Influence of additions of nanoparticles TaC on a microstructure laser cladding

M A Murzakov¹, V N Petrovskiy¹, V I Polski¹, V D Mironov¹, N M Prokopova¹, E V Tret'yakov²
¹National Research Nuclear University MEPhI, Moscow, Russia
²NPO CNIITMASH, Moscow, Russia
E-mail: VNPetrovskij@mephi.ru

Abstract. The features of a laser cladding of nickel-based powders with TaC nanopowder additives have been experimentally investigated. The minimum depth of pro-melting of a basis, microhardness distribution over the cross section of the substrate, and the saturation of the metal of the cladding with basis components has been determined in the experiments.

1. Introduction
Laser cladding is applied to the surface of the workpiece coating by melting the filler material. Moreover, since the base melts minimally coating properties mainly depend on the properties of the filler material [1].

Nanostructured coatings are the following step in the development of functional coatings. The modern mechanical engineering sets tasks of decrease in coefficient of friction at preservation of wear resistance, increase of coating viscosity together with preservation of anticorrosive properties. And answers to these questions can be found in application of nanocoating. Nanostructured coatings in a thickness from a few to hundreds of microns have properties of superior wear resistance, corrosion resistance not only in relation to the main material, but also to traditional coating [2-3]. Due to its unique properties, radically different from the properties of the macro- and micropowder of identical composition, nanopowder injected into the molten pool contributes to its modification, causing redistribution of harmful impurities between grain boundaries and reducing their size. Refractory nanoparticles having a melting point of over 1600°C can act as centers of crystallization.

2. Experimental setup
The experimental setup for cladding structurally consists of the following major parts:
- Robot ABB;
- ABB robot control unit;
- Fiber laser;
- Chiller;
- Scanning laser head;
- Control unit of the scanning laser head.

In the course of this work fiber laser LS-5 power of 5 kW and scanning laser head has been used.

The microstructure of deposited coatings was investigated using an optical metallographic microscope Neofot 30 manufactured by Carl Zeiss Jena (Germany) with magnification of the microscope 500x. Determination of the elemental composition of the samples was carried out by X-ray microanalysis in the analytical scanning electron microscope at an accelerating voltage EVO-50 10-20 kV (probe current 5-50 nA) using:
- energy-dispersive spectrometer of the INCA x-ACT with a resolution 133 eV produced by Oxford Instruments (UK);
3. **Technique of the experiment**

Experiments were made with use of standard powder on the basis of nickel 1350 made by, chemical composition of which is given in Table 1 and also when using powder 1350 with additives of nanopowder tantalum carbide (TaC).

**Table 1.** Chemical composition of the powder based on nickel 1350 and substrate.

|          | Ni  | C   | Fe  | Cr  | B   | Si  |
|----------|-----|-----|-----|-----|-----|-----|
| Powder 1350 base | 0.45 | 2.9 | 11.0 | 2.3 | 3.6 |
| Substrate | 0.12 | 0.17 | 98.54 | 0.14 | - | 0.42 |

Laser cladding of standard powder on the basis of nickel and powder with additives of TaC nanopowder was carried out on flat surfaces of substrates from low-carbonaceous steel, chemical composition of which is given in Table 1.

Before the experiments on a laser cladding both with standard metal powder on the basis of nickel, and standard powder with TaC nanopowder additives, the powder about 1 mm thick layer was put on a flat surface of samples beforehand with use water solution of cellulose as binding substrate.

When carrying out experiments on a cladding with additives of nanopowder mixes with concentration of nanoparticles of 10% and 20% were used. During the experiments the following parameters of a mode of processing were changed:

- Radiation power;
- Linear speed;
- The size of a laser radiation spot on a surface of a built-up sample.

Power of radiation varied in the range from 1500 to 3000 W with a step of 200-300 W, the speed of a cladding changed from 5 mm/s to 20 mm/s, with a step of 2-3 mm/s. The defocusing made +230 mm and +150 mm.

4. **Microstructural researches of obtained laser claddings**

Figure 1 presents microsection of laser cladding of standard powder on the basis of nickel 1350 with the indication of points of detailed shooting of sample structure. Cladding has sharp border with a substrate. The material of a cladding does not get deeply into a substrate, but has good coupling with a substrate.

![Figure 1. General view of laser cladding microsection of standard powder on the basis of nickel 1350.](image)

Figure 2 presents detailed photos of a microstructure of a cladding in the points designated by numbers 1-5 in figure 1.
Structure of the top part of a cladding (point 1) – large equiaxed grains with early stages of dendrites. The central part of a cladding (points 2 and 3) – dendritic structure, characteristic for the congealed melt. Point 4 is sharp transition from structure of the stiffened fusion of a cladding to structure of the zone of thermal influence (ZTI). Point 5 (ZTI) is structure, typical for needle martensite. Substrate structure is typical hypoeutectic steel: rather equiaxed grains of ferrite and perlite. Size of ZTI is insignificant (~ 300 microns).

In figure 3 results of microhardness measurement of a standard powder cladding on the basis of nickel 1350 are presented.

In figure 4 the microstructure of a cladding of standard powder 1350 with addition of TaC nanoparticles with concentration of 20% is shown.

In figure 5 detailed structure of a cladding of standard powder 1350 with nanopowder TaC additives. a) point 1; b) point 2; c) point 3; d) point 4; e) point 5 in Figure 4.
The main regularities of structure change are the same, as on the previous cladding with standard powder on the basis of nickel. Differences are in the following:

- in a body of a cladding a large number of finely divided inclusions (Figure 5a, c) is observed;
- the element analysis showed that black impregnations are chrome carbides, white impregnations are tantalum carbides;
- the ZTI area from a cladding decreased to 10 microns;
- the ZTI general area also decreased to ~ 200 microns.

The maximum microhardness is in a cladding (~ 4500 MPas), minimum is in a steel substrate (~ 1800 MPas).

As the conducted researches showed, microhardness of a cladding with additives of nanopowder of carbide of tantalum differs from the microhardness of a cladding of standard powder on the basis of nickel. And the tendency of increase in microhardness with reduction of concentration of TaC nanoparticles is shown.

The specified result is explained by the fact that in the course of cladding melted main powder and particles of nanopowder of a refractory material mix up. As nanoparticles of a refractory material have melting temperature higher, than temperature of a molten pool, they remain in a molten pool in a firm state and at the subsequent crystallization of metal of a molten pool are the centers of crystallization of forming crystallites and strengthening particles in the nanodimensional range.

5. Conclusion
Comparison of laser cladding structure obtained with use of standard powder on the basis of nickel and standard powder on the basis of nickel with additives of carbide of tantalum nanopowder with different concentration is carried out.

It is shown that microhardness of a cladding with carbide of tantalum nanopowder additives differs from the microhardness of a cladding of standard powder on the basis of nickel. And the tendency of increase in microhardness with reduction of nanoparticles of TaC concentration is shown. Increase of microhardness shows advantages of developing of surface layer with high operational characteristics with use for a cladding of standard metal powders with nanopowders of refractory materials additives.

Acknowledgments
The study was supported by the RFBR (project no. 14-02-00369-a) and the Ministry of the Education and Science (unique identifier PNIER RFMEFI58214X0004).

References
[1] Grygoryants A G, Shiganov I N, Misyurov A I 2008 Technological processes of laser processing M.:MGTU, 664.
[2] Chen C, Zhang M, Chang Q 2008 Laser in Engineering. 18 85
[3] Xue-song G, Zong-jun T, Zhi-dong L 2012 Transactions of Nonferrous Metals Society of China 22 2498