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Oxidation of HVOF sprayed coatings with NiAl intermetallic matrix and ceramic phases

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The results of high temperature oxidation of NiAl(Cr)-Al_2O_3 coating with and without seal at 1223 K are presented. The surfaces of HVOF sprayed coatings after the corrosion test were observed. Kinetics test was carried out by periodic oxidation method. The mass changes of studied coatings during the oxidation test are presented. The adherent oxidation scales of composite coatings after the corrosion test in air were analised by light microscopy observation. The morphology and chemical composition of the corrosion products on the surface of coatings are presented. The morphology of surface scale formed on NiAl(Cr)-Al_2O_3 coating with and without inorganic seal was homogenous. The phase composition of corrosion products was conducted by an X-ray diffraction method. All the results confirm good heat-proof of HVOF sprayed coatings with intermetallic NiAl matrix.

1. INTRODUCTION

The composite materials with NiAl intermetallic matrix are of great interest for elevated temperature applications. These materials have excellence oxidation resistance. The excellent properties of intermetallics based on the high aluminum activity are determinated through the formation of slow-growing, adherent alumina scales [1-3]. An overall summary of intermetalic applications are presented by Stoloff et al. [4]. The results of high temperature oxidation at 1223 K of composite coatings with NiAl intermetallic matrix and modified by ceramic phases and additionally sealed by the inorganic phosphate seal are presented. The modification by ceramic phases have been playing an active role in erosion resistance application [5-7]. In the present study it is shown, that the sealing process of coating surfaces increased the corrosion resistance of HVOF sprayed coatings. All investigations on corrosion resistance confirm good properties of composite coatings with intermetallic phases to application for elements working at elevated temperature and corrosion environments.

2. MATERIALS AND EXPERIMENTAL PROCEDURE

The base materials are composite powders of matrix NiAl intermetallic phases obtained by SHS method [8-9]. The structure and morphology of these materials are presented in figure 1. The composite powders were thermally sprayed on K10 steel by HVOF method in Jet Kote II system. The fine-dispersive coatings contain NiAl-Al_2O_3. One part of the composite coatings were sealed by the inorganic phosphate seal.

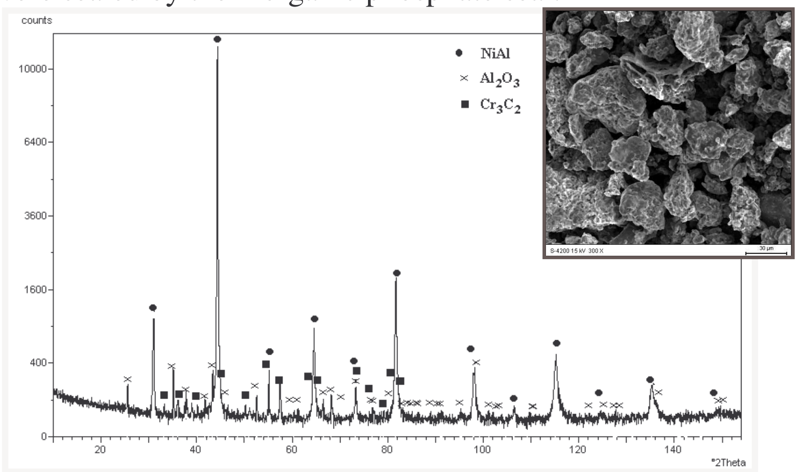


Fig. 1. The morphology and diffraction pattern of composite powders with NiAl intermetallic phase.

Kinetics tests of the mass change of the coatings are carried out by periodic oxidation method in Carbollite furnace. The procedure of oxidation resistance test at 1223 K obeys tree stages: heating to 1223 K ; annealing at this temperature during 24, 48, 72…500 hours and cooling to the room temperature. The weight of growing scale after 24, 48, 72…500 hours was determined. The surface of coating after corrosion test was observed by light microscopy (Richert 2). The morphology and chemical composition of the corrosion products after the test was determinated by Hitachi S-4200 scanning microscopy with voyager system (analysis system of the characteristic X-radiation of elements by Noran system).

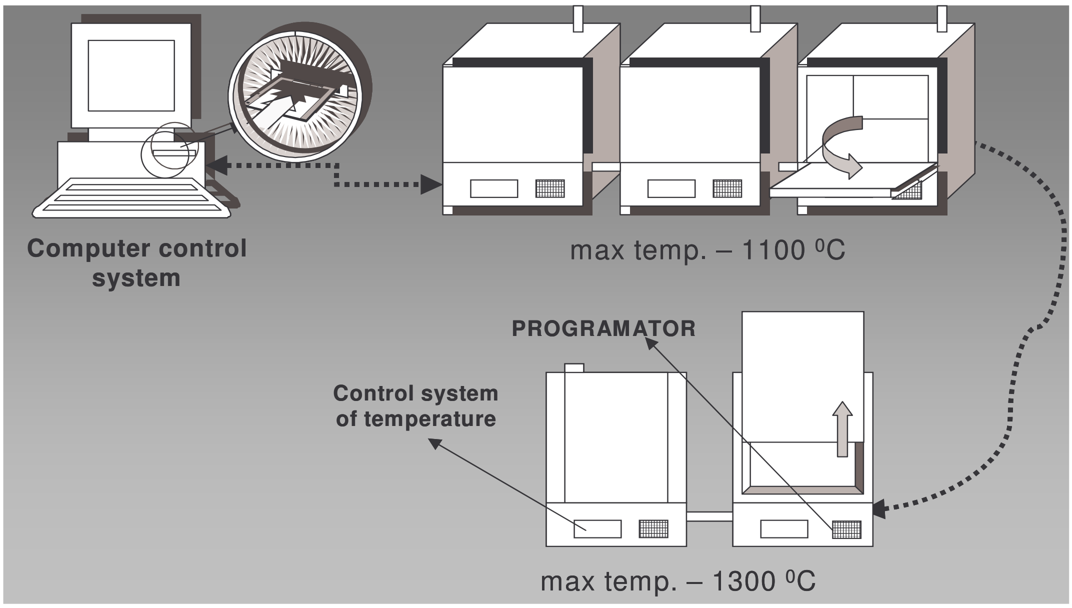
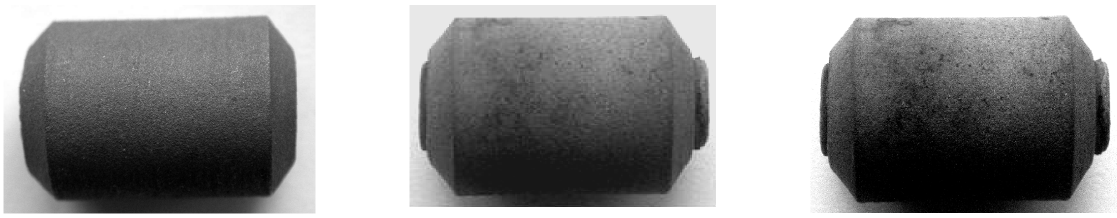


Fig. 2. The scheme of installation for research the corrosion in air

The phase composition of corrosion products was performed by an X-ray diffraction method. The diffraction pattern were collected using X-Pert Philips diffractometer equipped with graphite monochromator on diffracted beam and with the following slits (in the sequence from Cu tube to counter): Soller (2^o), divergence (1/2°), antiscatter (1/2°), Soller (2^o) and receiving (0.15 mm).

3. RESULTS AND DISCUSSION

The images of surface of NiAl(Cr)-Al_2O_3 coatings before and after oxidation test is shown in figure 3. The structure after 48 hours oxidation test have not any cracking and changes of colors. The mass change of the all studied composite coatings during the oxidation test are presented in figure 4. The oxidation process of these materials obeys parabolic rate law. The composite coatings with NiAl intermetallic phase have higher oxidation resistant then once with FeAl matrix.



a) before test b) without seal c) with seal

Fig. 3. The images of surface of NiAl(Cr)-Al_2O_3 coatings: a) before oxidation test and b-c) after oxidation test

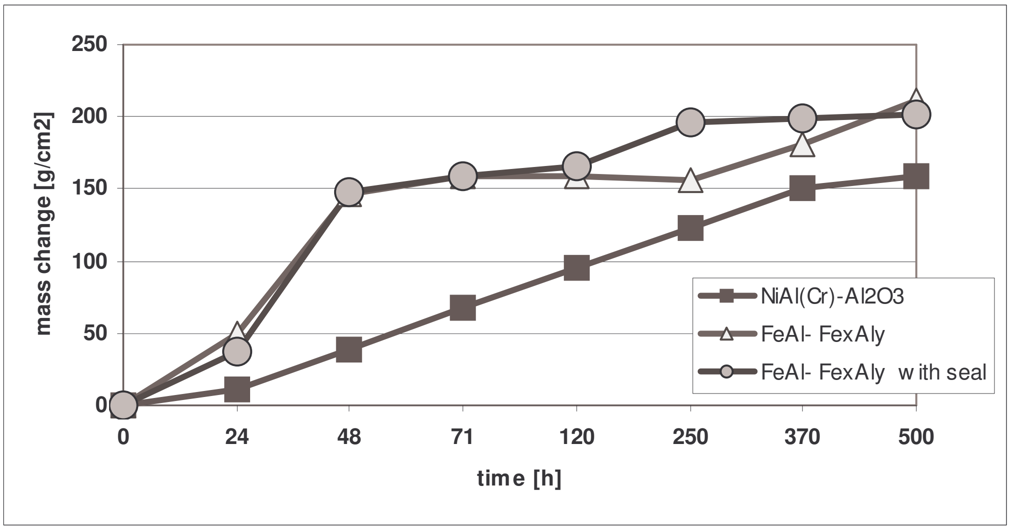


Fig.4. The curves of mass change as a function of the heating time

The structure of composite coatings before and after 48 hours oxidation test with adherent alumina scales is shown in figure 5. The morphology of the corrosion products on the intermetallic coatings after 48 and 500 hours corrosion test are presented in figures 6 and 7, respectively. The surface scale formed on the all coatings was homogenous and whiskers of oxides were not observed. The chemical composition of the coatings determinated by EDS technique are presented in the tables in figures 6 and 7, respectively. The morphology and the chemical compositions of the samples with phosphate-seal confirm high corrosion resistance of this materials. The phase composition of the corrosion products after the oxidation test is shown in figures 8 and 9, respectively. The stable alumna scale (α-Al_2O_3) was formed on the surfaces of all HVOF sprayed coatings.

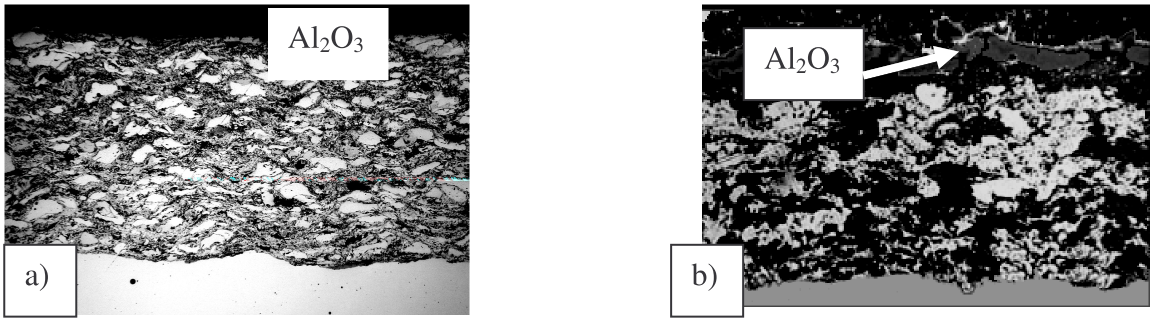
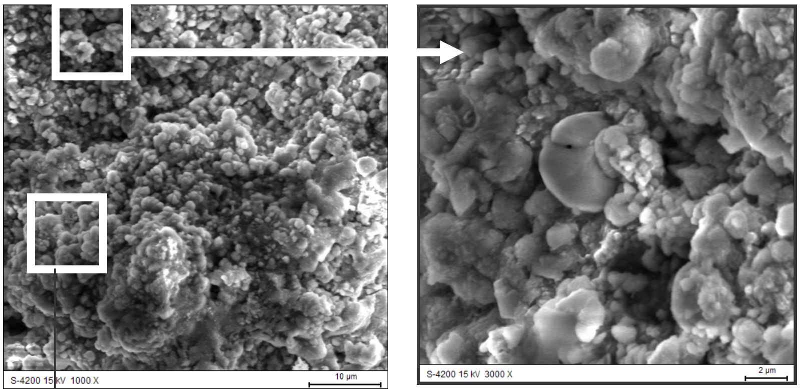
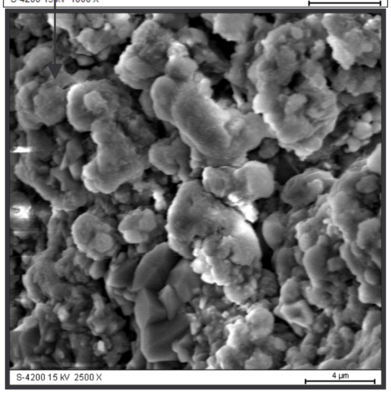


Fig. 5. The structure of NiAl(Cr)-Al2O3 coating with seal a) base material b) after 500 hours oxidation test



Average chemical composition		
	at. %	wt.%
O	34,08	18,65
Al	48,83	44,58
Cr	2,93	5,21
Ni	15,72	31,56



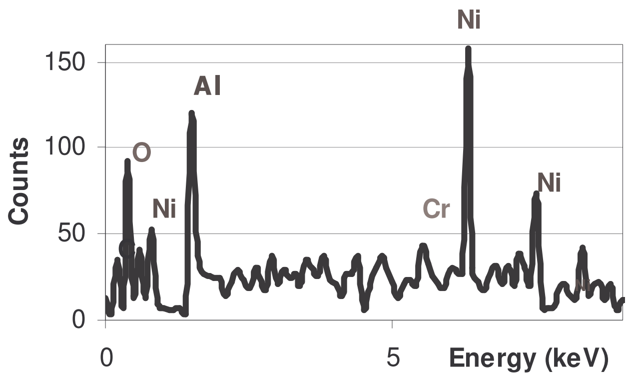
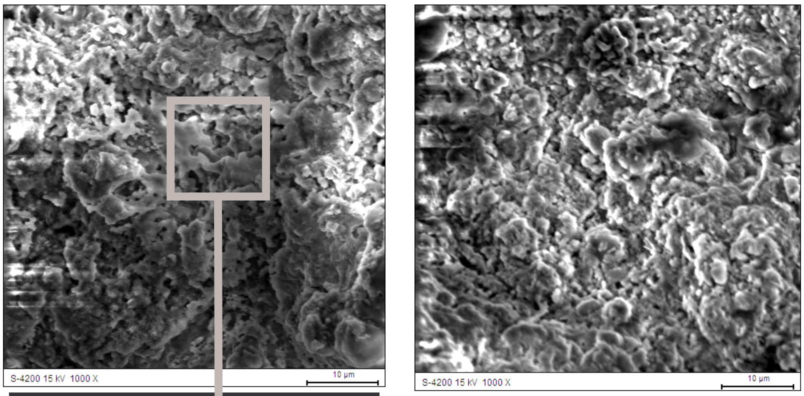


Fig. 6. The morphology and chemical composition of NiAl(Cr)-Al_2O_3 coating after 48 hours oxidation test



Average chemical composition :

	at. %	wt. %
O	34.05	14.07
Al	19.36	13.49
Cr	4.56	6.13
Ni	42.03	66.31

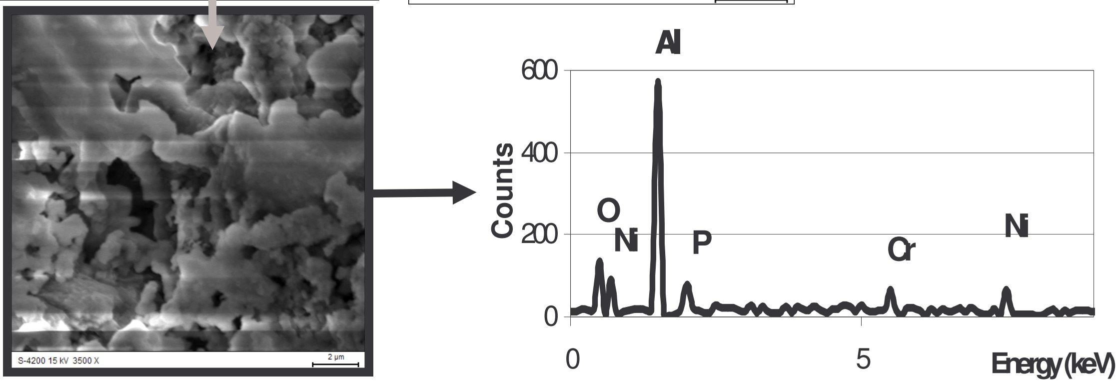


Fig. 7. The morphology and chemical composition of NiAl(Cr)-Al_2O_3 coating with seal after 48 hours oxidation test

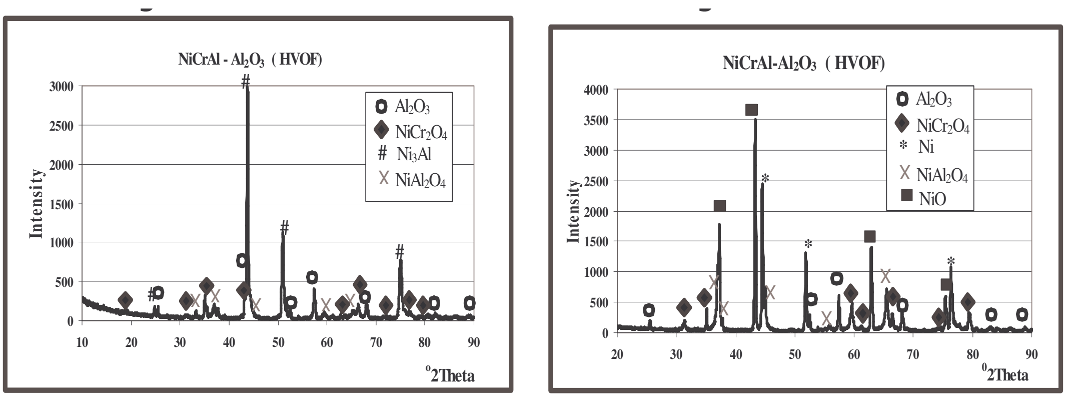


Fig. 8. The phase composition of the corrosion products on the NiAl(Cr)-Al_2O_3 coating after oxidation test a) 48 hours, b) 500 hours

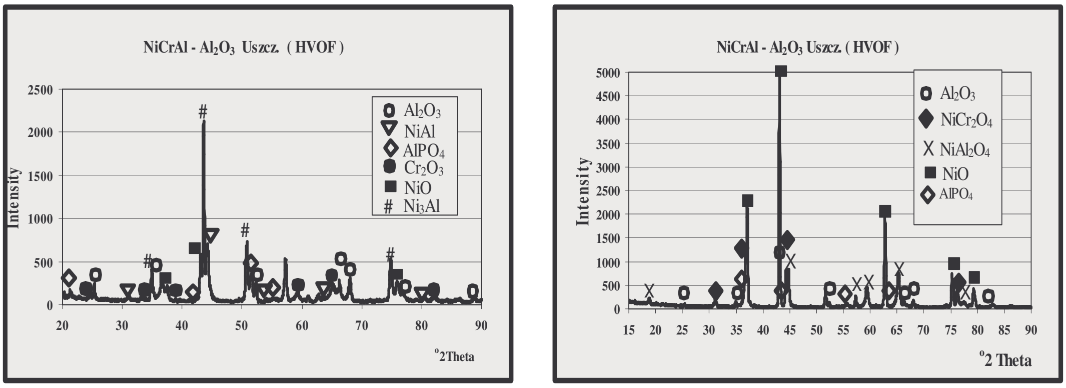


Fig. 9. The phase composition of the corrosion products on the composite coating with seal after oxidation test a) 48 hours, b) 500 hours

4. CONCLUSIONS

The corrosion rate of NiAl(Cr)-Al_2O_3 coatings is controlled by the diffusion of corrosion products in the channels. The composite coatings with NiAl intermetallic phase have higher oxidation resistant then once with FeAl matrix [10]. The phosphate seal on the surface changes greatly the corrosion law of the HVOF sprayed coatings in the test condition. The sealing process of coating surfaces increased the oxidation resistance of study coatings in the oxidation test at 1223 K. The good oxidation resistance of studied intermetallic materials are the result of the growth of the stable and adherence α-Al_2O_3 scale on the surface of these composite coatings. The coatings are preferred to application as protection of the water-walls and of boiler tubes for the waste combustion. The composite coatings are the perspective materials in applying at elevated temperature.

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REFERENCES

1. S. Yang, F. Wang, Z. Sun, S. Zhu, Intermetallics 10 (2002) pp. 467-471.
2. M. A. Montealegre, J.L. Gonzalez-Carrasco, et al. Intermetallics 8 (2000) 439-446.
3. K. Natesan, Materials Science and Engineering A258 (1998) pp.126-134.
4. N. S. Stoloff, C.T. Liu, S.C. Deevi, Intermetallics 8 (2000) pp. 1313-1320.
5. Q. Fang, P. S. Sidky, M. G. Hocking, Corrosion Science, vol39, no. 3 (1997) pp. 511-527.
6. W. W. Lee, D. B. Lee, M.H. Kim, S. C. Ur, Intermetallics, 7 (1999) pp. 1361-1366.
7. Sealing Technology vol. 2, no. 8 (2002) pp. 10.
8. B. Formanek, B. Szczucka-Lasota, A. Letsko, Achievement in Mechanical and Materials Engineering, ed. L. A. Dobrzanski, (2002) pp. 187-190.
9. B. Formanek, K. Szymanski, B. Szczucka-Lasota, B. Bierska, Inżynieria Materiałowa vol. 6, no. 137 (2003) pp. 617-620.
10. .B. Szczucka-Lasota, B. Formanek, AMME (2003), ed. L. A. Dobrzanski, (in this issue).