Development of thermal sprayed layers for high temperature areas in waste incineration plants

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Corrosion and wear in the hot gas area of thermal energy plants are severe problems, which often cause premature damage of components. In general, the most components of plants are made of materials, which are not stable under corrosive conditions. For corrosion protection (and also wear protection) and lifetime extension of these components, coatings with more resistant materials are applied. Because of the high concentration of corrosive species and the alternating composition of the atmosphere near to the components, the waste incineration plant is the “worst case” of high temperature corrosion. Nowadays, the most usual coating process to protect pipes in the waste incineration plants is cladding. In the last years alternative processes are under investigation because cladding is very cost-intensive. The specific costs of thermal spraying are much lower than the specific costs of cladding. In addition, the coating by thermal spraying reduces the risk of the dilution of substrate and coating material. Thermal spraying has the potential to create cost-efficient coatings to protect components in the critical zones of incineration plants.
Since many years, ATZ Entwicklungszentrum is involved in the development and/or advancement of materials, technologies and applications of thermal spraying for corrosion and/or wear protection in thermal energy plants. The main focuses of the investigations are layers for components in high temperature areas of waste incineration plants. On the basis of the present results different coatings (metal alloys, ceramics) and different spray technologies (e.g. HVOF, APS) have been tested by different strategies (corrosion tests under laboratory scale, air cooled material probes inside the hot gas area of an incineration plant and coated pipes in operation as part of the superheater of incineration plants). This paper will give an overview about the current results of these corrosion tests, in which the focus are the investigations with material probes. First results showed that with the combination of different thermal sprayed layers a significant corrosion protection can be achieved.

Keyword: thermal spraying, ceramic layer, self adoption, self-healing layer

1. Introduction

Waste incineration is a favourable combination of save waste disposal and energetic utilisation. The antagonism between receipt for solved energy and cost for investment and maintenance often determines the level of the energetic utilisation. So, about 90% of the waste incineration plants in Germany are characterized by the energetic utilisation via steam power process with live steam parameters of 4 MPa and 400°C. Rather low exergetic efficiency is the result of this antagonism under the actual condition. Based on the increasing costs for energy, the increasing of the exergetic efficiency is desirable also under economic aspects. The experiences with plants, which use from historical reasons higher steam parameters, have shown, that higher steam parameters demand special corrosion protective layers to reach acceptable live times of the heat exchanger materials. Nowadays, the most usual coating process to protect pipes in the waste incineration plants is cladding. Cladding has two essential disadvantages. The process is cost-intensive because of the high material consumption of materials with rapidly increasing prices during the last years and because of the time intensive process of the cladding. Beside this it is known, that cladded pipes often fail in high temperature areas in waste incineration plants. That’s why alternative processes are under investigation in the last years. Thermal spraying has the potential to create cost-efficient coatings to protect components in the critical zones of incineration plants.

2. Thermal sprayed layers under laboratory conditions

Thermal spraying represents a group of processes, which employs heat and velocity to coat the surface of one material with another, using powder or wire feedstock. These processes are characterized by near zero dilution of the substrate as a result of mechanical bonding, the ability to apply thin coatings, and a high rate of area coverage compared to arc welding processes. The low deposit temperatures (as compared to welding) mean no distortion or metallurgical degradation of the substrate. Thermal spray processes are all positional and can be operated in air, thus offering great flexibility for a wide range of applications.

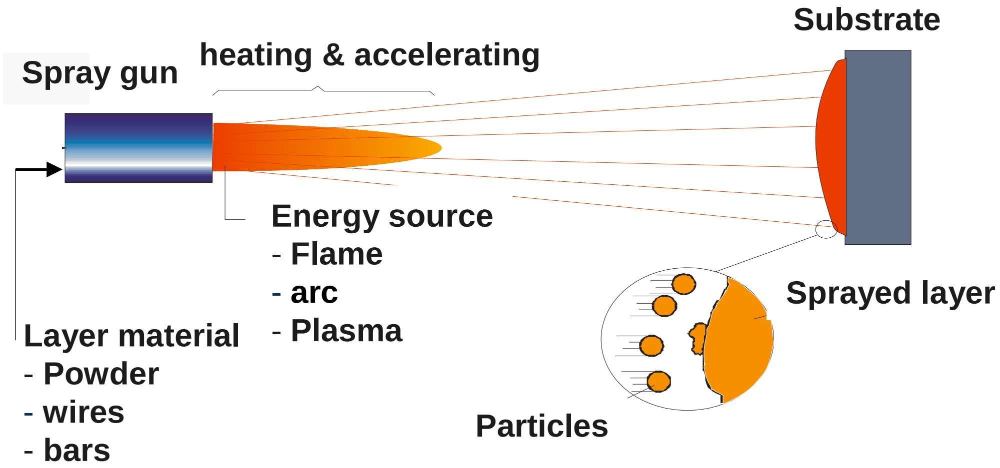


Figure 1 Thermal Spraying - Principle

In a first step to develop thermal sprayed layers for high temperature areas in waste incineration plants, peaces of pipe material coated by thermal spraying were exposed to model corrosive conditions. The coated pieces were laid with the coated side in synthetic salt (20%NaCl - 26%KCl - 24%Na2SO4 - 30% K2SO4) and a corrosive gas atmosphere (72,7%N2 - 17,7% O2 - 10% H2O - 0,08%HCl - 0,02% SO2) was adjusted to simulate the condition in a waste incineration plant.

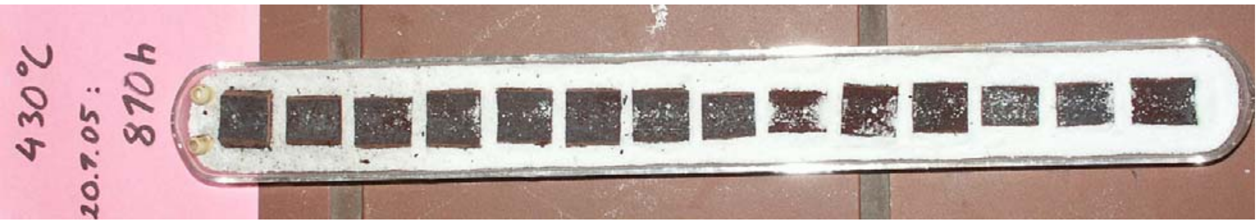
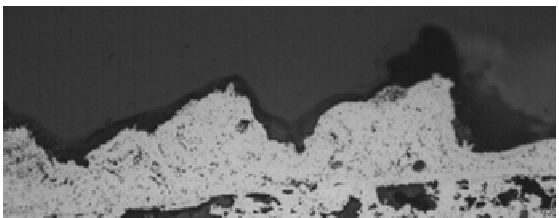


Figure 2 probes in synthetic salt

Uncoated pieces were included in this test to compare the condition with them in waste incineration plants. The expected symptoms of corrosion were to be seen at the uncoated pieces after the exposure time. The porous layer shaped structure of the corrosion products (as to be seen in figure 3a) is well known as characteristic for the corrosion in waste incineration plants.



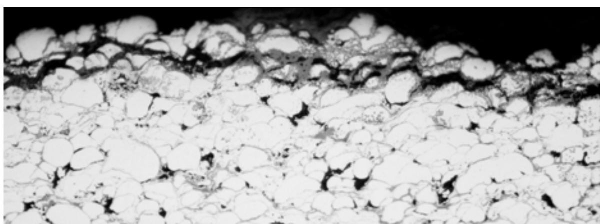


Figure 3a Layer shaped corrosion, partially flaking of corrosion products (substrate 15Mo3, exposure temperature 430°C, exposure time 470h)

Figure 3b Locale Corrosion along the particle borders (layer material Alloy690, 430°C/1115h)

A certain number of layers could not withstand the corrosive conditions without corrosion traces. Reasons for this are based on the material composition and on the parameters for the thermal spraying. Corrosion trough the particle is an evidence for an insufficient corrosion resistance of the layer material. The corrosion along the particle borders with layer shaped flaking of particles was observable in many cases (figure 3b). It can be assumed that a better corrosion resistance of the layer can be achieved by changing of the thermal spray parameter. No traces of corrosion could be observed by an acceptable number of layer systems.

3. Results with material probes in incineration plants

Layer systems, which demonstrated an acceptable corrosion resistance under laboratory conditions, were investigated under the conditions of waste incineration plants. Material probes were used for these investigations to start and stop the exposure of the layers to the corrosive conditions independently from the start and stop times of the incineration plant and to increase the useable parameter field of the corrosive conditions. The coated pipe on the outside of the material probe was air-cooled. The cooling air flowed through a centred smaller pipe to the top of the material probe. So a certain wall temperature (T0) was controllable.

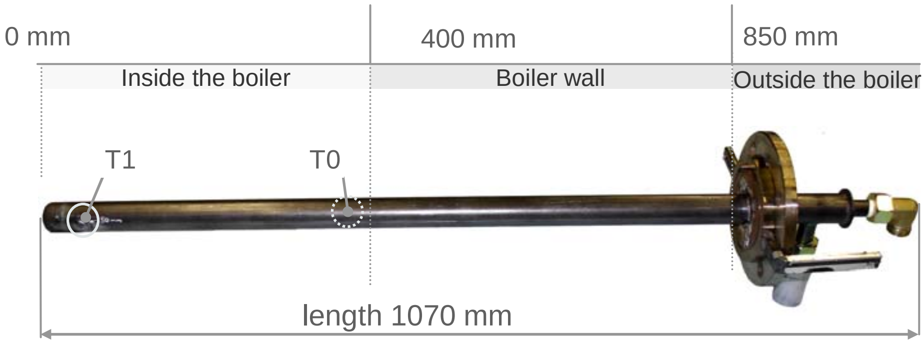


Figure 4 material probe

The material probes were placed in the second flue of the incineration plant. The off gas temperature was in the range of 680 – 740°C during the investigations. The wall temperature was tuned between 330°C and 600°C. A certain number of layer systems, which were positive tested under laboratory conditions, failed during the tests on the material probe. The reasons were again the corrosion resistance of the layer material (figure 5a and 5b) or problems, which seem to be fixable by changing the parameter of the thermal spraying. The porosity of the layers is one of these parameters, which can be influenced by the thermal spraying process. A high porosity of the layers leads to a penetration of the layers with corrosive species and results in a corrosion of the substrate (figure 5a). The results of a dense layer are thermal tensions, which result in a flaking of the layer system (figure 5c). In many experiments there was no porosity found, which prevent substrate corrosion and the flaking of.

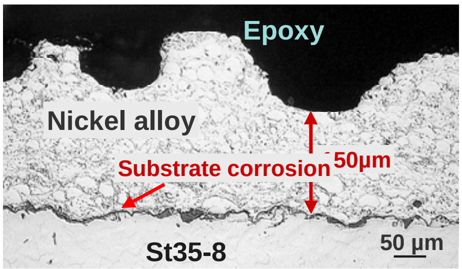


Figure 5a corrosion of the Nickel alloy (670h, 350°C)

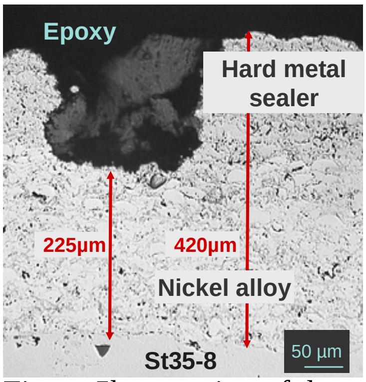


Figure 5b corrosion of the sealer (700h, 430°C)

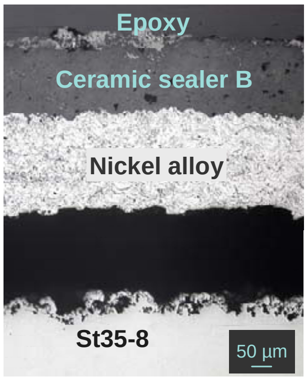


Figure 5c Flaking of the layer system (500h, 430°C)

The idea for a successful layer system is the self adoption. Two layers should be combined so that they create a thin dense film on the border between them. This thin film can be created by diffusion and by solvothermal processes. Cracks in this film reasoned by local fast heating (sticking on of burning particles) or cooling (cleaning process) should be self healed by restarting of the film forming process.

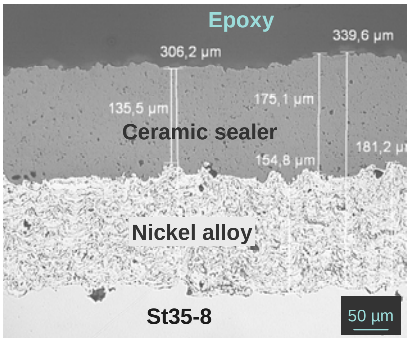


Figure 6a layer system as sprayed

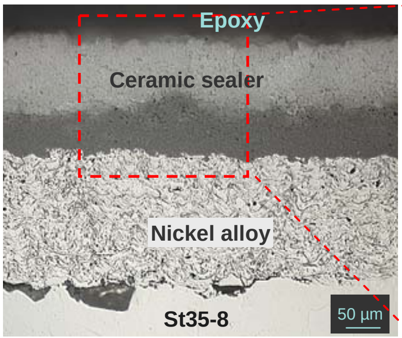


Figure 6a Layer system after use (500h, 540°C)

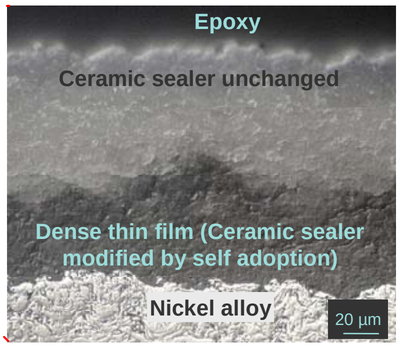


Figure 6a Detail view formation of a dense thin film between ceramic and nickel alloy

4. Summary and Conclusions

On the market available layer systems for corrosion and erosion protection often fail in the high temperature areas in waste incineration plants. A layer system was found, which withstood in the accomplished investigations the corrosive conditions. The positive tested layer system is able to form a quasi dense thin film between the two combined layers. Now are certain coated pipes are in use in several waste incineration plants. In a next step the film forming process has to be investigated. In future new self adopting layer systems for other temperature ranges have to be developed.

5. Acknowledgments

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