INTRODUCTION OF NANOTECHNOLOGIES AT RAILWAY FACILITIES

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ABSTRACT

The paper considers one of the promising directions for obtaining nanopowders by grinding materials in mills of various types and high power, as well as by dispersing alloys with a liquid or gas stream. Such nanopowders can be used as additives in the foundry industry in order to obtain more substantial strength characteristics of products intended for railway equipment. Widespread introduction of nanotechnology will ensure the dynamic development of Russian transport engineering and the creation of economical, highly efficient equipment that meets the requirements of reliability and sustainable operation of the transport complex.

The main direction of the introduction of nanotechnologies at railway transport facilities is the use of nanopowders to harden the steels used for production of cars, rails, wheel sets and other strained parts of a railway train.

Given the increased need for nanotechnology and nanopowders in the manufacture of modern technology, the question of including in the training programs for specialists in the field of operation of the transport complex sections on the study of the properties and characteristics of nanotechnology and nanopowders is ripe.

Keywords: nanomaterials, nanopowders, nanotechnologies, technical means of railways, cars, high-speed railways, railway track, rolling stock.

Background. *Abroad and in the Russian Federation there is an accelerated construction of high-speed highways, attention is being paid to the creation of high-strength elements of rolling stock metal structures. High speeds of movement of trains required introduction of new materials for infrastructure of track facilities, car building, bridge building, manufacturing of rails, wheel sets and other products.*

Ability to find popular materials is the most important condition for the development of mankind. Therefore, it is not accidental that different periods of its history are named for the material that the person has mastered. The twentieth century is often rightly called «the century of steel». The twenty-first century can be considered a period of nanotechnology and nanomaterials.

Objective. *The objective of the authors is to consider introduction of nanotechnologies at railway facilities.*

Methods. *The authors use general scientific and engineering methods, comparative analysis, evaluation approach, modeling.*

Results.

1.

For centuries of history of its development, man has learned to create and use a huge number of different materials and substances. More than 20 million of them are known. Each species has its own unique properties: thermal, mechanical, electrical, magnetic, etc. Often the possibility of creating a technical device – an airplane, a rocket, a locomotive, a computer – is determined by the properties of the raw materials available to the designers. Orientation in all this diversity is impossible without knowledge of the laws governing the formation of properties of materials, their dependence on chemical composition, structure, heat treatment and other features.

In recent years, Russian Railways is one of the main consumers of the products of the ferrous metallurgy market: freight and passenger cars, rails, rail fasteners, switch gears, wrought wheels, axles and axial blanks, wheel sets, steel spare parts and components for technical means of railway transport.

According to various estimates, every year railway workers purchase about 800 thousand tons of rails on the Russian market and about 200 thousand tons of rail fasteners. In this situation, with the supplied steel products, which go both for the repair of rolling stock, and for the development, repair and maintenance of the railway track infrastructure, its share in the total value of consumed railroad material resources is about 30 %.

Given this, as well as the high concentration of the steelmaking industry, the presence of a large number of enterprises, accounting for 53 to 93 % of steel and steel products that are to be produced, the goals of nanoinnovations will require significant efforts to assist at all stages of introducing nanotechnologies in many of the positions requiring modernization. In particular, this includes the mechanical properties of materials: hardness, strength, ductility, elasticity, etc.

To strengthen the metal today, methods are used for thermomechanical processing of steel, surface hardening of steel parts, hardening by high-frequency currents, flame-hardening, aging, plastic deformation, and cold steel treatment.

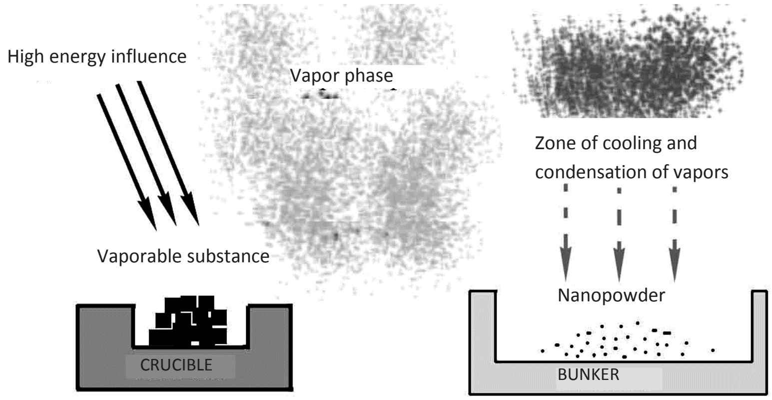
If the amount of deformation during processing is greater than the plasticity, the material will crack, break. To obtain large values of deformations, it is often processed step by step, conducting intermediate annealing. When heated, recrystallization occurs, after which the plasticity of the material is restored, the hardness decreases.

One way to improve the strength properties of steels is to alloy them, that is, add other metals to the metal or alloy as binding elements. Due to alloying the strength of steels increases by 5–10 times in comparison with pure iron, the material can be given corrosion resistance, heat resistance and other properties that increase its quality.

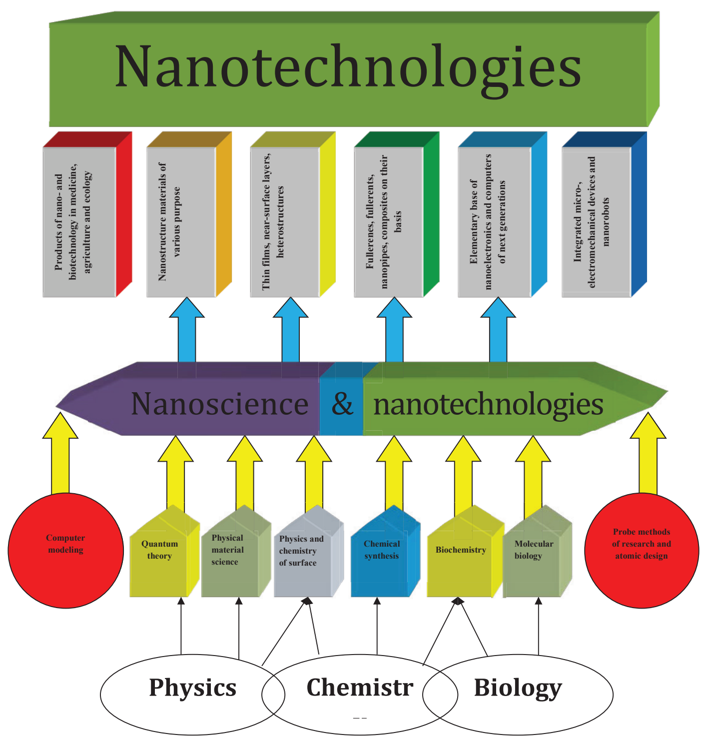
Alloyed steel is expensive, so they are produced in relatively small quantities and used where special material properties are required. Alloying is divided into surface and volumetric. When surface alloying elements are applied by high-temperature vacuum spraying or by electrolysis on the surface of the base material. In this case, the alloying properties of the metal are preserved until the surface layer is broken.

Volumetric alloying is carried out in the process of steelmaking. To do this, a rather large consumption of the alloying element is needed, but the alloying properties are preserved irrespective of the destruction of the surface layer of the metal.

The role of alloying elements – here we come to the main thing – can be performed by nanopowders,



Pic. 1. Preparation of nanopowder in a chamber with a controlled atmosphere.



Pic. 2. Areas of application of nanotechnology [2–4].

5

Pic. 2. Areas of application of nanotechnology [2–4].

prepared by special technology. One of the variants of this technology is shown in Pic. 1.

2.

Prospects for introduction of nanotechnology were considered by us earlier in a separate article [1]. Nanotechnologies have found wide application in various fields of science and technology (Pic. 2).

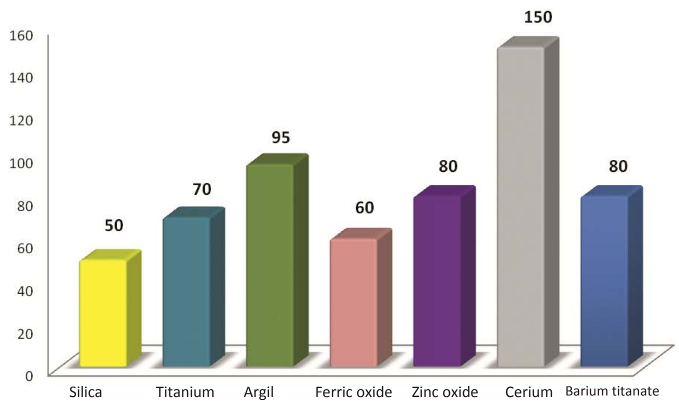
As a result of the research conducted by a number of authors, it has been established that the use as a dispersed phase of composite galvanic coatings of high-strength and wear-resistant nanopowders, a spherical shape based on tungsten carbide, with a particle size of 10–100 nm instead of 1–10 microns, makes it possible to increase the wear resistance of coatings of machine parts on average by 15–20 % (depending on the coating application regime and, consequently, the concentration of powder particles in the coatings obtained) [1].

On the basis of the method of depositing the powder of a hard alloy on a machine part, the

Table 1

The effect of alloying additives on the properties of steels

Alloying additives	Properties of steels					
	Hardness	Plasticity	Heat-resistance	Hardening capacity	Susceptibility to superheat	Strength
Chrome	+	–	0	+	+	+
Tungsten	+	0	+	+	+	+
Nickel	–	+	0	+	–	0
Vanadium	+	+	0	+	0	0
Molybdenum	+	+	+	+	+	0
Cobalt	+	+	0	–	–	+
Titanium	+	0	0	0	0	+
Manganese	+	–	0	+	–	+



Pic. 3. The price of one kilogram of nanopowders in mass production, in USD.

technology of electrodeposition of composite galvanic coatings (CGC) develops during their restoration and hardening. These are multi-purpose coatings. The essence of the method of precipitation of CGC is that, together with the metal from the galvanic bath, different powders fall on the component: oxides, carbides, borides or sulphides, as well as powders of polymers and metals. The inclusion of dispersed materials in the metal matrix significantly changes the properties of coatings, and most importantly increases their wear resistance, antifriction characteristics, thermal and corrosion resistance, which creates the prerequisites for the wide application of such coatings in a wide variety of devices.

Examples of the implementation of the deposition technology of CGC showed that galvanic coatings with dispersed phase have unique properties and can be used to solve complex innovative problems. The method has such advantages as comparative ease of coating directly on the part, relatively low cost, the possibility of automation of the process.

CGC are produced in various ways, but most often with the help of a galvanic bath. In the simplest version, an electrolyte is poured into the bath, the powder is poured, mixed, anodes are installed, a part is fixed on the cathode; the dispersed phase is maintained in a suspended state or transported to the cathode. When a current flows through the suspension, a coating is formed on the part.

The effect of alloying additives on the properties of steels is given in Table 1 [5].

The price of one kilogram of some nanopowders in mass production is shown in Pic. 3 [6].

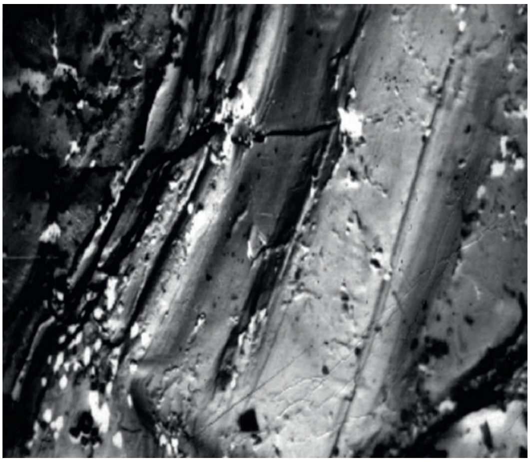
One of the large-scale directions of nanotechnology has been the synthesis and application of nanosized carbon fullerene-like structures, primarily nanofibres, nanotubes, graphenes, etc.

3.

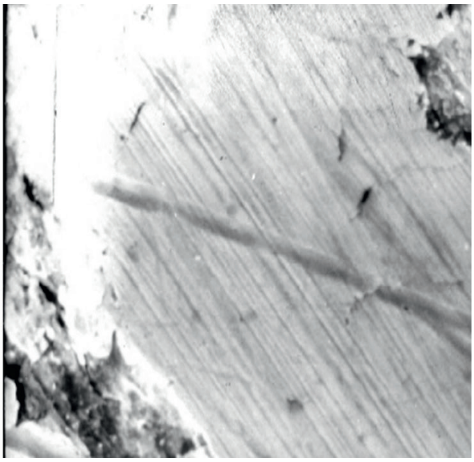
The discovery of new allotropic forms of carbon has attracted considerable interest from researchers all over the world and, as a result, an increase in the number of publications on nanocarbon materials in various sectors.

At the nodes of friction of machines and mechanisms of rail transport, antifriction materials with a metal matrix are now particularly widely used. The requirements for their tribotechnical and physicomechanical characteristics are increased due to increased operating loads and a reduction in the mass and dimensions of the mechanisms. Improvement of the properties of metal antifriction materials is possible just due to additives based on carbon nanostructures.

The application of coatings made of materials containing nanoscale elements on the friction surface is undoubtedly a promising option for reducing friction and wear in railway transport units. Modern technologies allow to apply coatings with a unique combination of characteristics that are fundamentally different from those of materials obtained by traditional methods. Composite coatings have a high hardness, corrosion and wear resistance. Moreover, these properties, coming from the presence of carbon nanostructures, are determined to a large extent precisely by the technology of applying protective layers to the surface of the parts.



before breaking-in



after breaking-in

Pic. 4. Changes in surfaces after breaking-in in with additives [7].

On the diesel locomotives of the Kuibyshev Railway, tests were carried out of the friction units of the machines, with the introduction of fluorinated graphite into the oil. Tests have shown that with this method the resource characteristics on average rise to 25 %, which is due to an improvement in the state of the surfaces of tribotechnical assemblies after running-in. The picture is illustrated in Pic. 4.

One of the current problems of electric transport is the increase in reliability and increase in the life of the current-collecting unit, designed to transfer electricity from the contact wire to the electric rolling stock. Now the current-carrying elements are made of copper and its alloys, aluminum alloys, low-carbon graphitized steel, powder materials on iron and copper bases, carbon and metal-carbon compositions. A promising one is the introduction of carbon nanostructures into such composites [8].

Conclusions. *The introduction of nanotechnology allows to ensure the dynamic development of Russian transport engineering and the creation of cost-effective, highly efficient equipment that meets the requirements of reliability and sustainable operation in a transport complex.*

The main direction at the railway transport facilities became the use of nanopowders to harden the steels used for the production of cars, rails, wheel sets and other strained train parts.

The specificity of the electronic structure of new allotropic carbon modifications gives nanomaterials unusual physicomechanical properties, which allows them to be considered as promising modifiers for composites with improved tribotechnical, mechanical and electrical properties.

Taking into account the increased need for nanotechnology and nanopowders in the manufacture of modern technology, the question has arisen of including in the training programs of specialists in the field of operation of the transport complex sections aimed at studying the properties and characteristics of nanomaterials, their technological features and design advantages.

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