Behaviour of NiAlMo APS-coatings in chlorine-based environments

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Introduction

Corrosion by chlorine at high temperature is a serious problem encountered in energy conversions, chemical and metallurgical industries, e.g., coal-fired boilers, waste incinerators and plastic/polymer decomposition mills. This chlorine corrosion process is well-known as “active oxidation” (Fig. 1). It leads to a catastrophic attack and needs to be limited. Corrosion resistance of materials at high temperatures in oxidizing atmospheres is usually obtained by the formation of a protective surface oxide scale. Under chloridizing conditions the situation is much more complex. The protective scale formation may be considerably affected by the presence of chlorine.

Experimental procedure

NiAlMo APS-coatings were applied on cylindrical Armco iron specimens. The behaviour of the coatings was studied under chloridizing atmosphere with low oxygen level at 800°C for 300 h.

Coatings characterization

A new type of diagrams (Fig. 2) where the rate of thickness loss of different elements was introduced as a criterion to distinguish between protective and corrosive range, has been developed [2]. These diagrams take into account the mass transfer kinetics and thermodynamic considerations. The line for each element separates the protective zone (below) and the non-protective zone above. Molybdenum seems to have a positive behaviour in “reducing”-chloridizing atmosphere, whereas aluminium has a positive behaviour in “oxidizing”-chloridizing atmosphere. For this reason, NiAlMo APS-coatings were developed and tested in chlorine-based atmospheres with low oxygen level. The exposed samples were then analyzed by optical microscopy and EPMA.

Heat Treatment

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Fig. 1 Corrosive attack of materials in chlorine environment “active oxidation process” [1].

Experimental point

Cl₂ corrosion test

Fig. 2: “Quasi-Stability” diagram of Al, Fe, Cr, Ni, Mo and Si as a function of Cl₂ and O₂ contents at 800°C [2].

Cl₂ corrosion test

Fig. 3: Cross section image of a NiAlMo APS-coating, 800°C, 300 h, Ar-1% Cl₂

Cl₂ corrosion test

Fig. 4: SEM image of a NiAlMo APS-coating surface.

Cl₂ corrosion test

Fig. 5: SEM contrast phase image of a NiAlMo APS-coating surface.

Cl₂ corrosion test

Substrate : Armco iron

Fig. 6: Cross section image of a NiAlMo APS-coating under Ar at 800°C, 100h.

No interdiffusion zone detected

Fig. 7: Cross section image of NiAlMo APS-coating, 800°C, 300 h, Ar-1% Cl₂-3 ppm O₂.

Fig. 8: Elemental mapping of NiAlMo APS-coating, 800°C, 300 h, Ar-1% Cl₂-3 ppm O₂.

Cl₂ corrosion test

Fig. 9: Cross section image of NiAlMo APS-coating, 800°C, 300 h, Ar-1% Cl₂-3 ppm O₂.

Optical microscopy

Fig. 10: Optical microscopy of NiAlMo APS-coating, 800°C, 300 h, Ar-1% Cl₂-3 ppm O₂.

Conclusion

The formation of an α-Mo phase in NiAlMo APS-coatings leads to a high resistance against chlorine attack. The aluminium rich Al₂(Mo,Ni) phase provides however internal oxidation and causes cracks. It should be interesting to produce the same coating but in by the HVOF process to avoid the extremely high amount of alumina.

References