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EFFECTS OF COMPLEX MODIFIERS CONTAINING NANOCARBON ADDITIVES ON THE STRUCTURE AND PROPERTIES OF HIGH-STRENGTH CAST IRON

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ABSTRACT

The solution to the issues of increasing the strength and working properties of castings, the reduction in their metal consumption at the current stage is possible by optimization of the existing technologies and the compositions of materials, as well as the application of the latest technologies and materials, in particular nanotechnologies and nanomaterials, taking into account new achievements in the field of research on the structure of multicomponent melts of cast iron, the use of heredity phenomena and the introduction of various methods of influence on melts. The paper examined the effects of a complex modifier containing nanocarbon components on the structure formation of high-strength cast iron. The microstructure and mechanical properties were evaluated.

It has been found that the modifiers under development, by directly introducing the crystallization centres into the melt in the form of dispersed carbon particles, can significantly increase the effect of modification and reduce the costs of modifiers due to their lower consumption.

Keywords: high-strength cast iron, complex modifiers, ligature, nanocarbon components, fullerene soot, structure formation, strength, hardness, efficiency of modification.

INTRODUCTION

The stability of the structure and high level of technological, mechanical and service properties of castings made of high-strength cast iron is achieved by the use of high-quality charge materials, progressive melting processes, modifiers with a guaranteed narrow-interval content of magnesium and other modifying elements, highly effective methods of modification, alloying and heat treatment [1].

Analysis of the current state of production of castings from various alloys shows that today and in the near future one of the most widely used casting structural materials, both in the Republic of Belarus and abroad, is cast iron.

The solution of questions of strength increase and operational properties of castings, decrease in their metal intensity at the present stage is possible at optimization of existing technologies and compositions of materials, and also application of the latest technologies and materials, in particular nanotechnologies and nanomaterials, taking into account new achievements in the field of researches on a structure of multicomponent melts of cast iron, use of the phenomena of heredity and introduction of various methods of influence on melts.

However, a number of issues in relation to cast iron in many respects is still not solved. In particular, the influence of modification on the processes control of structure and properties formation in cast irons has not been sufficiently studied [2 - 4]. The creation of new modifiers compositions, including the use of carbon components of different dispersion degrees and structuring, and rational technologies of their application, providing the required structure and properties, requires further study of the effect of separate and complex additives on the structure and properties of cast iron, the study of technological conditions of modification of cast iron by various additives on the effectiveness of their action [5]. Actual issues are the influence of overheating of liquid cast iron, its temperature during modification and the duration of exposure before pouring into molds on the effectiveness of various modifiers, preserving the effect of modification (heredity) after remelting.

The aim of this work is to study the structural state and mechanical properties of high-strength cast iron obtained using complex modifiers containing nanocarbon components.

EXPERIMENTAL

When developing complex modifiers of high-strength cast iron in the framework of this work, a spheroidizing modifier for cast iron with magnesium EM(PS) and a graphitizing barium modifier “Graphitplus” for inoculating modification of high-strength cast iron were chosen as the base. The recommended consumption of spheroidizing modifier is 0.8 - 1.8 % depending on the degree of purification of the melt and the method of input into the melt, recommended consumption of graphitizing modifier is 0.05 - 0.3 %.

Fullerene-containing soot was used as nanocarbon components. In order to ensure the assimilation of highly dispersed carbon particles by the melt, extruded aluminum-silicon ligatures containing nanocarbon components as additives in the complex modifier were used. At the same time, the high efficiency of aluminum in the compositions of long-acting modifiers is known, which determines the expediency of its use [6].

Samples of ligatures were prepared by preliminary mechanical activation in ball mills of crushed chips of silumin AL9 and fullerene-containing soot, followed by extrusion of Al-Si-C ligatures with the calculation of their content of 10 wt.% carbon [7]. The used carbon materials were obtained on the equipment of LLC “Fiztekhpribor” on the basis of the Physical-Technical Institute named after A.F. Ioffe RAS, St. Petersburg.

In the composition of the mixed modifier, an Al-Si-C ligature was used in an amount of 30 % in relation to the base graphitizing modifier.

The study of the influence of the developed modifiers on the structure formation was carried out using induction smelting cast iron smelted using cast iron scrap of the VCH40 brand to obtain a stable base chemical composition: 2.7 - 3.8 % C; 0.5 - 2.9 % Si; 0.2 - 0.6 % Mn; up to 0.1 % P, up to 0.02 % S. Modifier was introduced into a metal jet when poured into a casting crucible, which was preheated in a muffle furnace to a temperature of 750°C. It was produced at a temperature of 1400°C° - 1420°C. The temperature was controlled by a multi-channel RMT 39D recorder connected to a PC. Samples were taken to study the structure and characteristics of the properties.

The microstructure of the samples was studied on microsections before and after etching using a metallographic complex based on the MI-1 microscope. The phase composition was determined using Bruker’s D8 Advance X-Ray diffractometer, using X-RAY automation software for X-Ray phase analysis. Raman spectra at a fixed resolution (2 cm^{-1}) were recorded using a spectral-analytical complex based on a scanning confocal microscope “Nanofinder HighEnd” (LOTIS-TII, Belarus - Japan).

Thus, the samples of modified cast iron were obtained for further studies (Table 1).

RESULTS AND DISCUSSION

The results of studies of the phase and elemental compositions (Fig. 1) show that the studied fullerene soot basically consists of amorphous carbon as evidenced by a pronounced “halo” in the range of angles 2θ = 13 - 25°

Table 1. Samples of modified cast iron obtained during smelting.

Sample	Characteristic
A	Cast iron modified with 1.5 % of spheroidising modifier EM(PS) and 0.2 % of "Graphitplus” graphitizator
B	Cast iron modified with 0.8 % of spheroidising modifier EM(PS) and 0.2 % of "Graphitplus” graphitizator
C	Cast iron modified with 0.8 % of spheroidising modifier EM(PS) and 0.2 % of "Graphitplus” graphitizator and 0,3 % ligature (Al-Si+fullerene soot)

characteristic of the disordered amorphous state, contains ~8 % fullerenes and does not contain any foreign impurities, except a small amount of oxygen. The results of studies of extruded Al-Si-C ligatures showed unusual structural state of aluminum alloys [7]. Using X-ray diffraction analysis the structural transformation of carbon with the formation of an amorphous carbon phase in ligatures along with carbide formation was determined.

Raman spectroscopy of light in the carbon spectra revealed the presence of a line of different intensity to the left of the main peak (Fig. 2), indicating the amorphization and formation of glass carbon, which confirms the results of X-ray diffraction analysis.

This structural state of the obtained ligatures determines the possibility of their use as highly active additives in the composition of modifiers of cast iron-carbon alloys. One of the generally accepted criteria for evaluating the effectiveness of graphitizing modification of high-strength cast iron is the density of the distribution of spherical graphite inclusions in the structure. It is important to reduce the degree of hypothermia in the process of crystallization of eutectic.

The microstructure of samples of high-strength cast iron using nanocarbon components and without them is shown in Fig. 3.

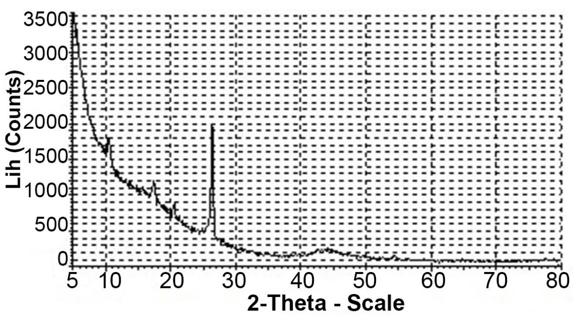


Fig. 1. Diffractogram of the fullerene soot.

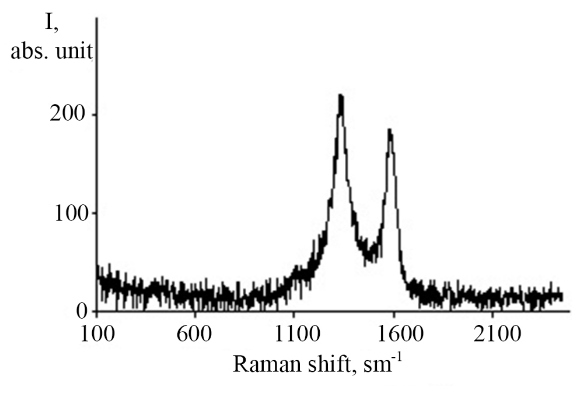
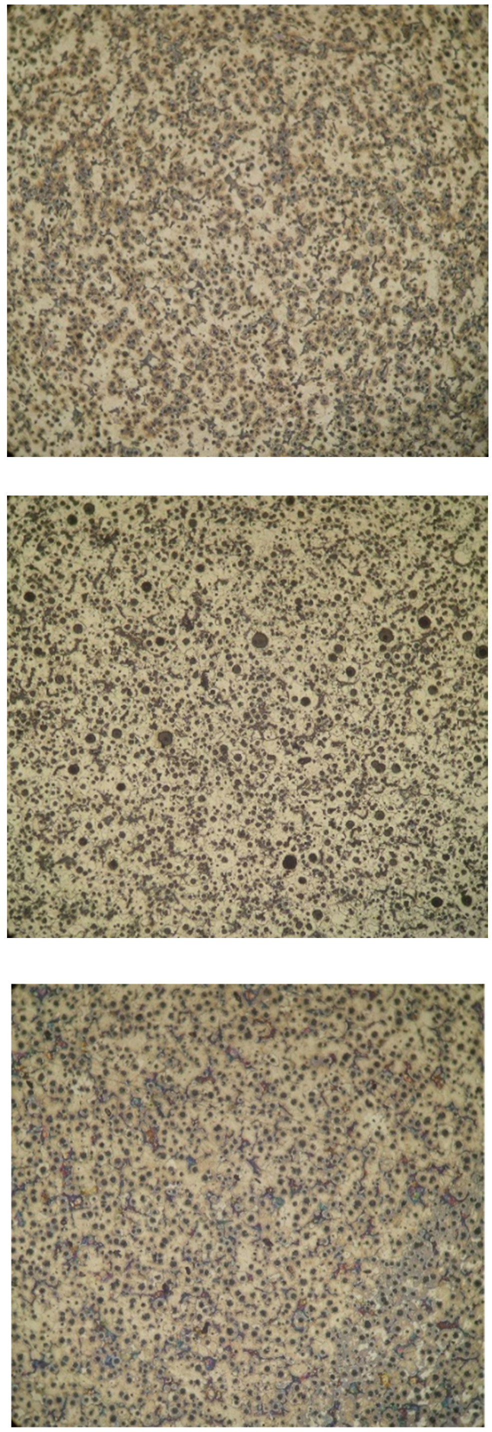


Fig. 2. Raman light scattering spectrum of Al-Si-C ligature sample.



a)

b)

c)

Fig. 3. Microstructure of modified cast iron: a) sample A modified with 1.5% of spheroidising: modifier EM(PS) and 0.2 % of «Graphitplus" graphitizator; b) sample B modified with 0.8 % of spheroidising modifier EM(PS) and 0.2 % of «Graphitplus" graphitizator; c) sample C modified with 0.8 % of spheroidising modifier EM(PS) and 0.2 % of «Graphitplus" graphitizator and 0,3 % ligature (Al-Si+fullerene soot) (x100)..

The analysis of structural state of the samples shows that sample C, where nanocarbon components were introduced, according to GOST-3443-87 graphite inclusions have regular shape and are uniformly distributed over the entire surface of the cone, diameter of inclusions is 15 µm, number of inclusions of graphite is SHG10, the metal base is: 10 % perlite and 90 % ferrite.

In the sample A containing 1.5 % spheroidizing modifier EM (PS) and 0.2 % "Graphitplus" there is a uniform distribution of graphite inclusions, number of graphite inclusions is SHG6, size of the inclusions is 25 µm, the metal base is: 20 % perlite and 80 % ferrite. Sample B with 0.8 % spheroidizing modifier EM (PS) and 0.2 % "Graphitplus" has an unequal distribution of graphite inclusions, number of graphite inclusions is SHG12, size of inclusions is 15-45 µm, the metal base is: 6 % perlite and 94 % ferrite. During the hardness measuring by the Brinell method, the following results are obtained. Sample C, melted with the addition of the developed ligature as part of a complex modifier has 200 HB, sample A has 220 HB, sample B has 190 HB.

The tensile strength of the sample containing nanocarbon components (sample C) was - 620 MPa, the sample of cast iron modified with a standard complex modifier (sample B) - 420 MPa, the sample of cast iron with twice the amount of complex modifier (sample A) - 600 MPa.

CONCLUSIONS

Modification of cast iron with a complex modifier containing nanocarbon components in the form of fullerene soot increases the mechanical properties of castings made of high-strength cast iron by grinding the structure of cast iron, and also reduces the cost of modifiers, due to their lower consumption.

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