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Microstructure of Modified Layer Produced Using Aluminum Oxy-Hydroxide Nanostructured Powders

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Abstract. The paper provides the results of experimental research into the influence of aluminum oxy-hydroxide nano-structured powders on the microstructure of modified layers. It has been demonstrated aluminum oxy-hydroxide nano-structured powders AlO(OH) applied as modifiers bring about the decrease in dendrite dimensions, support equilibrium microstructure formation, and cause the growth of microhardness.

1. Introduction

Mechanical, technological and service properties of modified layers are strongly dependent on form and dimensions of grains arisen from crystallization [1, 2, 3, 4, 5, 6, 7, 8]. It is modifying that can have a significant effect on grain dimensions. The most-pronounced outcome of modifying is provided under input of fine-grained particles into the melt. The fusion temperature of these particles exceeds that of steel. At present input of nano-dispersed metallic and non-metallic powders into metal to improve steel structural strength in modified layers is considered a promising method of modifying [9, 10, 11, 12].

The paper provides consideration of surface layer modification by aluminum oxy-hydroxide nano-structured powders.

2. Methods of Research

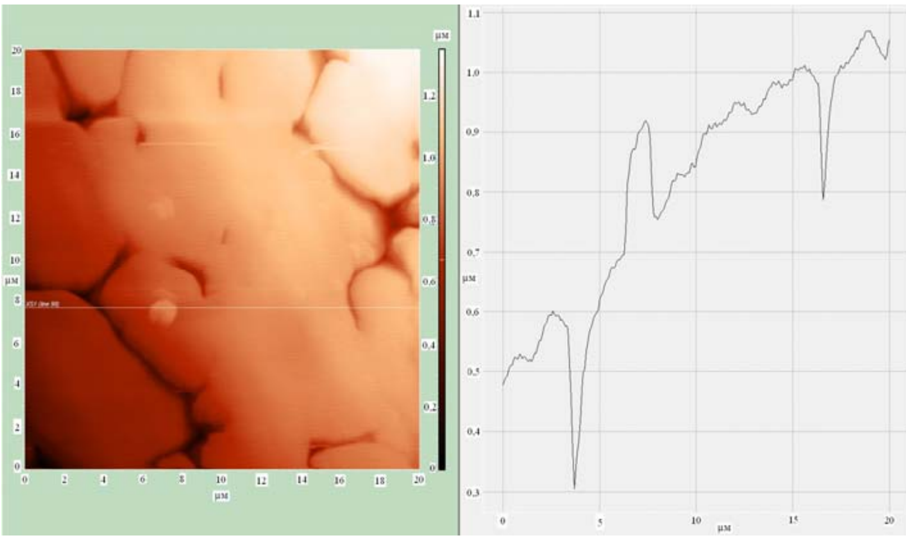
Samples of modified layers to carry out experiments were produced from austenite grade steel (chemical composition of the wire: 0.12% carbon, 18% chromium, 9% nickel; 1-15% titanium) via welding with consumable solid electrode wire 1.2 mm in diameter in argon atmosphere.

The samples were made according to two technologies: 1 – solid wire in argon atmosphere; 2 – solid wire in argon atmosphere supplemented with nanopowder AlO(OH) with the appliance designed by the authors and specified in [13]. Rational concentration of nano-structured powder in the shielding gas was calculated in view of methods provided in paper [14].

Metallographic sections were made and etched in each sample in terms of the mode described in [13]. Investigation into the structure of surfaced metal was carried out by atomic-force microscopy (AFM) with microscope Solver PH47-PRO.

3. Results and Discussion

A modified layer has been found out to consist of two sub-layers with considerably various structures. Main microstructure of the first adjacent to the free surface sub-layer consists of relatively short, highly-branched dendrites without a preferred orientation (Fig. 1).



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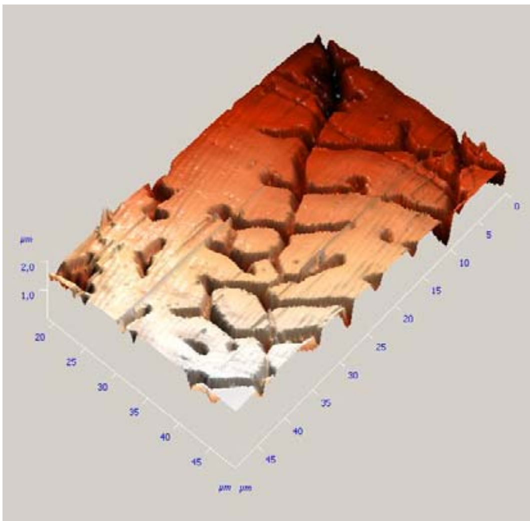

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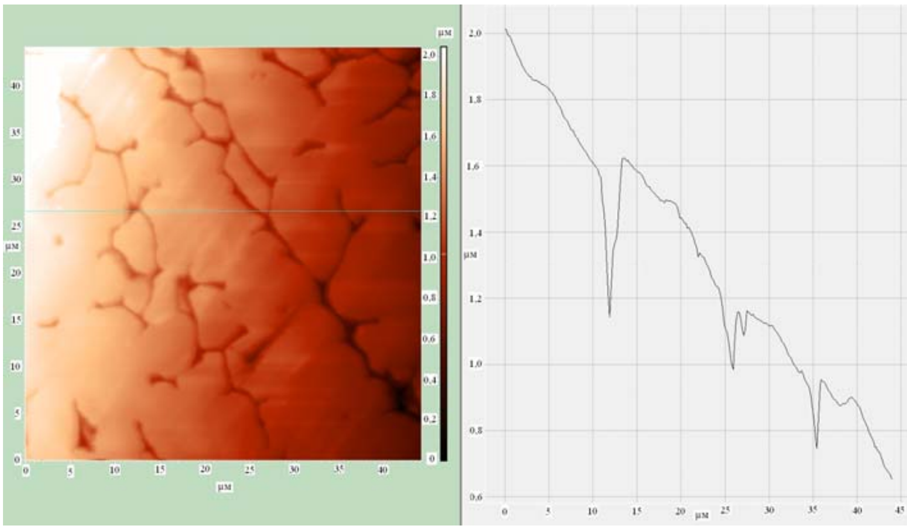
Figure 1 AFM 2D-image (a) and AFM 3D-image (b) of dendrites in the first sub-layer of Sample 1

The profilogram of 2D-image makes it possible to identify dendrite boundary width, which does not exceed 300 nm. 3D-image (Fig. 1 b) shows the overall view of short dendrites. They actually do not have a highly pronounced orientation towards the heat flow directions. Branches («branch pieces») of dendrites in this layer of Sample 1 without a modifier are not long (5…10 µm) as if compared with the axial length of a dendrite.

The layer of non-oriented dendrites is mostly pronounced in Sample 2 modified by nano-structured powder AlO(OH) (Fig. 2), the thickness of this sub-layer approximates to 1.5 mm. The dendrites build a practically gapless net in the sample without a modifier, whereas free surface spots can be found in the sample modified by nano-structured powder AlO(OH); the grain boundaries can't be identified there. The layer thickness of weakly-oriented dendrites in Sample 2 approximates to 1.2 mm.

Atomic-force microscopy has revealed the identity of dendrite boundary width in Sample 2 modified by nano-structured powder AlO(OH) to that in Sample 1 without a modifier (Fig. 2 a). It increases up to 1 µm in the contact points of adjacent dendrites.



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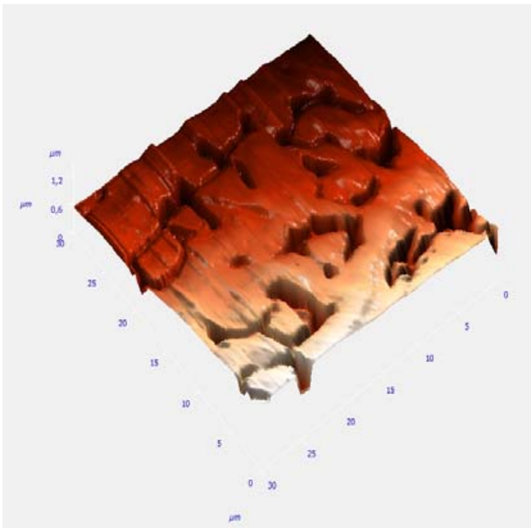

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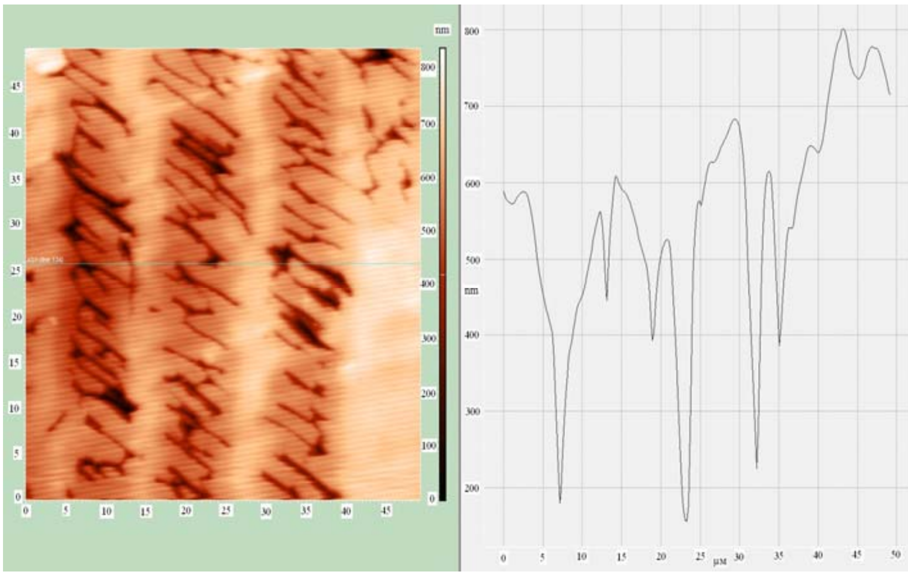
Figure 2 AFM 2D-image (a) and AFM 3D-image (b) of dendrites in the first sub-layer of Sample 2

The overall view and orientation of short dendrites in this layer of Sample 2 modified by nano-structured powder AlO(OH) (Fig. 2 b) is similar to the overall view of dendrites in Sample 1 without a modifier.

The layer of relatively short, highly-branched dendrites without a preferred orientation turns gradually into the next layer of oriented dendrites.

The orientation of dendrite long axes in the layer under consideration gets normal towards the fusion boundary – along the direction of heat flow into the base metal.

They form stripes separated by free surface spaces with unidentifiable grain boundaries close to the fusion boundary in Sample 1 without a modifier (Fig. 3). Long axes of dendrites are nearly parallel in each stripe, and there is no branching there.



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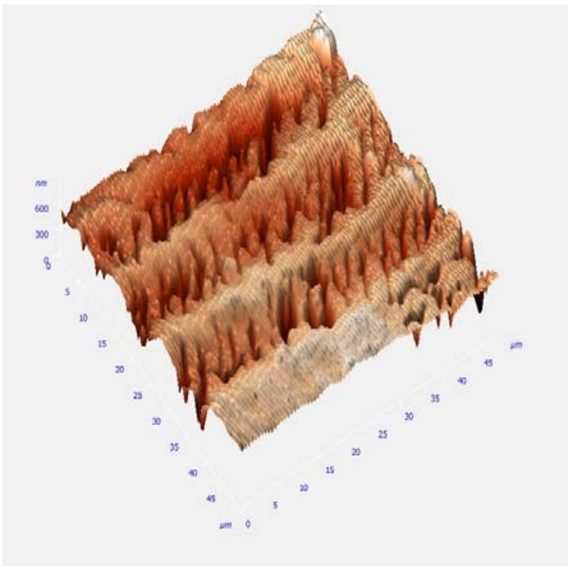

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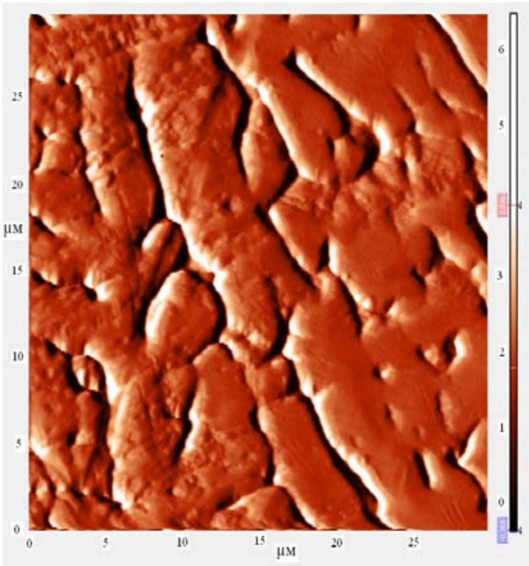
Figure 3 AFM 2D-image (a) and AFM 3D-image (b) of dendrites in the second layer of Sample 1

There are no dendrite stripes in Sample 2 modified by nano-structured powder AlO(OH), although parallelism of dendrite long axes is distinct there (Fig. 4).



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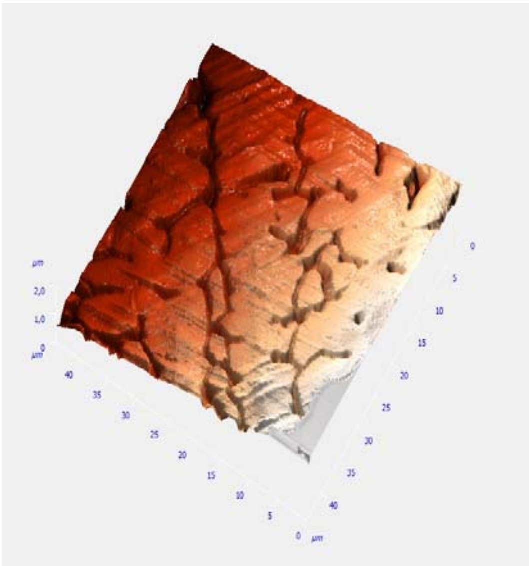

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Figure 4 AFM 2D-image (a) and AFM 3D-image (b) of dendrites in the second layer of Sample 2

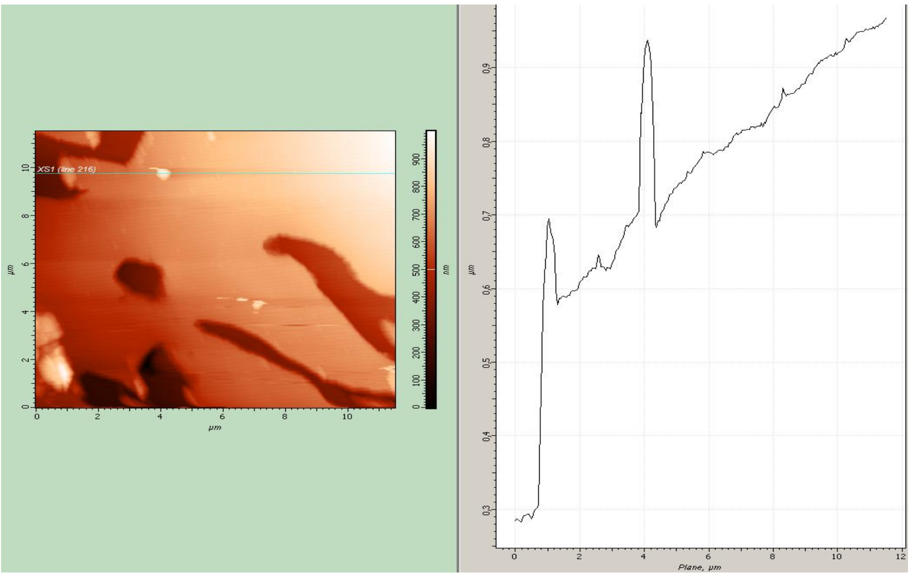
A more equilibrium structure of deposit according to dendrite dimensions is formed in the sample modified by nano-structured powder AlO(OH). That is, the average dendrite of the non-modified sample is 20-25 µm wide, and 1.2-1.6 µm thick, whereas the width and the thickness of the average dendrite in the sample modified by nano-structured powder AlO(OH) are 5-7 µm and 09-1 µm, respectively.

Application of nano-structured powders AlO(OH) affords ground for the influence on the composition and structure of the surface layer. It has been found out the surface layer has a layered structure due to the changing conditions of heat removal alongside with the depth of the liquid pool. Oriented dendrites occupy approximately a half of the surface layer volume. There is also a layer of non-oriented dendrites.

In view of generally accepted notions the more distinct the dendrite structure of the surface layer and the coarser structure of a dendrite are, the worse service properties products have.

Viewed in this way Sample 1 without modifiers yields to Sample 2 modified by nano-structured powder AlO(OH). That is, microstructure of a surface layer modified by nano-structured powder AlO(OH) is finer-grained, and equilibrium.

Atomic-force microscopy made it possible to discover secondary phase particles in the body of dendrites, especially near their boundaries. These particles are found both in Sample 1 without a modifier and (Fig. 5) and Sample 2 modified by nano-structured powder AlO(OH) (Fig. 6).



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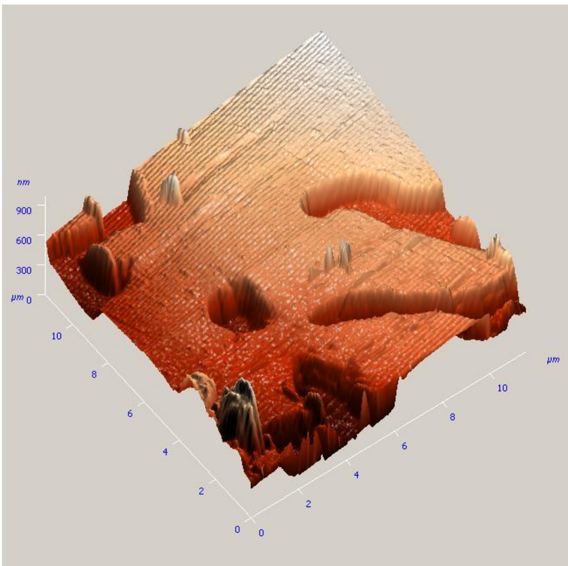

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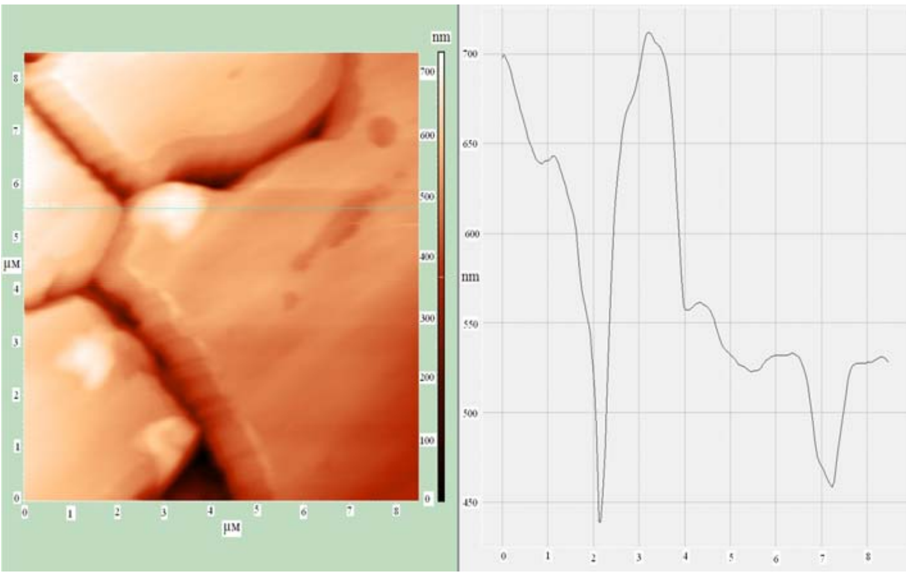
Figure 5 Secondary phase impurities in Sample 1 AFM 2D-image (a), and AFM 3D-image (b)

The mean diameter of these particles is 0.5…2 µm; and the height over the surface is 150…300 µm. Although we could not identify the composition of these particles, an assumption has been made they are conditional on the process of modifying.



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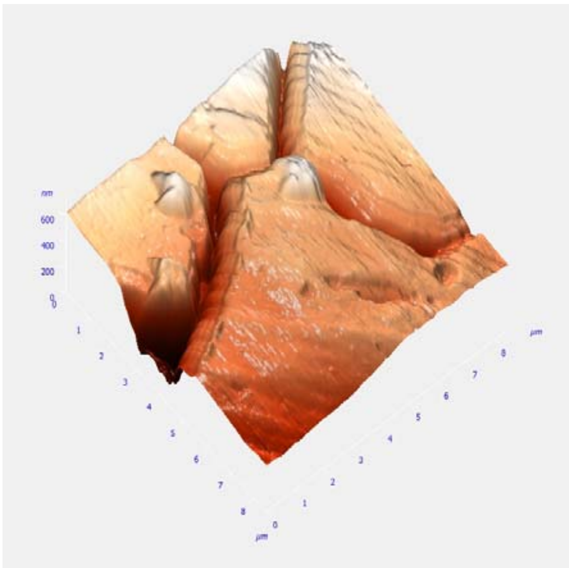

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Figure 6 Secondary phase impurities in Sample 2 (a) AFM 2D-image, and AFM 3D-image (b)

The change in microhardness (MPa) is depicted in Figure 7.

The microhardness of sub-layers comes down near the base metal. In sub-layers with a modifier microhardness is higher, especially in the second sub-layer.

In conditions of using the modifier AlO(OH) obtained from interaction of electro-explosive aluminum nanopowder with water microhardness is 14-16% higher than without a modifier.

Therefore, microhardness confirms a layered structure of the surface layer and emphasizes the influence of modifiers making the structure finer.

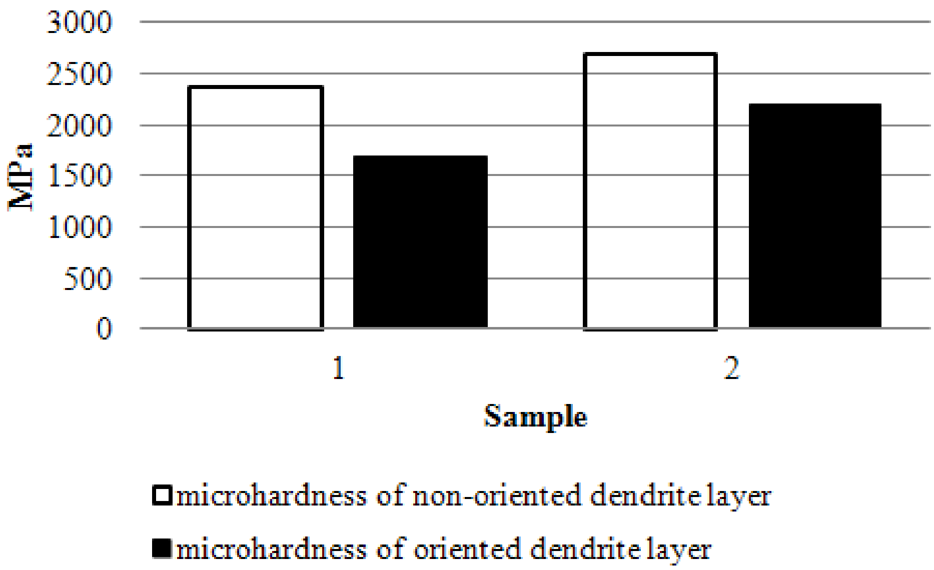

Figure 7 Influence of modifiers on the microhardness:

1 – Sample 1 without a modifier, 2 – Sample 2 modified by AlO(OH) powder

4. Conclusions

1. It has been found out nanostructured aluminum oxy-hydroxide powder supports surface layer modification.

2. We have determined the input of nanostructured AlO(OH) powders into the surface layer brings about the maximum effect of system Fe-C-Cr-Ni-Ti modification and improves service properties of the surface layer. It is caused by additional centers of crystallization forming in the melt. These centers are inoculators in crystallizing metal. The average dendrite is 1.5-2 times thinner (30-40%), and 2-3 times narrower (45-55%).

3. Nanostructured AlO(OH) powder applied as a modifier supports production of a more equilibrium structure of deposit according to dendrite dimensions.

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