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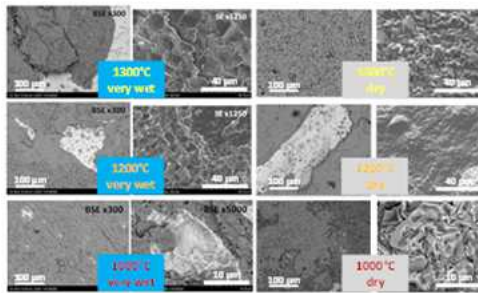
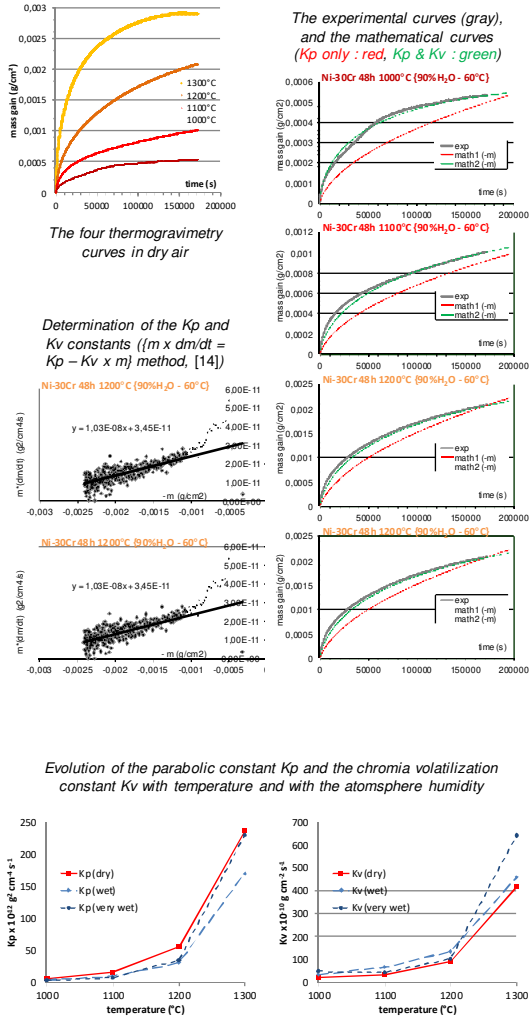
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Water vapor plays a particularly important role in the oxidation of the hottest pieces of jet engine and steam turbines for energy production. It may influence the high temperature oxidation which occurs for blades, as already observed in the cases of pure metals [1,2], intermetallic compounds [3,4], metallic coatings [5], alloys based on heavy refractory metals [6] and ceramic materials [7]. Water vapor is effectively known to modify the structural characteristics of the externally growing oxide scales (with consequences on the rates of mass gain or of mass loss [8]) and acts on the adherence of the external scale during isothermal oxidation [9] as well as when temperature varies [10,11]. The Cr-rich superalloys which resist high temperature oxidation by developing an external continuous chromia scale are especially sensitive to the presence of water vapor. Indeed their protective Cr₂O₃ scale can be affected by a re-oxidation described by the following equation: $\frac{1}{2} \text{Cr}_2\text{O}_3(s) + \text{H}_2\text{O}(g) + \frac{3}{4} \text{O}_2(g) \rightarrow \text{CrO}_2(\text{OH})_2(g)$. The oxy-hydroxides are volatile for temperatures high enough. For example, several works showed that volatilization into gaseous CrO₂(OH)₂ may start to be significant at temperatures as low as 600°C for binary [12] or commercial [13] Fe-based chromia-forming alloys. Such volatilization phenomenon induces, when the oxidation progress is followed by thermogravimetry, an underestimation of the mass gain rate and then of the oxidation kinetic.

The high temperature oxidation behaviors of a Ni-25Cr alloy and of a Co-10Ni-30Cr alloy (contents in wt.%), respectively bases of many nickel-based and cobalt-based superalloys, were studied between 1000 and 1300°C in (water vapor)-enriched air: mass gain kinetics (thermogravimetry runs) and post-mortem characterization. For the Ni-based alloy the results were compared to the ones obtained in parallel for the same alloys oxidized in dry air, allowing evidencing the effect of water vapor for several aspects of high temperature oxidation. For the Co-based alloy only the results in dry air are available, this being due to problems encountered with the apparatus before performing the thermogravimetry tests in humidified air.

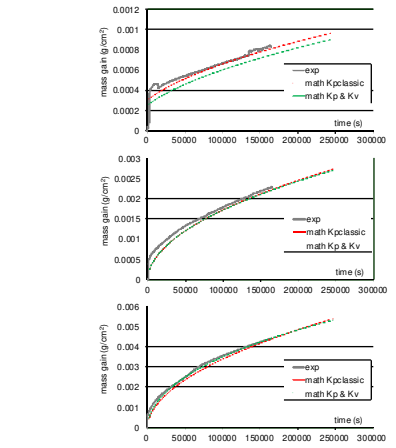
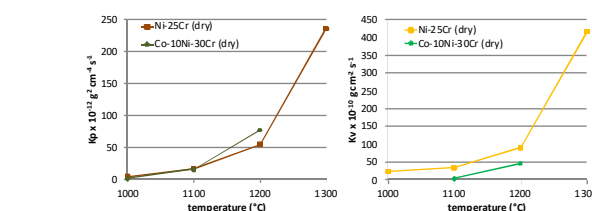
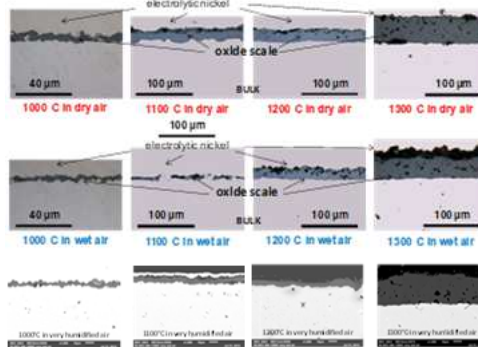
Cast Ni-25Cr alloy

Cast Co-10Ni-30Cr alloy

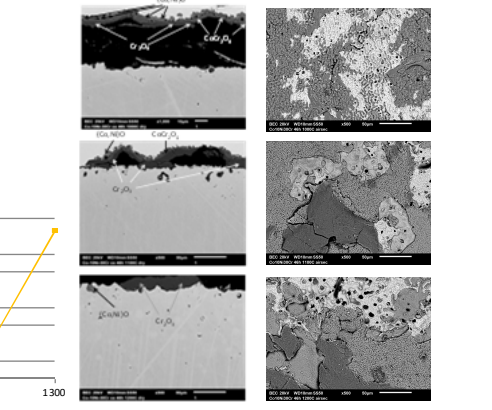


Surface observations (SEM/BSE and SE modes) of the oxidized Ni-25Cr samples for two atmospheres: very wet (90% H₂O at 60°C: 179bars, left) and dry (right)

Cross-section observations (SEM/BSE mode) of the oxidized Ni-25Cr samples for the three atmospheres: dry (top), wet (80% H₂O at 40°C: 59bars, middle) and very wet (90% H₂O at 60°C: 179bars, bottom)



Thermogravimetry curves for the Co-10Ni-30Cr alloy for only the dry atmosphere: 1000°C (top), 1100°C (middle) and 1200°C (bottom): experimental curves (gray), and the mathematical curves (Kp only: red, Kp & Kv: green)



Thus, the presence of rather high water vapor in hot air did not significantly change the high temperature oxidation behaviors of the chromia-forming nickel-based alloy. The behavior was not really deteriorated in humidified air (for the two contents tested) in term of oxidation kinetic (except an enhanced chromia volatilization at very high temperature). On the contrary a better adherence of the oxide scales on the alloy's surface was observed during the post-isothermal stage cooling, which lets think that water vapor may be favorable to a better behavior in thermal cycling.

The next step of this work will be thermogravimetry tests of the Co-based alloy in wet air, which were unfortunately not realized because of problems met with the vapor generator.

References

- [1] Jonsson, T., Pujilaskono, B., Hallström, S., Agren, J., Svensson, J.E., Johansson, L.G., Halvarsson, M., Corrosion Science, Vol. 51 (2009) pp. 1914-1924.
- [2] Pérez, P., Corrosion Science, Vol. 49 (2007) pp. 1172-1185.
- [3] Chevalier, S., Juzon, P., Przybylski, K., Larpin, J.P., Science and Technology of Advanced Materials, Vol. 10 (2009), art. n°045006.
- [4] Lin, Z.J., Li, M.S., Wang, J.Y., Zhou, Y.C., Scripta Materialia, Vol. 58 (2008) pp. 29-32.
- [5] Kaplin, C., Brochu, M., Surface and Coatings Technology, Vol. 205 (2011) pp. 4221-4227.
- [6] Hellström, K., Tang, J.E., Jonsson, T., Halvarsson, M., Pompe, R., Sundberg, M., Svensson, J.E., Journal of the European Ceramic Society, Vol. 29 (2009) pp. 2105-2118.
- [7] Yamauchi, A., Yi, X.M., Akiyama, T., Kurokawa, K., Materials Science Forum, Vol. 696 (2011) pp. 395-399.
- [8] Saunders, S.R.J., Monteiro, M., Rizzo, F., Progress in Materials Science, Vol. 53 (2008) pp. 775-837.
- [9] Othman, N.K., Othman, N., Zhang, J., Young, D.J., Corrosion Science, Vol. 51 (2009) pp. 3039-3049.
- [10] Zurek, J., Young, D.J., Essuman, E., Hänsel, M., Penkalla, H.J., Niewolak, L., Quadackers, W.J., Materials Science and Engineering, A 477 (2008) pp. 259-278.
- [11] Michalik, M., Hänsel, M., Zurek, J., Singheiser, L., Quadackers, W.J., Materials at High Temperature, Vol. 22 (2005) pp. 213-221.
- [12] Jonsson, T., Pujilaskono, B., Heidari, H., Liu, F., Svensson, J.-E., Halvarsson, M., Johansson, L.-G., Corrosion Science, Vol. 75 (2013) pp. 326-336.
- [13] Halvarsson, M., Tang, J.E., Asterman, H., Svensson, J.-E., Johansson, L.-G., Corrosion Science, Vol. 48 (2006) pp. 2014-2035.
- [14] Berthod, P., Oxidation of Metals, Vol. 64, No. 3/4 (2005) pp. 235-252.