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Molten $(\text{Na}, \text{K})_2\text{SO}_4\text{-NaCl}$ salt corrosion of Ni_3Al alloy

Caoliu Zen, Jianqing Zhang and Weitao Wu

Corrosion Science Laboratory, ICPM, 110015 Shenyang, China

Two Ni_3Al alloys namely Ni_3AlB (Ni-18 3Al-0.2B (in at.%)) and $\text{Ni}_3\text{AlBCrZr}$ (Ni-18.0Al-0.2 B-6.0Cr-0.5Zr (in at.%)) were tested. Specimens of $15 \times 5 \times 3$ mm were cut from the extruded bars. A commercial nickel base superalloy IN 738 was used as a reference material. The corrosion tests were conducted at 750, 800 and 850 °C in (0.9 Na, 0.1 K) $_2\text{SO}_4\text{-25 NaCl}$ (in mole %) melt in air. The measurements include free corrosion potential (E_{corr}) and linear polarization resistance (R_p). The test results show that during a test at 800 °C the E_{corr} of IN 738 shifted gradually to a more noble direction and then stayed around -200 mV. With the same tendency, after 30 h its R_p reached about 100 ohm cm^2 and become stable. The results proved that a protective oxide scale formed gradually on IN 738. In contrast, the corrosion behavior of $\text{Ni}_3\text{Al-0.2 B}$ was somewhat different. During test at 800 °C, its E_{corr} dropped rapidly to -970 mV soon after immersion and R_p was only about 5.6 ohm cm^2 , e.g. one order of magnitude lower than that of IN 738. Obviously, the corrosion rate of $\text{Ni}_3\text{Al-0.2 B}$ was much higher, which can also be proved by the corrosion morphology that IN 738 was kept intact with a thin oxide scale on the surface after 100 h, whilst the whole specimen of $\text{Ni}_3\text{Al-0.2 B}$ was entirely corroded after only 6 h immersion.

Fig. 1. — Time dependence of E_{corr} and R_p of the alloys tested.

When one compared the corrosion tests of $\text{Ni}_3\text{Al-0.2 B}$ at 750, 800 and 850 °C, it follows that its E_{corr} shifted more negatively and R_p dropped to a lower value with increasing temperature. This means that its corrosion rate increased with increasing temperature. However,

the addition of Cr + Zr to Ni₃Al-0.2 B made its E_{corr} at 800 °C shift to a greater extend, e.g. to -1150 mV and R_p dropped to only about 3 ohm cm², which implies that the addition of Cr and Zr accelerated the corrosion. The corrosion product of Ni₃Al-0.2 B consisted of Ni, Ni₃S₂, NiO and small amount NaAlO₂ and Al₂O₃ in such a form that a large fraction of Ni islands were surrounded by Ni₃S₂, NiO, NaAlO₂. The whole product was porous. The alloy with Cr + Zr showed the same features, together with some Cr₂O₃.

Ni₃Al has good oxidation resistance because of the formation of a protective scale. But from the above results, its corrosion resistance to molten salt is very poor. In molten salt systems, the boundary between specimen and salt can be considered as an environment with low oxygen partial pressure. It is thought that under these conditions, Al₂O₃ scale would easily form. However there is no continuous Al₂O₃ scale observed on the corroded sample. It could be expected from the kinetic point of view that since the diffusion rate of sulfur and sulfidation of nickel are faster than the growth rate of Al₂O₃, the sulfide and oxide of nickel would overgrow the discontinuous Al₂O₃ particles formed earlier, suppressing the formation of a continuous scale.

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