17th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2013, Istanbul, Turkey, 10-11 September 2013

INCREASING OF MACHINE PARTS WEAR RESISTANCE BY NANOSTRUCTURING

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ABSTRACT
This paper presents the scientific rationale for the use of a new generation of functionally graded nano-(L = 50-500 nm) based on the Al-N, Ti-N, Ti-C, Al-O and Mo-S nanolayers (l = 1-10nm) on steel to improve durability for operation in extreme operating conditions of parts and units of machines and mechanisms
Keywords: steel, nanocoating, wear resistance

1. INTRODUCTION

Nowadays the need to create materials with new functional properties makes the search for new approaches to the synthesis of these materials [1]. The material of machine detail used in condition of friction must have a high wear resistance. According to statistics, most of the cars (85-90%) fail as a result of wear surfaces of the individual detail - bearings, shafts, gears, cylinder liners and other friction pairs. Costs for repairs and maintenance of the machine are several times higher than its cost. Creating a machine that does not require major repairs will save a huge amount of financial resources, labor and materials.

The main performance characteristics of machine details - wear resistance, strength, corrosion resistance, etc are largely determined by the state of the surface layer defined manufacturing technology [2].

Wear resistance and fatigue strength of the details are the main performance characteristics the increasing of which is ensured by the production of coatings by various technological methods.

Coatings and reinforcing micron layers long been used in engineering (carbidization and nitriding of surface details, deposition of hardening coatings, etc.). Known methods of hardening increases the wear resistance of products by 1.5-3 times [2]. But these results do not satisfy consumers as necessary to change the properties of the products of hundreds and thousands of times.

The most promising direction in the decision of these problems is based on the idea of creating a functionally graded materials (FGM) [1]. The main idea carried out in the synthesis of FGM is a combination of different types of material and using the advantages of each of them for the obtaining the functional properties. For most practical applications of functionally graded materials are developed in the form of a massive (micron) coatings.

This paper considers the possibility of making and using nanostructured functionally graded coatings, for example on the steel. Examples of formation nanostructured functional - gradient nanolayers on the steel with size (thickness) of 0.5-10 nm and material coating with a total thickness of up to 50-500 nm are given. The possibility of the implementation of the various spatial location of nanolayers in the synthesized nanocoating and regulation of the strength properties are discuss.

2. MATERIAL AND EXPERIMENTAL METHODS

Carrying out of the experimental work is based on our developed theoretical foundations of the method of surface design (ML-ALD) [3] and the proposed method of nanostructured functionally graded coatings (50-500 nm) represented the controlled to within 0.3 nm (monolayer) alternating in the order given nanolayers of substances (oxides/nitrides/carbides/silicide metal). This method can be used to produce metal parts with improved performance characteristics [3-5].

In this paper we investigate the relationship between the synthesized functional gradient nanocoatings with a given order of atoms in the volume of nanocoatings (see Fig. 1) and mechanical properties, for example, microhardness and wear resistance. The proposed synthesis method allows to make multilayer composite coating with alternating layers of different hardness or coating with a uniformly varying hardness.

This makes it possible to provide an optimal combination of wear resistance and fracture strength of coatings for various operating conditions coated parts.

Synthesis of functional gradient nanocoating (L = 50-500 nm) based on Al-N, Ti-N, Ti-C, Al-O and Mo-S nanolayers (l = 1 - 10nm) on steel (St-45H) was carried in the gas phase (dry nitrogen) at a temperature of 300^0C.

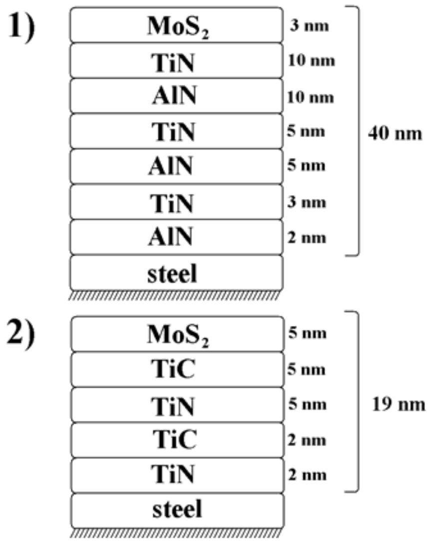

Fig. 1 Examples of (1 and 2) possible functionally graded nanocoatings on the steel: (1) the surface MoS_2 nanolayer, sharply increasing the wear resistance of all the material; (2) the surface MoS_2 nanolayer, protecting nanocoating from oxidation at high temperatures.

As the low molecular weight reactants used TiCl4, AlCl3, MoCl5, NH3, CH4, H2S. The thickness of nanolayers is regulate by the number of reactions cycles between the reactants. For example, in the synthesis of Ti-C monolayers on the steel surface the following reactions are proceed:

$$[Fe]_a - CH_3 + TiCl_4 \rightarrow [Fe]_a -C-TiCl + 3HCl\uparrow \quad (1)$$

$$[Fe]_a-C-TiCl + 0.5H_2 \rightarrow [Fe]_aC-Ti-H + HCl\uparrow \quad (2)$$

$$[Fe]_aC-Ti-H + CH_4 \rightarrow [Fe]_aC-Ti-CH_3 + H_2\uparrow \quad (3)$$

$$[Fe]_aC-Ti-CH_3 + TiCl_4 \rightarrow [Fe]_a-C-Ti-C-TiCl + 3HCl\uparrow \quad (4)$$

The method allows previously to obtain metal hardening and then antifriction coating, it is possible to regulate the hardening properties of nanocoatings.

3. RESULT AND DISCUSSION

Features of layers produced by chemical assembly is absence of phase formation at certain conditions of synthesis [4] (nucleation), which allows to obtain materials with better mechanical properties.

As can see from Figure 1, production method allows to put the pre-hardening and then the antifriction coating on the metal, it is possible to regulate the strength properties of n applied anocoatings. Moreover, when using the pastes based on MoS_2 usually steel friction coefficient lies in the range of values f_{fr} = 0,11 - 0,24, and for micron thick coating MoS_2 f_{fr} = 0,05 - 0,09, then for proposed method the coefficient of friction decrease of 0.01.

Table 1. Characteristic comparison of the produced material (steel with functionally graded nanostructured coating, Comparised material, ML-ALD) with a standard analog (CT15M (H05-H25) - alloy with wear resistant coating obtained by the method for the treatment of hardened parts, Comparised material, CVD)

№ п.п	Indicator name	Unit	Comparised material, CVD	Comparised material, ML-ALD
1	Type of coating	—	compositional multi-layer coating	compositional and multi-layer coating
2	Summer thickness of coating	nm	10000	50 - 500
3	Microhardness	GPa	Up to 40	from 40 to 80
4	Coefficient of friction	dimensionless	from 0,1 to 0,05	Up to 0,01
5	Wear resistance (mass loss during its operation for details)	dimensionless •)	At the level of $1x10^{-6}$	At the level of $1x10^{-8}$
6	Work temperature of detail	°C	Up to 500°C	Up to 700°C

•) according to the procedure wear rate determine in dimensionless form as the ratio of linear wear to the friction path for the time between a given mode

4. CONCLUSION

Discussed approach of the synthesis of new metallic materials allows to create a new type of coating materials of construction material — functionally graded nanocoatings that can meet the stringent performance requirements in industries such as energy, nuclear fusion, the petrochemical industry, the production of hydrogen engines, cutting tools, gas turbines and etc.

The main advantages of metal materials with functionally graded nanostructured coating in comparison with the currently available metallic material with a coating obtained by the CVD method are:

1) The increase in microhardness of samples from 40 GPa to 80 GPa;
2) Reducing the coefficient of friction from 0.05 to 0.01;
3) The increase Increased wear resistance (from $1x10^{-6}$ to $1x10^{-8}$);
4) The increase of detail temperature range on 200°C.

Work is executed at financial support of the Federal target program «scientific and scientific-pedagogical personnel of innovative Russia» for 2009-2013., state contract № 8575, of September 13, 2013.

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