

# Corrosion-resistant Coatings for Refractory Lining Anchors in Aggressive High Temperature Environments

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 Funded by: BMWI via AiF  
 Period: 01.06.2009 – 31.06.2011



## Background



Fig. 1: Metallic anchors for refractory linings

A large number of technical incineration processes use refractory linings to protect their furnace chambers at high temperatures. Metallic anchors (fig. 1 and 2) are used to attach these linings to the metallic furnace walls.

Technical problems arise due to the permeability of the refractory materials to gases as well as liquid condensates. These deposits can cause severe corrosion damage when coming in contact with the metallic anchors.

Especially critical are high chlorine containing compounds, halogens, alkalis and heavy metal compounds. Damage caused by anchor failure is extremely cost-intensive.

The presented project aims at developing corrosion-resistant coatings (diffusion coatings, nickel-plating and combined procedures) for anchors, thereby providing an effective, yet still competitive solution to the problem.

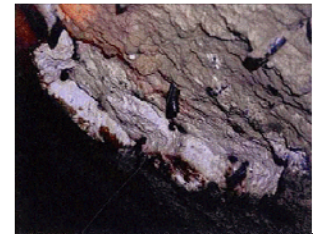


Fig. 2: Bursting of the refractory lining and corroded anchors [Osthövener, Kollenberg, 2007]

## Materials and Methods

1) Development of coatings for **typical materials** used in waste incineration and cement plants – one ferritic (1.4016/X6Cr17), two austenitic (1.4845/X8CrNi25-21, 1.4862/X8NiCrSi38-18) and one nickel base material (2.4633/NiCr25FeAlY). Several **coating techniques** are employed. **Nickel plating**, **pack cementation** (a CVD-diffusion-process) and a **combination** of these processes.

2) Coated and uncoated samples are tested for their **corrosion-resistance in process-environments**. Two types of test-environments were chosen to simulate realistic corrosion conditions:

**A) Hot gas corrosion environment (fig. 3):**

T = 800°C; gas phase: N<sub>2</sub> + 9%O<sub>2</sub> + 2,5g/m<sup>3</sup> HCl + 1,3g/m<sup>3</sup> SO<sub>2</sub>

**B) Molten salt environment (hot corrosion):**

T = 600°C; covering: 14NaCl – 13KCl – 27K<sub>2</sub>SO<sub>4</sub> – 16ZnSO<sub>4</sub> x 7H<sub>2</sub>O – 30Na<sub>2</sub>SO<sub>4</sub>; oxidising environment: air

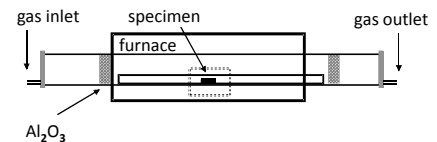


Fig. 3: Furnace for hot gas corrosion tests

## Results and Discussion

### Coatings:

- 24h nickel plating led to a coating thickness of about 50µm.
- Nickel plating followed by pack cementation showed good results for the ferritic material.
- Pack cementation led to promising results for austenitic and nickel base alloys. The diffusion temperature and the aluminum content determine the resulting coating thicknesses, phases (fig. 4) and sometimes appearing cracks and pores. Best results were achieved with 5-7.5%Al at 1000°C, when no cracks and pores occur.

### Corrosion tests of the uncoated specimen:

- Uncoated ferritic material 1.4016 shows severe corrosion after exposure in hot gas corrosion environment A. A mixed oxide layer is formed, but there is no good adhesion and it spalls off continuously. Beneath the oxide layer sulphur and chlorine can be found.
- Uncoated austenitic materials 1.4845 (fig. 5) and 1.4862 show similar behavior. The loss of 250 µm material is about half of the loss of the ferritic material. The nickel base alloy 2.4633 shows good behavior after exposure. A continuous, thin and adhesive oxide layer is formed.
- In contrast, in molten salt environment B all uncoated materials show severe corrosion (fig. 6). In each case a several hundred micrometer thick layer of oxide and salt melt deposits forms. Beneath the base material is corroded along the grain boundaries accompanied by pore formation. More than 1mm of each base material gets lost after 1000h.

### Corrosion tests of the coated specimen:

- Just nickel plating and subsequent hot gas corrosion testing led to the formation of pores beneath the nickel plating already after 100h exposure. Furthermore the nickel plating is attacked and no long-term protection can be expected. Thus no further examination has been done with this type of coating.
- The nickel plated and pack cementated ferritic material 1.4016 shows good protection in the hot gas corrosion environment (fig. 7). The whole coating thickness is preserved. On top and in the former boundary between the coating and the substrate Al<sub>2</sub>O<sub>3</sub> can be found. Chlorine and sulphur can be detected only at the surface of the coating. In the molten salt environment the coating successfully delays the attack of the base material for more than 700h.
- The corrosion resistance against hot gas corrosion of the pack cementated austenites and nickel base alloy depends strongly on the aluminum content of the powder pack mixture. As an example the results of the material 1.4845 are presented (fig. 8). With 5%Al an oxide layer is formed. Beneath there is a 10-20µm zone with pores. The remaining diffusion coating is not attacked, but cracks from the surface through the coating occur. The pores and cracks heal by Al<sub>2</sub>O<sub>3</sub> and no chlorine or sulphur can be found. With 7.5%Al no cracks and pores can be found. All samples with 10%Al show severe damage caused by pores. These zones arise only in the outer region of the diffusion zones, where the aluminum-rich ((Fe,Cr,Ni)Al<sub>3</sub>)-phases had been. The phase with less aluminum ((Fe,Cr,Ni)Al) is not attacked. In the molten salt environment the pack cementated specimen shows a similar corrosive attack as the uncoated ones. But the depth of the corrosive damage in all tested coatings (5 and 7.5%Al) is much less (<250µm). No attack of the base material occurs.

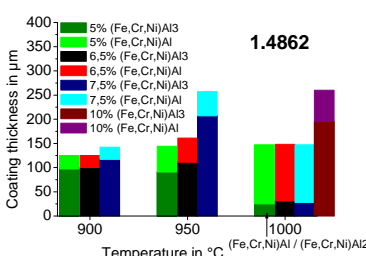


Fig. 4: Coating thicknesses of the phases after pack cementation for the different aluminum contents of the powder and for the different temperatures (material 1.4862)

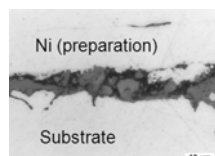


Fig. 5: No good adhesion of the oxide layer and fine spallation of the uncoated material 1.4845 after exposure in hot gas atmosphere for 1000h; about 250µm are damaged

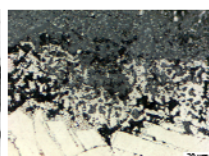


Fig. 6: Oxide layer and corrosion along grain boundaries of the uncoated material 2.4633 after exposure in molten salt environment for 1000h; several hundred micrometers are damaged

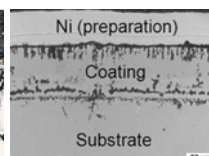


Fig. 7: Good corrosion resistance of the nickel plated and pack cementated material 1.4016 after exposure in hot gas atmosphere for 1000h; on top and inside the coating Al<sub>2</sub>O<sub>3</sub> can be found

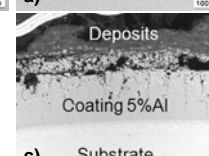
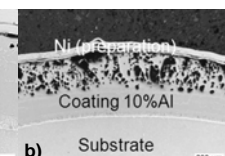
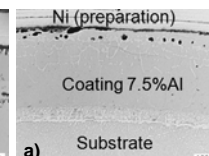


Fig. 8: Corrosion resistance of the nickel plated and pack cementated material 1.4845 after exposure in hot gas atmosphere (a+b) and molten salt environment (c) for 1000h

## Acknowledgement

This work was funded by the German Ministry of Economics and Technology through the German Federation for Industrial Research ("Arbeitskreis industrieller Forschungsvereinigungen", IGF-Nr. 16078 N), which is gratefully acknowledged.