TECHNICAL INFORMATION

CHARACTER OF DISTRIBUTION OF THE ELEMENTS AND THE COMPOSITION OF THE INCLUSIONS IN BORON MICROALLOYED GRAY IRON

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Microalloying of gray iron with about 0.02% boron causes refinement of the primary structure and the formation of fine lamellar graphite and a uniform dispersed pearlitic matrix in casting in a sand mold. At the same time there is a significant change in the antifriction characteristics and wear resistance of the alloy under different conditions of friction and wear and a significant increase in the load for seizing and galling.

The nature of such specific tribotechnical properties of boron microalloyed gray iron has been investigated far from completely. In particular, the question of the influence of boron on the composition and distribution of the inclusions in the microalloyed gray iron remains insufficiently studied and discussed. This question is especially important since it makes it possible to determine the mechanism of the increase in tribotechnical properties of gray iron in microalloying of it with boron.

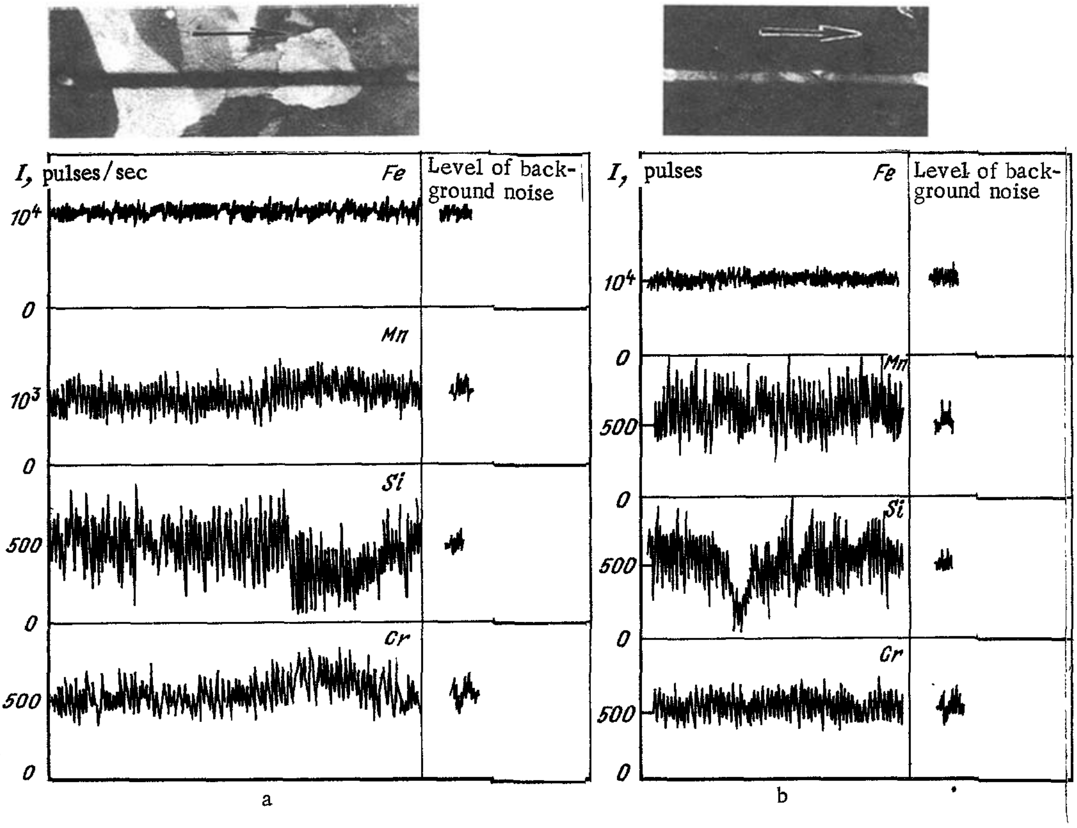

Fig. 1. Microstructure (800×) and Fe, Cr, Mn, and Si distribution in the pearlite of unalloyed (a) and boron alloyed (b) gray iron.

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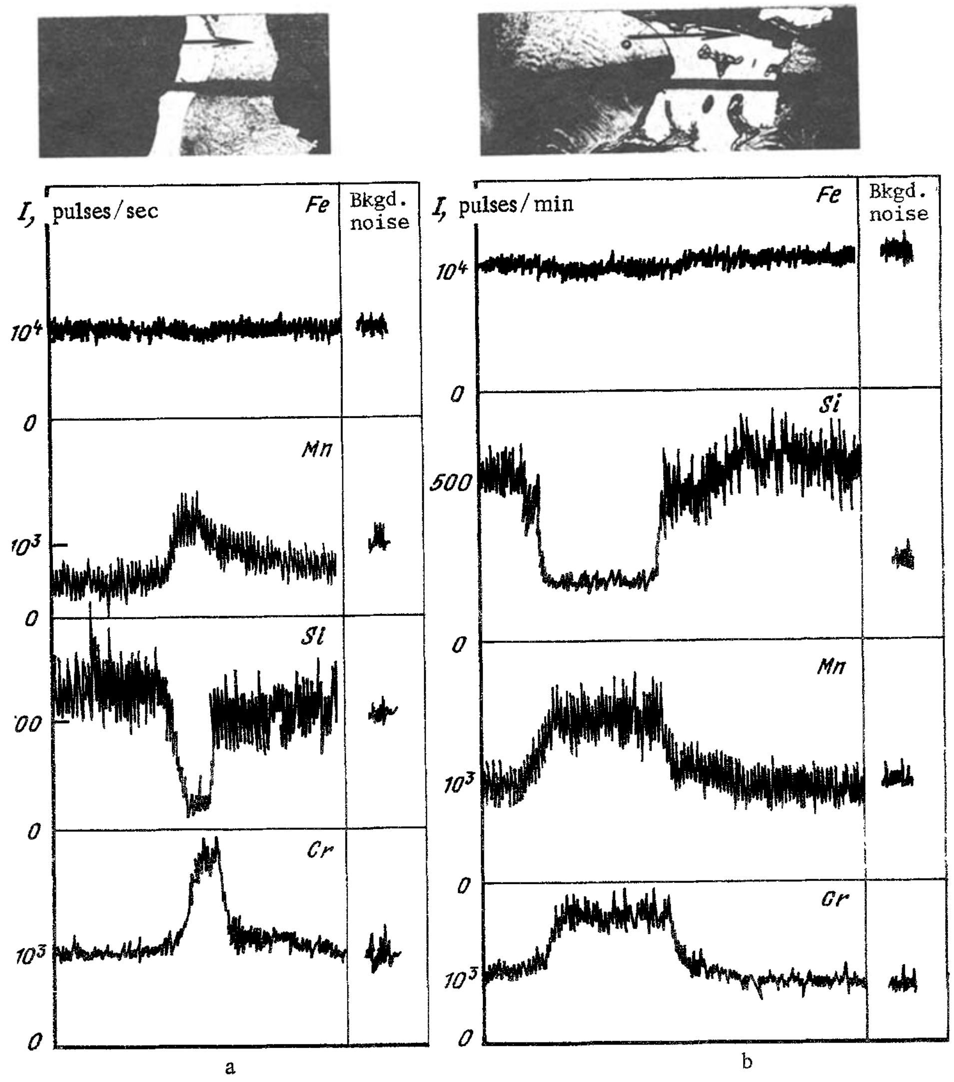

Fig. 2. Microstructure (800×) and Fe, Cr, Mn, and Si distribution in a carbide inclusion and phosphide eutectic of unalloyed (a) and boron microalloyed (b) iron.

The influence of microadditions of boron on the character of distribution of Mn, Cr, and Si in gray iron and the composition of the inclusions formed were studied. The irons were melted in an IST-016 160-ton electric induction furnace. The original charge materials were type L5 foundry cast iron, steel scrap, and production returns. After melting of the charge its temperature was increased to 1600-1630°C and the copper added. After holding of the metal for 3-5 min the iron was poured into a ladle heated to 600°C on the bottom of which were the calculated amounts of FB-1 ferroboron and SK-30 calcium silicide. Castings were produced in parallel without the addition of boron.

The iron castings produced in such a manner* had a chemical analysis of 3.15% C, 1.84% Si, 0.43% Mn, 0.71% Cu, 0.025% S, and 0.25% P. The iron castings microalloyed with ferroboron also contained 0.02% B.

To investigate the influence of microadditions of boron on the character of distribution of the elements in the matrix of the iron and to determine the composition of the inclusions metallographic, electron microscopic, and spectrographic investigations and micro-x-ray spectral (on a CAMECA MS-46 microprobe) and x-ray diffraction analyses were made.

The metallographic investigations made it possible to establish that microadditions of boron to gray iron with simultaneous economical alloying with copper provides the formation of a uniform dispersed pearlitic structure. At the same time the character of distribution

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*The experimental heats of iron were cast under the supervision of V. A. Priimak.

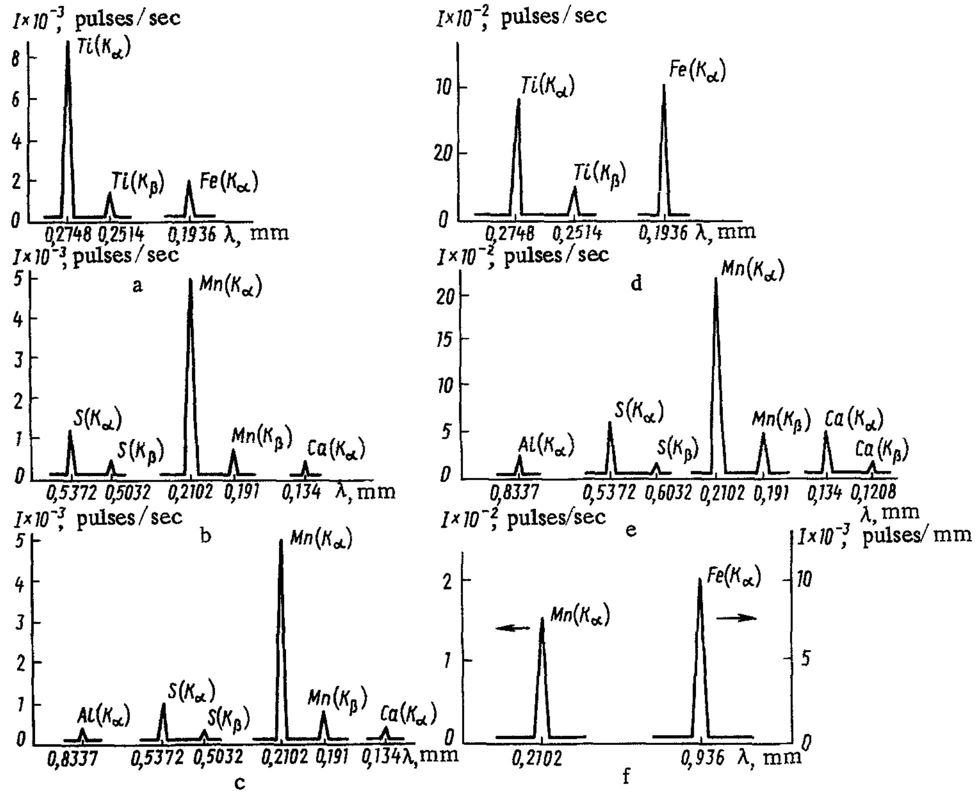

Fig. 3. Spectra of the characteristic x-radiation from inclusions in gray iron without additions of boron (a-c) and microalloyed with boron (d-f): a, d) titanium carbonitride; b) Mn and Ca sulfide; c, e) complex Mn, Ca, and Al oxysulfide; f) borides.

of Si, Mn, and Cr in the iron does not change and practically uniform distribution of them in the pearlite is observed (Fig. 1). Only some change in Si and Mn content in different grains of the pearlite constituent of the irons and also in the grain boundaries may be noted. There is a significant change in the Si, Mn, and Cr concentration in the areas of the phosphide eutectic and in individual comparatively small inclusions of carbides (Fig. 2).

Investigation of the composition of the inclusions in the boron microalloyed iron was of special interest. Metallographic investigations made it possible to establish that in the gray iron not alloyed with boron in the as-cast condition the following types of inclusions are formed: 1) bounded, primarily of rectangular or rhomboid form, coarse inclusions of pinkish color with a size of 5-10 μm; 2) bounded inclusions of gray color with a size of d_t = 3-5 μm (in the transverse direction) and more rarely up to 10 μm; 3) dark apparently oxidized inclusions of irregular form; 4) complex "double" inclusions with a center round darker portion and a peripheral lighter zone (size d_t = 3-5 μm).

In the boron microalloyed iron there are practically no gray bounded inclusions but dark inclusions of round form (d_t < 0.5-1.0 μm) are observed. In addition all of the inclusions are significantly finer.

As the result of petrographic investigations it was established* that in the unalloyed gray iron comparatively coarse bounded (size 4-10, more rarely 1-3 μm) inclusions of nitrides, carbonitrides, and oxynitrides of titanium are encountered most frequently and also gray bounded inclusions of manganese sulfides.

The addition of ferroboron causes not only refinement of the primary structure of the alloy and a decrease in graphite size but also a change in the composition, dimensions, and morphology of the nonmetallic inclusions. For example, the size of the inclusions in the boron microalloyed gray iron as a rule does not exceed 1-2 μm. They are primarily inclusions

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*The petrographic investigations were made by V. P. Pirozhkovaya.

of titanium nitrides, carbonitrides, and oxynitrides and occasionally of manganese sulfides with a less clearly expressed (in comparison with the particles in the unmodified iron) crystallographic faceting. Simultaneously there may be noted an increased quantity of fine, smaller than 1 μm, apparently oxidized inclusions the nature of which it was not possible to reveal petrographically.

X-ray microanalysis of the inclusions in the unalloyed and the boron microalloyed iron showed the following (Fig. 3). As a rule, in the unalloyed gray iron bounded (size 3-10 μm) titanium-base inclusions, apparently titanium carbonitrides and oxynitrides, are encountered most frequently. Of the other inclusions manganese and calcium sulfides and also complex oxysulfides, the composition of which includes Al in addition to Mn and Ca, are observed.

In the boron microalloyed gray iron titanium carbonitrides (oxynitrides) are also typical inclusions and inclusions of complex Mn and Ca sulfides containing Al are sometimes encountered. In addition in the iron there are fine, not larger than 1 μm (most frequently finer than 0.5 μm), inclusions of dark color. These inclusions have an irregular rounded form and do not contain Mn, Ti, Cr, Si, Ni, Ca, or S (Fig. 3). It should be noted that the intensity of the characteristic manganese K_α-radiation from the microvolume of the alloy with the inclusion being analyzed is somewhat lower than from the metallic matrix without inclusions. It may be assumed that these inclusions are boron containing phases.

X-ray diffraction analysis of fractions electrolytically extracted from the unalloyed and boron microalloyed iron made it possible to conclude that the specific disperse inclusions in the boron iron are FeB borides and B_4C boron carbides.

The formation of the dispersed boride inclusions in the boron microalloyed gray iron leads to practically no change in the hardness of the alloy and in its machinability but at the same time significantly increases its wear resistance under various load and rate conditions of friction and wear both with liberal lubrication and under conditions of semidry and dry friction. At the same time the boron microalloyed iron preserves the high antifriction properties and good running in of the unmodified gray iron. The use of boron microalloyed gray iron as the material of a transportation air conditioner rotary compressor eccentric shaft in place of high-strength cast iron with spheroidal graphite made it possible to reduce scrap in production of it and to increase the service life of the eccentric shaft—rotor contacting parts and of the compressor as a whole.

The approximate saving was 180,000 rubles.