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Experimental Research on the Development of Meta-stabile Layers Obtained with the NiCr Powder System

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Abstract

The wear resistance of thermal powdered layers applied on different parts is due to hard phases and metallic matrix characteristics, and it's definitely influenced by the percentage of rough materials in the structure, by their type, shape, grain distribution.

Key words: *plasma, structure, hard coatings*

Introduction

In order to obtain wear-resistant layers, hard materials are used, in powder form, or mixes of hard materials with matrix-forming components, usually applied with plasma-jets, or high-velocity flame. The commonly used materials are carbides, borides, silicates and/or oxides of metals found in the fourth, fifth and sixth groups of the periodic system.

Tungsten carbides are the roughest, closely followed by chrome, titanium, niobium, tantalum, and mixed tungsten-titanium carbides /1, 2, 5/.

Rough alloys are multi-phased metallic materials, obtained in melt state, and their structure is a tenacious matrix, based on metals like iron, cobalt and nickel, where rough materials are incorporated such as carbides, borides, and rarely silicates.

Microstructure and Chemical Composition of the NiCr Powder

Judging from the base material and the elements found in the metallic matrix, the characteristics of the applied layer can be obtained (Table 1) /3,4,5/..

The NiCr alloy has hard phases and can be used for layer application for recondition and preventive coating for parts. Adding boron and silicon to this hard alloy will help reduce the oxides, allowing autonomous flux properties to the alloy, facilitating the layer-sub layer metallurgic adherence, without the need of additional link layer when coating.

Chrome (16%) increases the corrosion and oxidation resistance, boron and silicon have a pronounced effect on melting temperature decrease. Boron and carbon form together hard phases, increasing wear resistance. The novelty in this alloy is Yttrium, who decomposes slowly in water, even in normal conditions, and with less-active non-metals forms compounds with a metallic character, with high melting points like borides, carbides, silicates.

Yttrium has a low atomic radius (1,801Å), and can easily defuse, raising layer adherence and intensifying the mutual inter-diffusion.

Table 1. Field of use of multi-phased metallic materials.

Base Material	**Elements of the metallic matrix**			**Layer Characteristics**
	Elements forming carbides or rough phases	**Metalloids**	**Other elements of the matrix**	
Iron, Fe	Cr, W, Mo, V	C, Si, B	Mn, Ni	Wear resistance;
Cobalt, Co	Cr, W, Mo	C, Si, B	Ni, Cu	Wear and corrosion resistance; thermal stability
Nickel, Ni	Cr, W	C, Si, B	Cu, Fe, Co	

The wear resistance of thermal powdered layers applied on different parts is due to hard phases and metallic matrix characteristics, and it's definitely influenced by the percentage of rough materials in the structure, by their type, shape, grain distribution. The matrix determines the coating's mechanical and chemical resistance.

In order to accomplish the experimental tests, the NiCr alloy system was used as an applied material, showing the chemical composition described in Table 2 /3,4,6,7/.

Table 2. The chemical composition of the NiCr powder

Developed NiCr powder	**Powder symbol**	**Chemical powder composition of the alloy materials in weight percents % gt**						
		Fe	Ni	Cr	B	Si	C	Y
	NiCr-SiBFe CY	4,0	72, 0	16,0	3,5	3,0	0,9	0,6

Using these compositions, the effect of the B, Si, C, Y metalloids on the phases and their properties will be the following: the iron substitution using nickel increases the corrosion resistance, the B and C metalloids increase roughness, Y increases cold diffusion, due to it's low atomic radius, as well as the adherence of the applied layer through thermal spraying, and the wear resistance.

Fig. 1. Electronic microstructure of the NiCr powder.

The grain shape, as well as the surface oxides can lead to difficulties to the plasma generator injection. The grain will gain less temperature when going through the spraying jet, because the oxide layer slows the thermal transfer coefficient through the plasma jet (figure 1).

The NiCr alloy grains are found in a 95% spherical shape, they don't have an oxide surface, and look as they're formed of crystal grains, as shown in Figure 1.

An important characteristic for the NiCr powder is its fluidity, influenced by the particle shape, grain distribution, friction coefficient, liquids or gases absorbed on the particle shape, oxidation level, magnetic and electric characteristics, etc. The powder fluidity directly influences the quality of the layer applied through thermal spraying.

Table 3. Data regarding NiCr powder fluidity

NiCr Powder	**Alloy elements**	**Fluidity of developed powders, sec/50g**
	Ni Cr Fe Si B C Y	20,6

The fluidity value, determined using the Hall flow-meter are shown in Table 3, and they clearly show the effect of the shape and oxidation degree of particle surfaces, NiCr powder having a good fluidity as there are no oxides on the particles, and their spherical shape. The NiCr alloy has a spherical particle shape that allows a fluent flow through a calibrated hole. (Table 3)

Fig. 2. Plasma-jet thermal coatings using NiCr powder

Figure 2 shows the microstructures of the meta-stable layers with an amorphous structure, applied through plasma-jet thermal spraying and NiCr powders as following: sample 16 – steel sub-layer, sample 29 – brass sub-layer, sample 35 – copper sub-layer, sample 37 - aluminum.

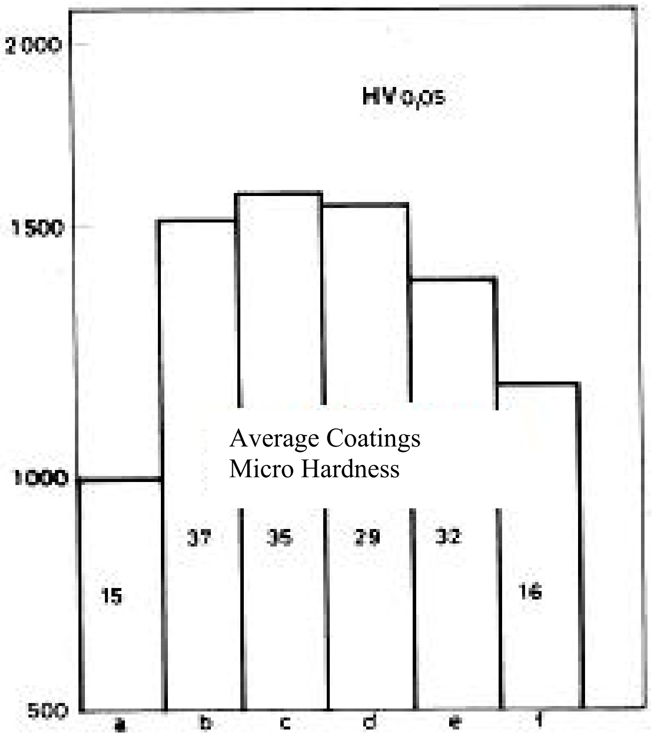

Fig. 3. Average values of the micro hardness applied through plasma jet and powder coating.

In the Figure 3, the micro hardness for the base materials (sub layers) are: sample a – steel; sample b – aluminum; sample c – copper; sample d – brass; sample e – copper; sample f – steel.

Judging by the dislocation theory, the material hardening is determined by the brake on the dislocation movement by the internal barriers, as grain limits, etc.

On amorphous materials, the stress limit coincides with the break limit, because the plastic deformation phenomenon is missing due to the lack of crystalline grains to stop the dislocation movement /2/.

The model that describes the best the amorphous state is Bernal – Scott. This model shows that in amorphous state, the atoms are densely and randomly paired (random dense packing) in an amorphous state, featuring mostly short-distance order, so that the atoms can’t align in ordered crystal structures on a long distance.

The short distance order is on a short field of 10...20 Å, being determined by geometrical restraints, due to atom size and their chemical links.

The amorphous phase ratio depends on the nature of the sub-layer material, as shown in Table 4.

The ratio of the amorphous phase on the plasma-jet applied NiCr powder was between 18,8% and 85,9% on the applied layers.

Table 4. Amorphous phase ratio determined through X-ray diffraction.

Sample Number	**Sub-layer type**	**Amorphous phase ratio %**	**Crystalline phase ratio %**
16	Steel	18,8	81,2
35	Copper	52,8	47,2
29	Brass	85,9	14,1
37	Aluminum	48,0	52,0

In order to obtain layers of the NiCr powder able to form 100% amorphous phases, the cooling speed must be increased, increasing the roughness of the alloy, due to the alloy degree increase, in order to disable the boride and carbide formation, those being dissolved in acid solution.

Conclusions

In order to obtain wear-resistant layers, hard materials are used, in powder form, or mixes of hard materials with matrix-forming components, usually applied with plasma-jets, or high-velocity flame. The commonly used materials are carbides, borides, silicates and/or oxides of metals found in the fourth, fifth and sixth groups of the periodic system.

Tungsten carbides are the roughest, closely followed by chrome, titanium, niobium, tantalum, and mixed tungsten-titanium carbides.

Adding boron and silicon to this hard alloy will help reduce the oxides, allowing autonomous flux properties to the alloy, facilitating the layer-sub layer metallurgic adherence, without the need of additional link layer when coating. Chrome (16%) increases the corrosion and oxidation resistance, boron and silicon have a pronounced effect on melting temperature decrease. Boron and carbon form together hard phases, increasing wear resistance. The novelty in this alloy is Yttrium, who decomposes slowly in water, even in normal conditions, and with less-active non-metals forms compounds with a metallic character, with high melting points like borides, carbides, silicates. Yttrium has a low atomic radius (1,801Ậ), and can easily defuse, raising layer adherence and intensifying the mutual inter-diffusion.

The wear resistance of thermal powdered layers applied on different parts is due to hard phases and metallic matrix characteristics, and it’s definitely influenced by the percentage of rough materials in the structure, by their type, shape, grain distribution. The matrix determines the coating’s mechanical and chemical resistance.

The fluidity of the NiCr powder is very good, because the NiCr alloy grains are 95% spherical, have no oxides on their surface, and look as formed by crystal grains.

On fast hardening, the cooling speed can’t be measured directly, but only through it’s effect – the microstructure of the thermal sprayed layers.

The powder particle of the NiCr alloy has a solid solution Ni - α and the eutectic with dispersed particles of Chrome Boride (4000HV) and Chrome and Yttrium Carbides (2500HV)

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Cercetarea experimentală a straturilor dure rezistente la uzură depuse prin pulverizare termică cu jet de plasmă

Rezumat

Rezistența la uzură a straturilor depuse prin pulverizare termică pe diferite piese se datorează atât fazelor dure cât şi caracteristicilor matricei metalice şi este influențată hotărâtor de procentul de materiale dure din structură, de tipul acestora, forma, distribuția granulometrică