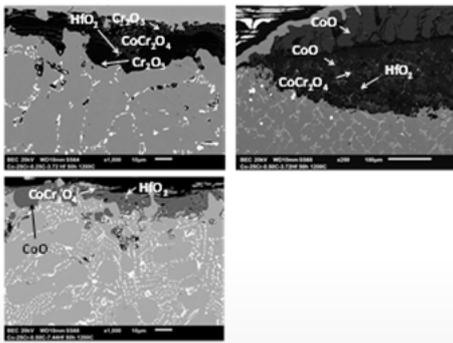
K_p values classically determined: $45 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$
 K_p and K_v values issued from the $\{m \times dm/dt = K_p - K_v \times m\}$
method [5]: not applicable

Fe-25Cr-0.50C-3.72Hf

K_p values classically determined: $605 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$
 K_p and K_v values issued from the $\{m \times dm/dt = K_p - K_v \times m\}$
method [5]: not applicable

Fe-25Cr-0.50C-5.56Hf

K_p values classically determined: $990 \times 10^{-12} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$
 K_p and K_v values issued from the $\{m \times dm/dt = K_p - K_v \times m\}$
method [5]: not applicable



Hafnium carbides can be obtained in cast Co-based, Ni-based and Fe-based Cr-rich alloys with the same morphologie and repartition as the more common tantalum carbides. They are more stable than the latter ones during high temperature exposures but so high Hf contents obviously tend to weaken the resistance of the alloys to high temperature oxidation. The very fast mass gains observed for the Co-based alloys and for one of the Fe-based alloys (which are much higher than the ones that can be shown by the corresponding HfC-free M-Cr-C ternary alloys) as well as the complex natures of the oxides formed, clearly evidence these detrimental consequences. However one can think that their behaviors may be improved by increasing the chromium contents of these alloys – to 30wt.% for example – or by applying Cr-rich protective coatings.

Only the two low-Hf Fe-based alloys and the three Ni-based alloys showed an intrinsic good behavior in oxidation at 1200°C. These ones appear to be ready for applications at this high temperature for which they can be interesting candidates: thanks first to the creep-resistance allowed by their very stable reinforcing HfC carbides, and second to their good resistance against high temperature oxidation which is obviously not decreased by the presence of so high Hf contents and/or of so dense HfC carbides.

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