Subminiature eddy current transducers for studying boride coatings

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Abstract. Strengthening of parts and units of machines, increased reliability and longer service life is an important task of modern mechanical engineering. The main objects of study in the work were selected steel 65G and 50HGA, wear-resistant boride coatings ternary system Fe–B–FeₙB which were investigated by scanning electron microscopy and eddy-current non-destructive methods.

1. Introduction

In modern industry, enormous attention is paid to improving the reliability of parts and increasing their service life. Strengthening of parts and units of machines, increased reliability and longer service life is an important task of modern mechanical engineering. There are two different approaches to resolve this issue: the use of high-strength and wear-resistant materials and the processing of existing traditional materials can significantly increase the strength and other characteristics of the components. When processing materials with a view to improving operational characteristics of components, occupies an important place receiving and research of wear-resistant coatings suitable for use in the movable conjugations and working elements machines.

Currently, greatest distribution was received the hardening of details by means of induction hardfacing hard alloys and white cast iron. Nevertheless, the results of tests performed in the work – show that the most promising class of materials with a maximum erosion resistance is the hard coating (H > 10 GPa) made on the basis of metal carbides. However, among the factors influencing the erosion resistance, relates the thickness of the applied coating, its modes of deposition and the quality of the preliminary surface preparation. For example, for a titanium alloy, decrease the coating thickness to less than 15 μm led to a significant reduction in the erosion resistance.

As an promising materials for protective-strengthening coatings, offered matrix composites based on the ternary system Fe–B–FeₙB, formed directly on the surface of the reinforcing parts, when it boriding in conditions of induction heating of the charge of the original composition and the various functional fillers.

Coating the ternary system Fe–B–FeₙB formed by induction heating on the surface of the reinforcing parts when passing exothermic topochemical reaction between iron steel and boron the charge, the reaction captures the surface layer of the base-material and the reaction products form with it a single whole and characterized by smoothly changing the chemical composition of the transition at the interface base-coat that determines their high adhesion strength and wear resistance, special properties.
2. Materials used and the methods
The main objects of study in the work were selected steel 65G and 50HGA, wear-resistant boride coatings ternary system Fe–B–Fe₃B which were investigated by scanning electron microscopy (Philips SEM-515) and eddy-current non-destructive methods (ECT) [1, 2].

3. Materials used and the methods
The studied compositions of two-component mixture for boriding, applied to the steel specimens 65G, 50HGA as composition based on a liquid glass, the hydrolyzed ethylsilicate or polymer-based for boriding using induction heating, are presented in table 1.

| Composition | Component 1/mass %/base component |
|-------------|----------------------------------|
| 1           | B₄C/92                           |
| 2           | B₄C/84                           |

Table 1. Formulations composition for wear resistant coatings using induction heating.

Four main types of structures wear-resistant boride coatings produced using induction heating, have been found (figure 1): (a) – in the form of iron-boride eutectic carbide with closed regions; (b) – coating consisting of boride manganese crystals in the form of plates arranged in a softer matrix of a ledeburite-like, iron-boride eutectic; (c) – structure in the form iron-boride eutectic with large grains; (d) – a covering consisting of needle crystals manganese boride or chromium, disposed in a softer matrix of iron-boride ledeburite-like eutectic.

Figure 1. Types of structures wear-resistant boride coatings.
On figure 2(a) is represented by microhardness distribution in thickness boride coating obtained by using the composition 2 for different times, which shows that the coating is obtained for 76 and 106 s, has a higher microhardness (HV100 13 770 MPa) as compared with coatings obtained in 120 and 136 s, or, for example, a coating formed from the composition 1 at the same time boriding. Figure 2(b) shows the results of wear resistance tests boride coatings obtained on steel 65G using induction heating in the formulations 1 and 2 for different times.

![Figure 2](image)

**Figure 2.** Microhardness distribution in thickness (a) and the wear resistance of boride coatings on steel 65G (b) obtained from formulations 1, 2 (table 1) for different times.

Scanning the sample was carried out using two differentially connected sensors. Scan scheme is shown in figure 3.

![Figure 3](image)

**Figure 3.** Scan scheme.

Figure 4 shows the results of studies of coatings produced using the eddy-current method. A clear link electromagnetic and strength characteristics of the coating was established. When scanning the sample with no coating, the rate of fall of the signal amplitude, carrying information about the properties of the substance considerably exceeded the rate of fall of the signal when the sample is scanned with coatings. Comparison of test results shows the presence of the dependencies between the electromagnetic characteristics and wear resistance of coatings.

Increased wear resistance of hardened layers with increasing of time induction heating in the composition 2 (table 1) explained by a decrease of hardness the main strengthening phase. This permits asserting that the characteristics of boride coatings obtained on the structural and alloyed steels using induction heating, do not change monotonically and have a certain optimum in their function of time.
To control these characteristics, it is advisable to use non-destructive eddy-current methods to promptly investigate the resulting coatings and draw conclusions about their quality.

References
[1] Malikov V N, Dmitriev S F, Sagalakov A M and Ishkov A V 2014 Instruments and experimental techniques 6 751–4
[2] Dmitriev S F., Katasonov A O, Malikov V N and Sagalakov A M 2016 Russian Journal of Nondestructive Testing 1 32–7