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The corrosion resistance of HVOF sprayed coatings with intermetallic phases in aggressive environments

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Properties

ABSTRACT

Purpose: The cyclic corrosion behavior of coatings with intermetallic matrix (FeAl, NiAl and FeAl-TiAl) was investigated in aggressive gases.
Design/methodology/approach: The composite coatings strengthened by a fine dispersive Al_2O_3 and other ceramic phases were thermally sprayed by HVOF method in Jet Kote 2 system. A kinetics test was carried out by periodic method for exposure times of up to 500 hours. Mass changes of the studied coatings during the corrosion test are presented. The surfaces of the composite coatings after the corrosion test in aggressive environments were analyzed by scanning microscopy observation.
Findings: All the results confirm good heat proofness of HVOF sprayed coatings with an AlFe and AlNi intermetallics.
Practical implications: Owing to the properties of intermetallic phases and HVOF sprayed coatings, they are anticipated to be applied for the protection of super heater tubes in conventional boilers or in boilers burning multicomponent waste, and combusted biomass including chlorides.
Originality/value: The results show that the coatings with AlFe and AlNi intermetallic phases have very good corrosion resistance and they are the best coatings from all the coatings investigated in aggressive environments.
Keywords: Intermetallic phases; Ceramic phases; Composite powders; HVOF coatings; Corrosion resistance

1. Introduction

Intermetallic phases show advantageous strength properties at high temperatures [1-10]. They show resistance to the action of many aggressive environments at an elevated temperature and at ambient temperature. As regards Fe-Al, relatively low costs of components have made intermetallic phase based alloys become a prospective constructional material [9]. Intermetallic phase based alloys with an aluminium fraction belong to the new generation of heat-resisting metal materials characterized by unique physicochemical and mechanical properties.

Over the past years, a lot of research has been conducted, aimed at better learning of the properties and strength of intermetallic phases at high temperatures, inter alia of aluminides of such elements as: nickel, iron, titanium, niobium or cobalt [1-10]. Aluminides of intermetals have a high aluminium concentration, which allows the formation of a continuous, adhering aluminium film in the surface, in atmospheres with oxygen content. The amount of aluminium in aluminides is much higher than in the traditionally applied alloys [8].

Owing to the properties of intermetallic phases and HVOF sprayed coatings, they are anticipated to be applied for the protection of superheater tubes in conventional boilers or in boilers burning multicomponent waste, and combusted biomass including chlorides [10-20].

The objective of the study was to determine and compare the resistance to high-temperature corrosion of HVOF sprayed coatings containing intermetallic phases and aluminium oxide in a model atmosphere of a complex chemical composition, containing oxygen, sulphur, chlorine and nitrogen, corresponding to the waste burning conditions.

The scope of the research encompassed:

- the selection of powder materials to produce the coatings,
- the fabrication of coatings using the HVOF spraying method,
- the carrying out of a corrosion test in a model atmosphere containing N_2 + 8% O_2 + 0.02% SO_2 + 0.01% HCl,
- structural investigation of the coatings after corrosion tests and determination of the chemical composition using the EDX method on a scanning electron microscope.

2. Materials and experimental procedure

The base materials were composite powders of a matrix with FeAl, NiAl or FeAl-TiAl intermetallic phase obtained by SHS method. The composite materials were thermally sprayed on K10 steel by HVOF method in a Jet Kote II system. The 5 stages the samples preparation to investigation were presented in papers [18-20]. The thickness of the coatings was in the range of 200-250 μm.

In order to determine the corrosion resistance of the fabricated coatings, corrosion tests were carried out in a model atmosphere of the following composition: N_2 + 8% O_2 + 0.02% SO_2 + 0.01% HCl. The tests were conducted at temperatures of 500°C and 600°C for up to 1000 hours. During each test, the change of samples' mass in time was measured. Each type of two samples with respective coatings was weighed. Afterwards, the results was averaged and plotted on diagrams. The measurement of mass was conducted after 50, 100, 200 and 500 hours of exposure. Based on the results obtained, the kinetics of the corrosion process in the investigated coatings was determined.

The samples with coatings after the corrosion tests conducted at 500°C and after 500h were cut and mounted, and metallographic specimens were made. Next, structural investigations were carried out and the local chemical composition was determined by the EDX method using a scanning microscope. Observation of the structure and determination of the chemical composition took place using a Hitachi scanning electron microscope S 4200 cooperating with a Voyager 3500 Noran Instruments X-ray spectrometer. The morphology of the corrosion products either on the surface or inside the coating, as well as their quantitative and qualitative composition were determined.

3. Research results

The changes in samples' mass during the corrosion test conducted at 500°C for 500 hours are presented in Figure 1.

A comparison of the curves of mass change shows that the best protective properties were represented by a sample with a NiAl-Al_2O_3 coating, for which sample the course of corrosion was consistent with the parabolic law. A comparison of the morphology and chemical composition of coatings with FeAl and NiAl matrix are presented in Fig 2-3 and Tables 1-2. The chlorides were not found in the avarage chemical composition on the coating with NiAl matrix.

The largest mass decrement was found in a sample with a NiCr-FeAl-TiAl-Al_2O_3 coating (Fig. 1).

In the test conditions, that sample showed the worst protective properties, which was then corroborated by the results of morphological investigations of the corrosion products. The occurrence of corrosion foci containing chlorides was found on it. (Fig. 4).

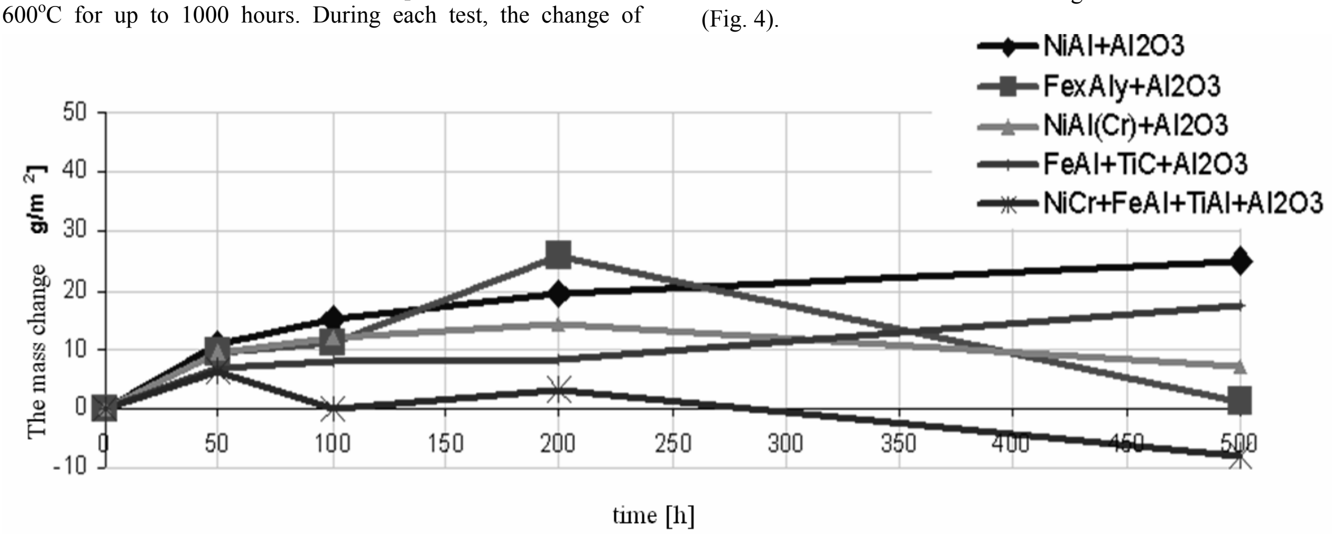


Fig. 1. The mass change of the coatings as a function of heating time. The corrosion test in 500C

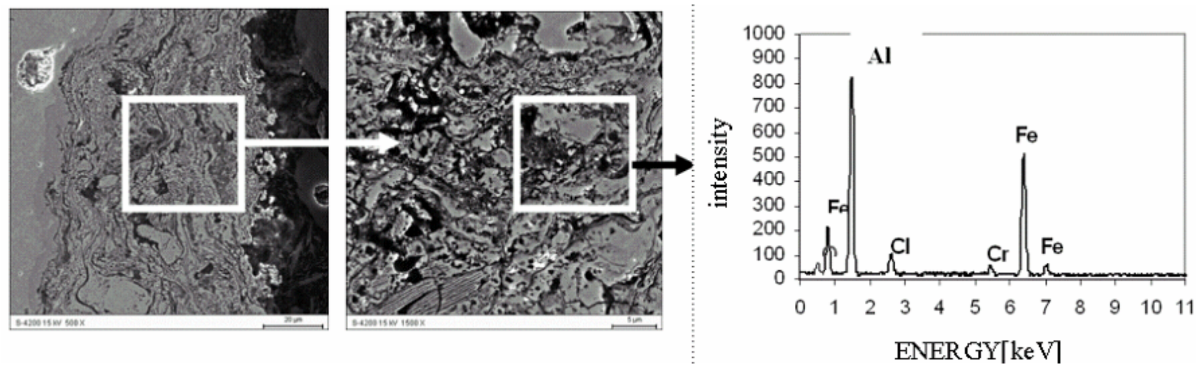


Fig. 2. The morphology of the corrosion products on the $Fe_xAl_y + Al_2O_3$ coating after the corrosion test

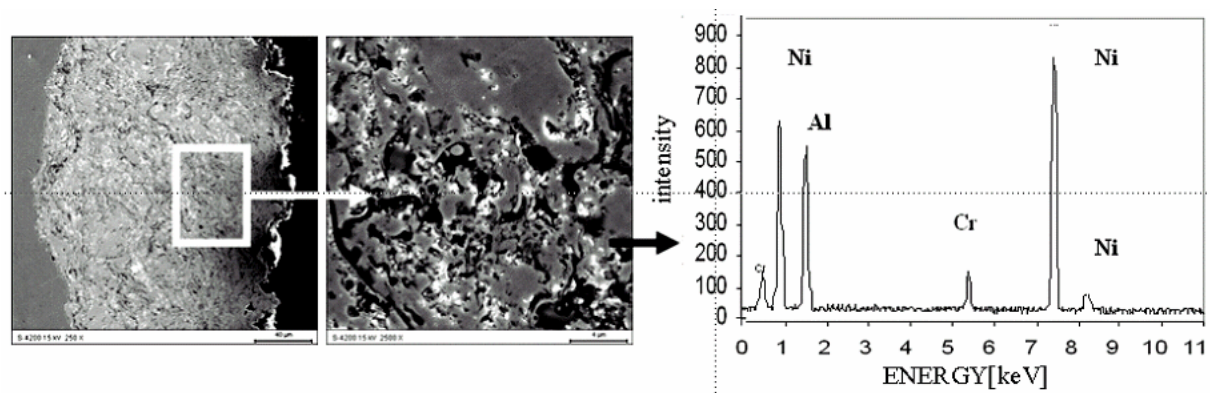
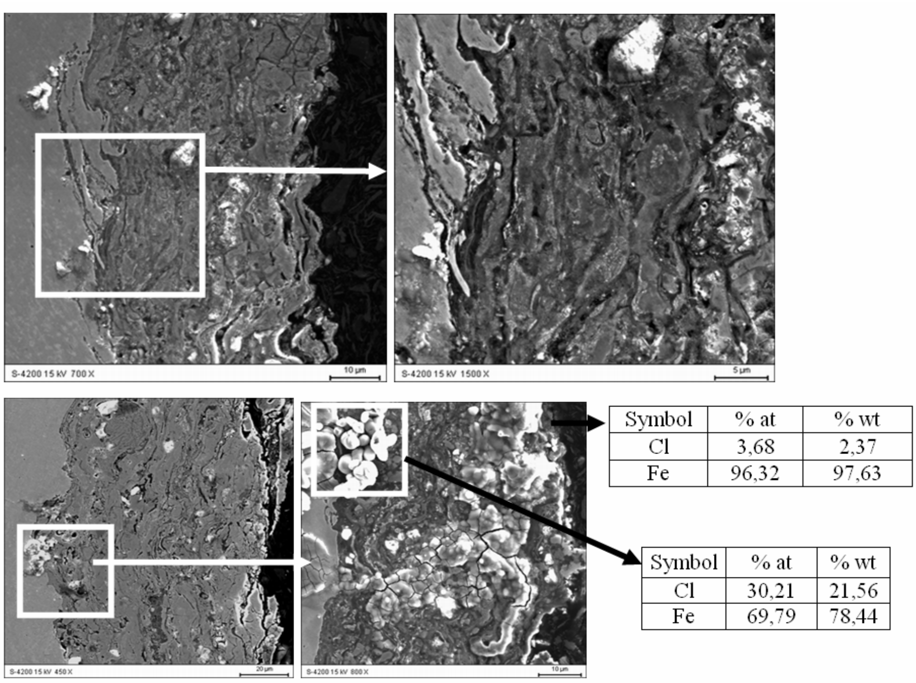


Fig. 3. The morphology of the corrosion products on the NiAl(Cr) + Al_2O_3 coating after the corrosion test



Symbol	% at	% wt
Cl	3,68	2,37
Fe	96,32	97,63

Symbol	% at	% wt
Cl	30,21	21,56
Fe	69,79	78,44

Fig. 4. The morphology of the corrosion products on the FeAl+TiC+Al_2O_3 coating after the corrosion test

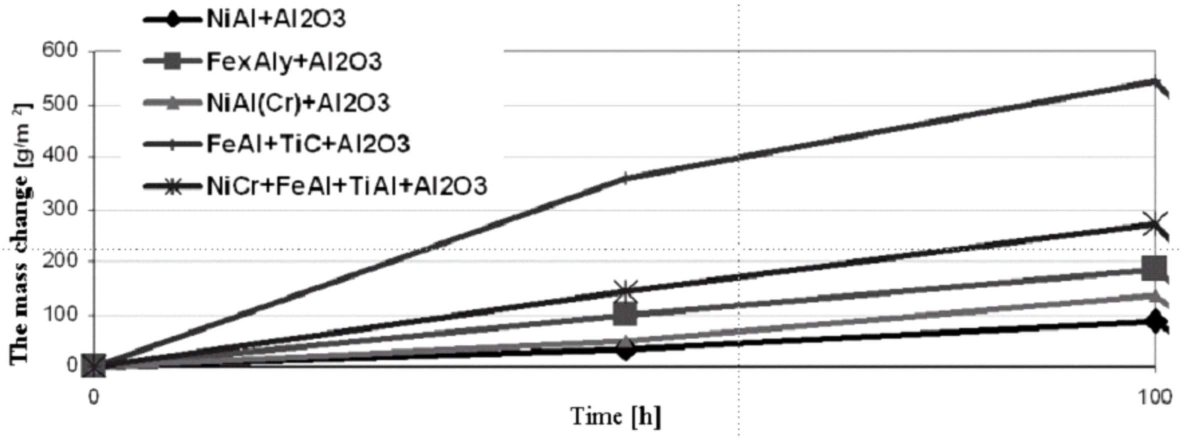


Fig. 5. The mass change of the coatings as a function of heating time. The corrosion test in 600°C

Table 1.
The chemical compositions of the corrosion products on the Fe_xAl_y + Al_2O_3 coating presented in figure 2b

symbol	% at	% wt
Al	46,78	30,09
Cr	1,38	1,72
Fe	50,17	66,79
Cl	1,66	1,4

Table 2.
The chemical compositions of the corrosion products on the NiAl(Cr) + Al_2O_3 coating presented in figure 3

symbol	% at	% wt
Al	22,84	12,04
Cr	3,79	3,85
Ni	73,37	84,12

Additional investigations of the samples were conducted in a corrosion test at a temperature of 600°C and time of 100h, in an analogous atmosphere (Fig 5). In that test, none of the samples showed a mass decrement The initial course of corrosion consistent with the linear law for all samples may suggest too high a temperature and a loss of protective properties of the coatings in a longer time of the test duration.

4. Conclusions

Based on the corrosion test conducted at a temperature of 500°C for 500 hours, one can affirm that the fabricated coatings show good corrosion resistance. The increments of samples' mass were in the range of 10-20g/m2 and they could be arranged in the following decreasing order with respect to corrosion resistance: NiAl + Al_2O_3, FeAl+TiC+Al_2O_3, NiAl(Cr)+Al_2O_3, FexAly + Al_2O_3, NiCr+FeAl+TiAl+Al_2O_3. Based on the conducted tests and structural investigations, it has been found that the coatings are subject to destruction due to a non-uniform pitting corrosion mechanism coupled with the dislocation of aggressive components of the SO_2, HCl atmosphere in the direction of the substrate. The formation of NaCl and $FeCl_2$ chlorides was noticed on the surface of coating.

The research has not corroborated the occurrence of sulfides. Based on former investigations presented inter alia in [17-27] and on the coatings' morphology investigation results, one may expect that the coatings will show a considerable improvement of their corrosion resistance after the application of sealing Such a process should influence the degree of samples surface development (decrease porosity) as well as accelerate the formation of a passive film on their surfaces, which film is responsible for corrosion resistance of the investigated materials.

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