Process and materials oriented development of advanced high temperature corrosion- and abrasion-resistant arc sprayed coatings

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Introduction

Due to its high application rates, arc spraying has been employed for many decades in applying large scale metallic corrosion- and abrasion-resistant coatings. In comparison to other spraying processes, arc spraying offers particular advantages such as high coating capacity in conjunction with low process and capital outlays. This economic potential has led to growing interest in small and medium sized enterprises to substitute current coating techniques such as overlay welding, atmospheric plasma coating (APS) and high velocity oxy-fuel (HVOF) coatings with arc sprayed coatings. Due to the large surface areas that can be applied using arc spraying, power stations and waste incineration are particularly interesting fields for coating application.

The predominating temperatures of over 300°C and the reactive HCl and KCl containing atmospheres in waste incinerators (see Figure 1) lead to increased corrosion rates due to the formation of molten phases and/or "chlorine induced corrosion" of the construction materials.

Emphasis on materials research in previous years has been the development of wear- and high temperature corrosion-resistant coatings. Corrosion protection in power stations and waste incineration plants requires particularly high demands on the homogeneity of the coating and alloy design. The development of new alloy compositions for coating materials with increased corrosion resistance based on iron, chromium and silicon offers enormous potential for the improvement of coating technology. The development of cored wires for arc spraying is based on investigations from overlay welding and plasma spraying techniques, however, characteristics of the process and coating development need to be considered.

Due to the economic advantages of shortened downtimes as well as extended maintenance intervals, arc spraying has the potential to establish itself well as a coating application in the waste incineration industry.

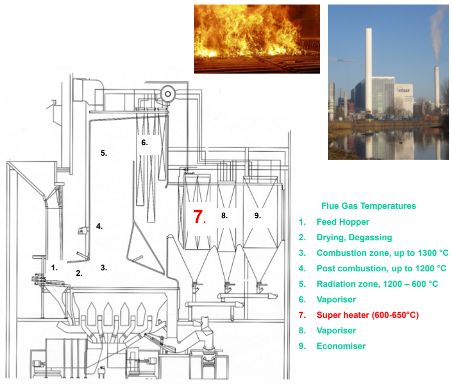


Fig 1: Typical design of a waste incineration facility.

Approach

The aim of the present investigation is to develop the arc spraying process into a form that is suitable for the application of corrosion resistant coatings to waste incineration equipment . With the aid of the computational thermodynamics software program Thermo-Calc, equilibrium phase assemblages in the coatings have been determined, as seen in Figure 2 for the Fe-Cr-Si system.

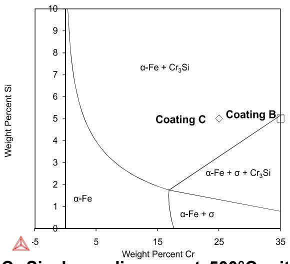


Fig 2: Fe-Cr-Si phase diagram at 500°C with selected arc sprayed coating compositions.

These diagrams assist in the optimisation of coating properties and allow for a better understanding of the investigated coating systems. Newly developed spray coating compositions are shown in Table 1:

Alloying Element (wt. %)	Fe	Cr	Si	B
Coating A	**Rest**	**30**	**5**	**1**
Coating B	Rest	35	5	-
Coating C	**Rest**	**25**	**5**	**-**
Coating D	Rest	25	5	5
Further Coatings	Rest	25-35	3-10	1-5

Table 1: Fe-Cr-Si-(B) arc sprayed coating compositions.

Arc spraying, which has been industrially established for decades, is a process whereby an arc is generated between two wires (either the same or different) and their ends melt. An atomiser gas, e.g. air, accelerates and sprays the molten liquid and after impacting the component surface solidifies and builds up the coating (see Figure 3).

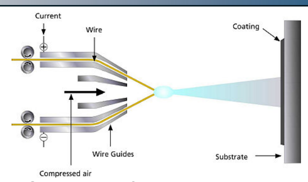


Figure 3: Schematic of arc-spraying process.

Before exposure, coated samples were characterised using scanning electron microscopy. This aided in identifying phases and defects present in the microstructure (see Figure 4).

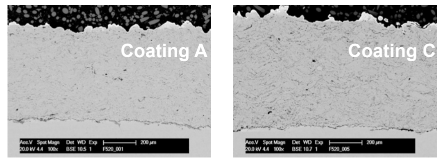


Figure 4: SEM images of as-sprayed coatings.

Arc sprayed coating performance – short term exposures

Samples were exposed to the following gas atmosphere (*94,9 vol-% N_2, 5 vol-% O_2, 0,1 vol-% Cl_2*) at 500°C for a time of 100 h in a horizontal resistance wound furnace (see Figure 5). Corroded samples were embedded and examined metallographically. To examine the extent of attack and elucidate possible degradation mechanisms, samples were investigated using the EPMA. Element maps were generated and examples are shown in Figures 6 & 7.

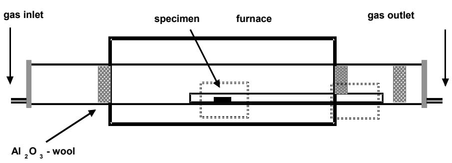
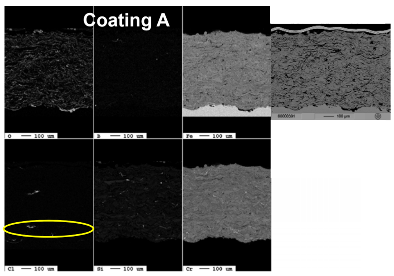
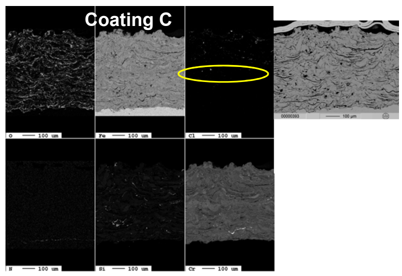


Figure 5: Furnace set-up for corrosion experiments.



- Chlorine attack at coating/substrate interface
- Substrate partially oxidised

Figure 6: EPMA element maps for Coating A after 100 hour exposure at 500°C.



- **No** chlorine attack at coating/substrate interface
- Substrate partially oxidised

Figure 7: EPMA element maps for Coating C after 100 hour exposure at 500°C.

References & Acknowledgements

- R. Bender, M. Schütze, *Mat. Corr.*, **54**(9), 652 - 686 (2003)
- H Schroer, C.; Spiegel, M.; Grabke, H.J.; Schriften des FZ Jülich: Reihe Energietechnik Band 5,2 789 - 798 (1998)
- Schülein, R.; Eiteneuer, F.; Dampferzeugerkorrosion; Verlag Saxonia Standortentwicklung; 321-347 (2005)
- Weber, T.; Bender, R.; Schütze, M.; Hochtemperaturkorrosion in chlorhaltiger Verbrennungsatmosphäre - Schutzkonzepte für metallische Werkstoffe, Optimierung der Abfallverbrennung 1, K.J. Thomé-Kozmiensky (Ed.), TK-Verlag, Neuruppin, 581-598 (2004)
- Lee, Y.Y., McNallan, M.J., Met. Trans Y., **18A**, 1099-1107 (1987)

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Outlook

To deal with porosity in arc sprayed coatings, two methods are proposed: (i) a pre-oxidation procedure to close the pores in the coating, and/or (ii) the use of a sealant to close external surface pores in the coating.

The best candidates will be exposed to a second, more aggressive atmosphere (*76,75 vol-% N_2, 8 vol-% O_2, 0,25 vol-% HCl*) at 500°C for times up to 1000 h and will be embedded in an artificial ash mixture that simulates real process deposits.