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MICROSTRUCTURE OF METALLS COATINGS NiCrAlY

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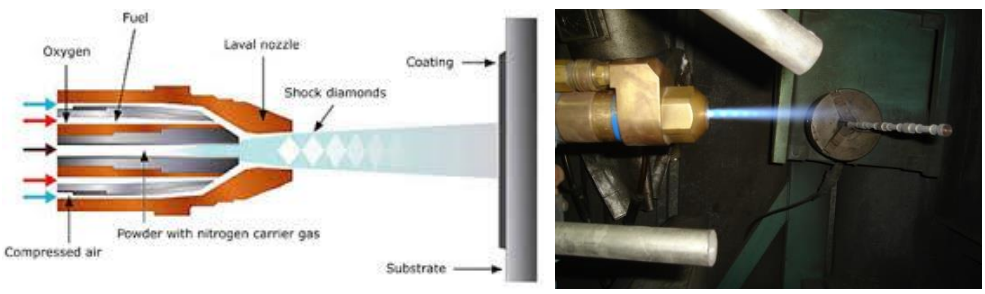
ABSTRACT
In conducted research was made a characterisation of microstructure and powder NiCrAlY, before and after applying on the base material. Coating was carried out by using HVOF Diamond Jet procedure, which uses the kinetic energy of the metal particles produced by on explosion of combustible gases. Characterisation was based on chemical analysis of metals powder particles, their size and structural composition and testing the composition, and structure of the applied coating on iron base alloy A286 with intermetallic strengthening. We used the classical testing methods of composition of metal powder and coating and optical and scanning electron microscopy in determining the phase composition. By testing with scanning electron microscopy, it was found that at the joint is present aluminium oxide with the presence of yttrium oxide, which play a significant role in the prevention of high-temperature oxidation of the base material. At the joint areal so analyzed and the concentration changes in the content of alloying elements. In addition to determining the phase composition of applied metal coating was used and x-ray structure analysis concentration changes in the content of alloying elements.

1. INTRODUCTION

The paper describes the microstructural examination of a joint of the base material, iron base alloy A286 with intermetallic strengthening classified according to its chemical composition and properties according to standard SAE AMS 5528 and metallic coating marked as NiCrAlY 4516 according to manufacturer catalog Sulzer Metco. Coating is applied using HVOF Diamond Jet procedure. Basic material together with applied coating is designed to operate at elevated temperatures. By testing with optical and scanning electron microscopy, and X-ray analysis it was found that at the joint is present aluminium oxide with the presence of yttrium oxide, which plays a significant role in the prevention of high-temperature oxidation of the base material [1]. At the joint areal so analyzed microstructure and the concentration changes in the content of alloying elements. It was found that after the high temperatures affect, at the joint border are aluminum and yttrium oxide, which have an important role in preventing high-temperature oxidation of the base material. For the stability of the coating are important thermodynamic conditions of formation of oxide phases, which depend on the activity of certain metals in the alloy, the partial pressure of oxygen and affinity of metal elements to oxygen. Due to differences in affinity to oxygen between the elements in the alloy, there is a tendency that alloy during oxidation process is covered by thermodynamically most stable oxide. Initial formed unstable oxides, are gradually transformed into thermodynamically stable oxide phases. The basic aim is to form a continuous protective layer of oxide composed of phase α- (Al_2O_3), which is resistant to high temperature oxidation, and which can additionally be strengthened by yttrium oxide(Y_2O_3).

2. EXPERIMENTAL

For the carried out tests were made samples at the plate dimensions ≠ 5X15X40 mm from iron alloy A286 (14.35% Cr, 25.0% Ni, 2.35% Ti, 0.10% Al). The metal coating is applied to samples by Diamond Jet procedure, using detonation gun. Metal powder NiCrAlY (64.5% Ni, 24.5% Cr, 10.5%Al, 0.20%Y), is dosed in the charging of powder, which is, by nitrogen flow inducted in a plasma flow, which dumps it rapidly and applies it on the sample [2]. Figure 1a) and b) shows a diagram of the Diamond Jet procedure (1a), and process of applying coating to the sample (1b).



a) Scheme of the procedure *b) the process*

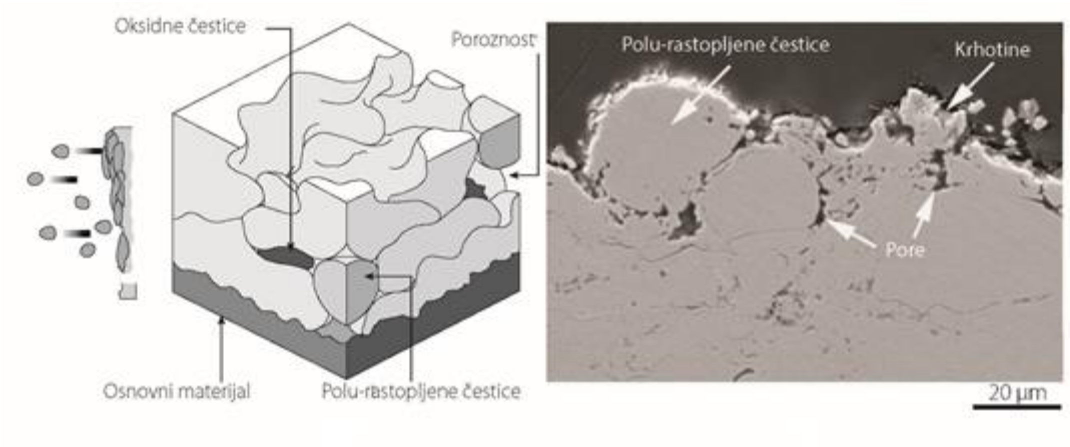
Figure 1. Scheme of the procedure HVOF Diamond Jet (a) and of the process of coating of the sample (b)

On the samples were carried out heat treatments by solution annealing at 980 ºC and precipitation strengthening at 720 ºC during a period of 12 hours. Oxidation kinetics and mechanism of the stabilization process of the microstructure at elevated temperatures, were tested after oxidation in air at a temperature of 1000 ºC during a period of 124 hours. In order to determine the mechanisms that take place in the structure of the coating and at the phase boundaries, at high temperature, were examined microstructures in cross-section of samples in strengthen condition, and surface of coating after oxidation. The samples were etched in a reagent Kalling, and structure tests were performed by Scanning Electron Microscopy Joel JSM 5610 SEM and X-ray analysis by Panalitical X Pert Pro.

3. RESULTS

To understand the mechanisms that occur in the process of deposition of coatings on the base material, pre- tests of metal powders were performed, so as pre-tests of coating after applying coating and heat treatment. It was found that the cast spherical particles of metal powder whose size is about 25 μm, are made of two phases: ϒ' - a solid solution of chromium and nickel, and β - intermetallic phase NiAl. Structure X-ray analysis subsequently determined, that metal coating is consisted of the same phases. After dissolving annealing β-phase $Ni_{1.1}Al_{0.9}$ is partially transformed into ϒ' - Ni_3Al phase.

Metal coating NiCrAlY applied to the alloy, is composed of molten and partly molten particles, oxides, pores, and broken particles (debris), showed a Figure 2a) and b) [3].

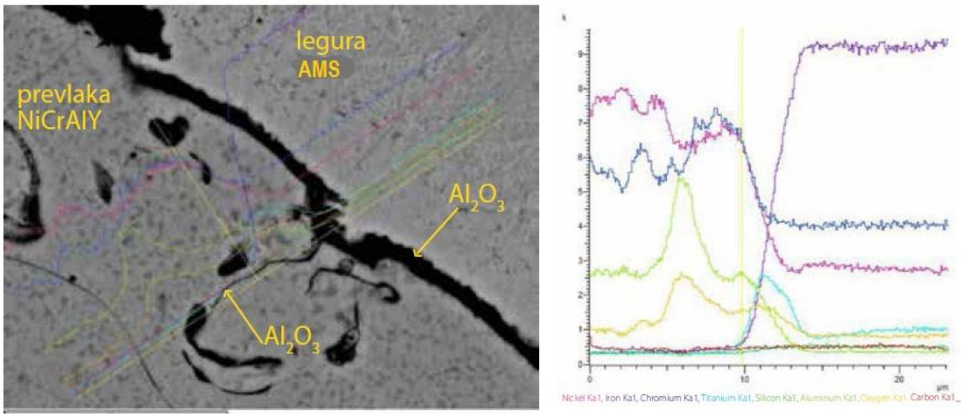


a) 3D schematic *b) Metal coating*

Figure 2. Metal coating applied to the alloy, 3D schematic (a) and coating (b)

The structure of the alloy in a strengthen state is consisted of austenitic Y-base, with a separate coherent Y'-phase (Ni_3Al). X-ray structure analysis showed that the coating is composed of intermetallic phase ß ($Ni_{1.1}Al_{0.9}$), and the cubic phase (Cr_2Ni_3), and after the intermetallic strengthening, ß-phase ($Ni_{1.1}Al_{0.9}$) becomes Y'- phase (Ni_3Al). This means that in the alloy and in the coating NiCrAlY, similar mechanisms of strengthening are conducted, which is important in the selection of the coating. The boundary between the coating and the alloy is a mechanical mixture resulted without diffusion and dissolution, and the bonding process is carried out by mechanical activation, similar to connecting metals by explosion.

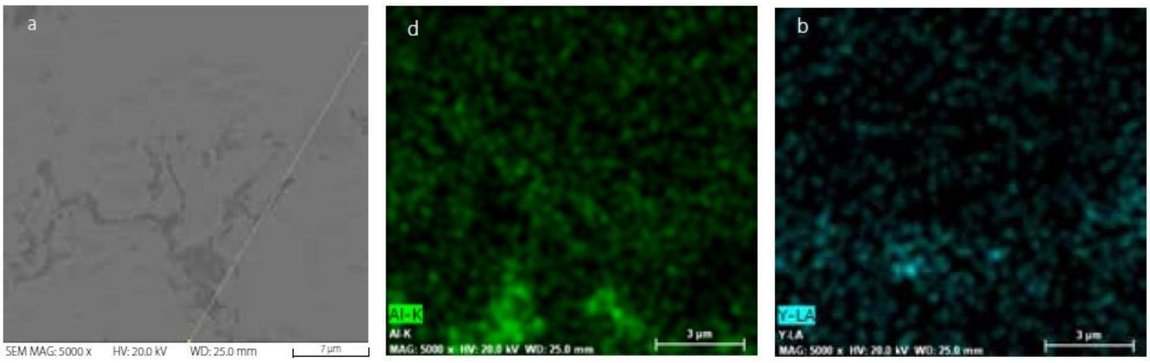
Microstructure tests were conducted by Scanning Electron Microscopy (SEM). On SEM image (Figure 3a), we can see the microstructure of NiCrAlY coatings, joint coating -alloy, and interfacial boundaries between the molten and infusible particles. Line EDS analysis (Figure 3b), shows increased content of aluminum, yttrium and oxygen in the coating, on the interphase boundaries, and especially on the border alloy-coating, and on that basis, it can be concluded that aluminum oxide (Al_2O_3) and yttrium oxide (Y_2O_3) are formed. The presence of yttrium, in the form of finely dispersed particles of yttrium oxide (Y_2O_3), can strengthen and increase the stability of aluminum oxide (Al_2O_3).



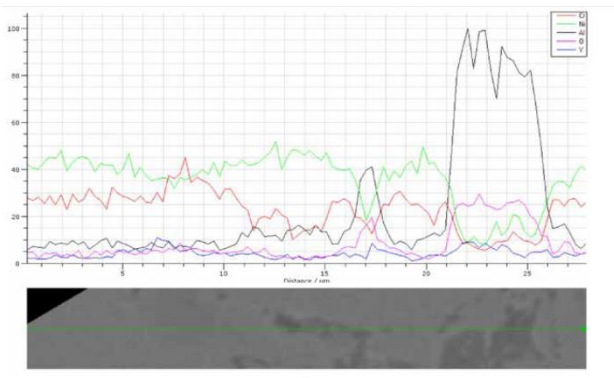
a) SEM structure *b) EDS line analysis*

Figure 3. SEM structure of the coating and alloy (a) and EDS line analysis (b)

Test of coating surface after cyclic oxidation annealing in air at a temperature of 1000 ºC during a period of 124 hours, at the interphase and the phase boundaries, by EDS mapping and linear analysis, it was confirmed even more expressive presence of aluminum oxide and yttrium, Figure 4a), b), c), d). In the initial stage of the oxidation process, is formed a grey oxide phase rich in chromium, predominantly on the surface of the coating, between the debris and pore, because there is a large reactive surface which easily penetrates oxygen. Under the grey oxide phase, on the semi-molten particles is the dark phase of alumina oxide, which can be strengthen by yttrium oxide.



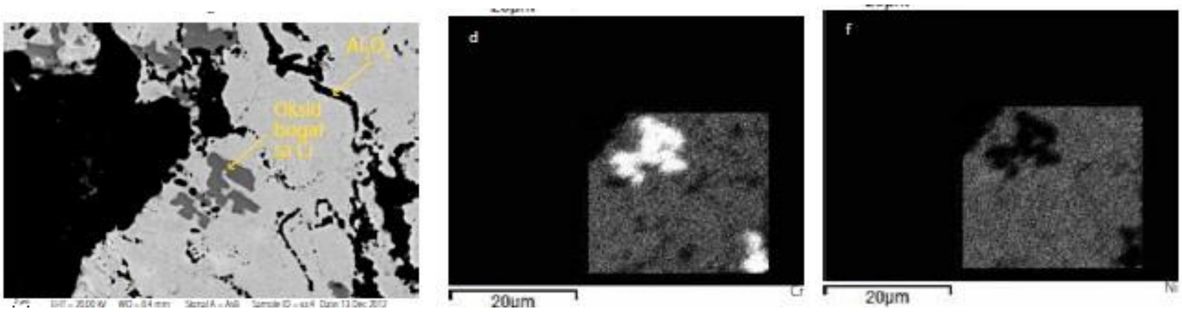
a) SEM structure *b) Aluminum* *c) Yttrium*



d) Line analysis

Figure 4. SEM structure of the coating surface after annealing at 1000 ºC during a period of 124 hours (a), EDS mapping analysis aluminium (b), yttrium (c) and line analysis (c)

With the presence of oxides of chromium and nickel, the coating becomes poor in aluminum content, which speeds up formation of the grey oxide phases, which changes the thermodynamic equilibrium, and thus improves the diffusion of aluminum towards the joint-alloy-coating. Testing the structure by SEM and EDS mapping and line analysis confirmed that grey oxide phase rich in chromium, initiates the formation of protective aluminum oxide layer under the grey oxide phase, Figure 5a), b) and c).



a) SEM structure of the coating *b) Chromium* *c) Yttrium*

Figure 5. SEM structure of the coating surface after annealing at 1000 ºC during a period of 124 hours (a) and EDS mapping analysis (b, c)

4. CONCLUSION

Metal coating NiCrAlY applied to the alloy, is composed of molten and partly molten particles, oxides, pores, and broken particles (debris).

The structure of the alloy in a strengthen state is consisted of austenitic Y-base, with a separate coherent Y'-phase (Ni_3Al), and X-ray structure analysis showed that the coating is composed of intermetallic phase ß ($Ni_{1.1}Al_{0.9}$), and the cubic phase (Cr_2Ni_3), and after the intermetallic strengthening, ß-phase ($Ni_{1.1}Al_{0.9}$) becomes Y'- phase (Ni_3Al).

To form a stable protective layer against the effects of high temperatures, it is necessary to form stable aluminum oxide (Al_2O_3), strengthen with yttrium oxide (Y_2O_3) and chromium oxide (Cr_2O_3) on the interphase boundaries within the coating, and on the joint coating - alloy.

It can also be concluded that on the basis of test content and distribution of alloying elements, is defined mechanism for the formation and evolution of oxide on the coating NiCrAlY after oxidation at 1000 ºC during a period of 124 hours.

The semi-molten particles, debris and pores in uncompact layer, result in the formation of grey oxide mixture and the loss of the oxidation resistance of this layer.

The grey oxide phase rich in chromium, initiates the formation of a stable aluminum oxide which is allocated on the interphase boundaries and on borders of the joint coating-alloys.

5. REFERENCES

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