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RESEARCH POSSIBILITIES IMPROVEMENT PROPERTIES ALLOY A286 BY MODIFICATION SURFACE BY PROCEDURE DIAMOND JET

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ABSTRACT
Modern trends in the development of automotive industry, constantly setting new requirements in terms of improving the work and performance of the engine. Research has mainly focused on increasing the mechanical and exploitation properties of materials used to operate at elevated temperatures. One possibility is a new procedure to modify the surface of ferrous super alloys A286, applying metallic coatings NiCrAlY, and using HVOF (High velocity oxyfuel) procedure Diamond Jet.
Key words: super alloy, metalic coatings, microstructure, mechanical properties, fire resistance

1. INTRODUCTION
The ferrous super alloy A286, accordance to standard UNS S66 286 (hereinafter referred to alloy A286), has long been present in the air and rocket technology, and more recently finding increasing application in the automotive industry. One way to improving the properties of alloy A286 is surface modification applying metallic coatings using *HVOF* procedure *Diamond Jet.* The coating material was chosen NiCrAlY metal powders, which after application and subsequent heat treatment, improves the properties of materials when working at elevated temperatures. In this paper, we conducted extensive experimental studies, which included the production and processing of experimental melts, coating procedure Diamond Jet on samples of A286 super alloys, which are used for complex laboratory tests.

2. DIAMOND JET PROCEDURE

2.1. Procedure coating detonation of combustible gases
Base element in *HVOF* detonation procedure Diamond Jet is detonation gun. A mixture the combustion gases are fed into the combustion chamber and burns, and detonation combustion caused the explosion, while in the one second occurs 4 to 8 explosive impulses. Due to detonation is created flaming front that accelerates through the nozzle, until it forms a detonation wave. Detonating wave propagation speed is 44 m/s. That high speed gas flow provides essential acceleration of the powder particles, which are pre-axially in a stream of nitrogen fed into the chamber. The result of the explosion is developing temperature to 4200 °C, which dissolves most of the metal powder particles, wherein the particles in plasma current speed up to 700 m/s.
Figure 1 shows a schematic description of the procedure of detonating gun formation and detonating shock wave and diamond shock.

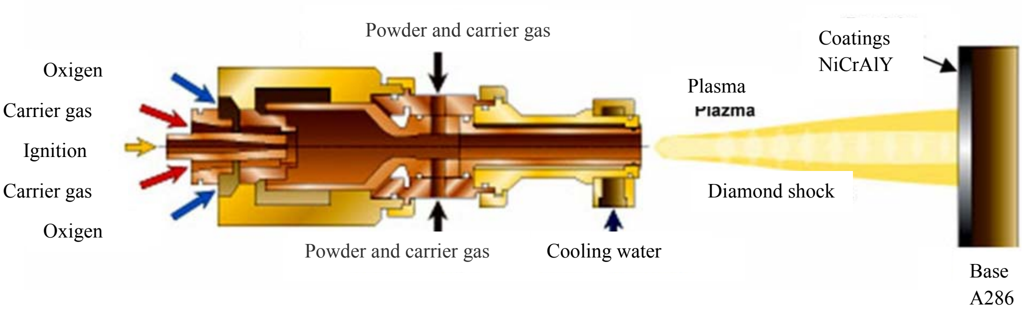

*Figure 1. Schematic description of the procedure **Diamond Jet***

2.2. Materials research

Ferrous super alloy A286

Super alloy A286 *(UNS S66 286)* classified by chemical composition and properties accordance to standard *SAE AMS 5528*, belongs to the group of austenitic stainless steels with intermetalic hardening, and used for work at temperature above 740°C. Microstructure of alloy A286 consist of ϒ- austenite body centered cubic matrix, which hardening during precipitation annealing, by coherent intermetallic phase ϒ' (Ni_3Al,Ti). Additional strangthening of alloy, can be achieved by secondary precipitation of fine titan carbonitrides within the grain and at grain boundaries, and much smaller, due to the solution hardening.

Metallic coatings NiCrAlY (64%Ni, 24%Cr, 9%Al, 0,3%Y)

Metallic coatings, formed by applying a metal powder NiCrAlY by *HVOF* procedure *Diamond Jet* on material surface, are dense nonporous coatings with high strength and toughness. Characteristics of the deposited layers and their phase composition, proportion and distribution of oxides, the proportion of pores and insoluble particles affect the properties of the coating. In metallic coating NiCrAlY depending on the temperature treatment, most present the following structural phase: ϒ- austenite (Ni), ß - intermetallic phase (NiAl), ϒ'- coherent intermetallic phase (Ni_3Al), α- aluminium oxide (Al_2O_3), Cr_2O_3 - chromium oxide and Y- yttrium oxide (Y_2O_3).

3. EXPERIMENTAL RESEARCH

For research purposes, made four experimental melt in vacuum induction furnace with varying primary alloying elements, chromium, nickel and titanium. Batches are processed by hot deformation in the rod dimensions ϕ 15 mm, of which are made samples for testing. Metallic coating NiCrAlY is applying on samples by procedure Diamond Jet. Applied layer with two different thicknesses, 70 µm and 100 µm. All samples are solution annealing at 980ºC for at 90 minutes and precipitation annealing at temperature 760ºC for at 720 minutes.

Performed as standard and some non-standard laboratory tests on samples without and with coatings. For each test, were performed by the same two samples, which have been tested under the same conditions, in order to achieve the greatest possible reliability of the results. Tested the tensile properties at room and elevated temperatures, hardness, fire resistance, and microstructure on the optical and scanning electron microscope. Content of the basic elements and the values of tensile strength at a temperature of 20 ºC and 760 ºC, the samples with and without applied coating is given in Table 1.

There are significant differences in the content of titanium in the experimental batches of alloy A286. These differences have a large impact on the tensile properties, so that the increase in titanium content leads to a significant increase tensile properties and at ambient and elevated temperatures, which is certainly related to the increase of the part ϒ'- intermetallic phase (Ni_3Al,Ti) in the structure. It also notes that it is not expressed effect coatings on these properties. Trend of values of tensile strength at room temperature is shown in the histograms in Figure 2.

Table 1. Content of the basic elements and the values of tensile strength of experimental batches

Batch	Content of element, %							Rm, Mpa					
	C	Cr	Ni	Mo	Ti	B	Al	20 °C			760 °C		
	max 0.08	13.5 16.0	24.0 27.0	1.0- 1.5	1.9 2.35	max 0.01	max 0.35	Layer thickness (μm)			Layer thickness (μm)		
								0	70	100	0	70	100
1	0.03	14.35	25.0	1.32	2.35	0.007	0.10	1131	1057	1052	391	296	363
2	0.03	15.50	23.9	1.45	2.20	0.004	0.12	1082	1056	1027	422	425	452
3	0.03	13.90	24.2	1.35	1.85	0.006	0.12	611	634	636	270	194	214
4	0.04	15.80	25.5	1.25	1.20	0.011	0.11	281	282	284	210	212	210

Established a correlation between the content of the main alloying elements and thickness of coatings, with the values of tensile properties at room and elevated temperatures using statistical mathematical analysis. Performed relations are in agreement with the results of tests, with the achieved high correlation coefficients. But the biggest advantage of this technology is reflected in the high fire resistance when operating at high temperatures and aggressive environments. Value for the rate of oxidation at a temperature of 1000 °C in air atmosphere in cyclic warming 24 to 120 hours, for specimens with and without coating were comparatively given in Figure 3. Influence of applied coating is fully expressed.

Research has found that the coatings have significantly higher hardness compared to the base alloy A286, which is definitely a big advantage that allows the application of this technology Figure 4a and 4b.

Microstructure of NiCrAlY coating and alloy A286 and EDS line analysis of the content of alloying elements are given in Figure 5. The microstructure of the coating are visible melted layers, undissolved particles, debris and intermediate boundaries. From linear analysis are clearly visible concentration differences between the applied coating and the basic alloy. In the coating is clearly evident that the boundary layer applied - alloy spaced aluminum oxide, which is located on the interphase boundaries in the coating. Aluminium oxide, yttrium oxide strengthened, creating a protective layer against oxidation, and they are major carriers of the fire resistance of these coatings.

4. CONCLUSIONS

Research results showed that the coating metal powder NiCrAlY, can improve the working properties of superalloys A286, especially when working at high temperatures. It was found that in these alloys with standard chemical composition, with the coatings, can significantly increase the resistance to the effects of high-temperature oxidation, and then achieve a high surface hardness, with a slight decrease tensile properties. It was also found that the A286 superalloys with the coatings, can make and with reduced nickel and chrome, if you provide the content above 2.0% titanium and aluminum above 1.2%.

5. REFERENCES

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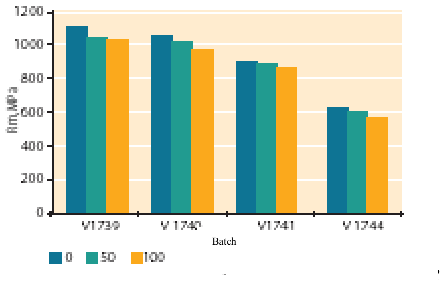
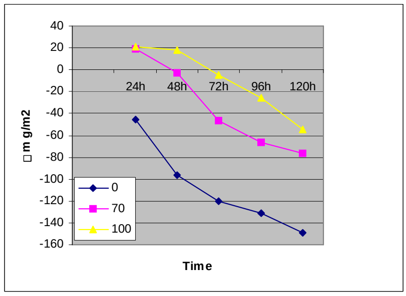
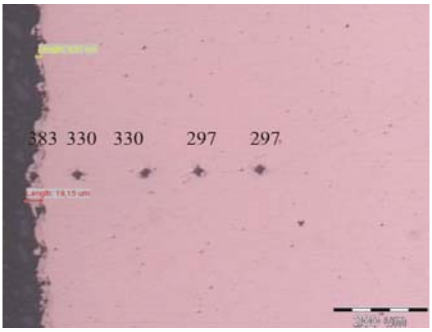
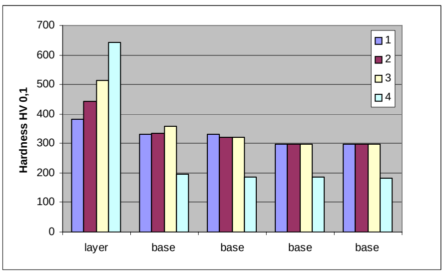






a)



b)

Figure 4. Hardness values

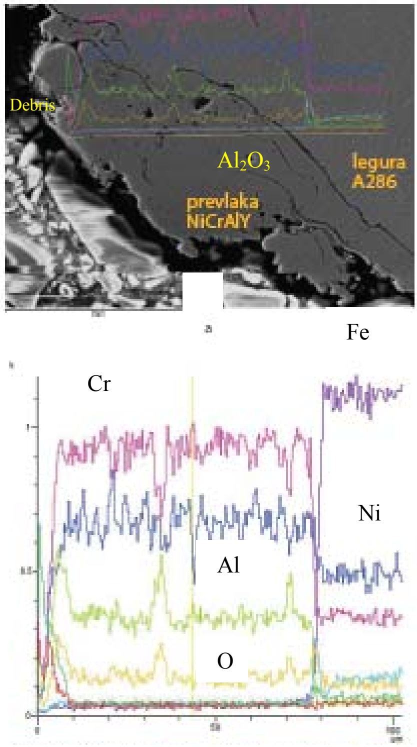


Figure 5. EDS line analysis of the content of alloying elements