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Stereology of carbide phase in modified hypereutectic chromium cast iron

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Abstract

In paper are presented results of studies of carbide phase stereology modified hypereutectic wear resistance chromium cast iron which contains carbon about 3,5% and chromium about 25%. Three substances were applied to the modification: boron carbide (B_4C), ferroniobium (FeNb) and mixture of ferroniobium and rare-earth (RE). The measurements of geometrical features of carbides were conducted on microsection taken from castings wich were cooled with various velocities.

Keywords: Chromium Cast Iron, Crystallization, Modification, Stereology of Carbides

1. Introduction

Chromium cast iron belongs to casting materials finding the wide use in mining industry, processing of minerals, energetics etc., first of all on the elements (castings) takes the part in mines, crushes, milling, transport of mineral materials [1÷7]. Castings these during the work are subject on destroy result from the processes of the abrasion mainly, but happens that they have to also be resistant on temporary enlarged loads or impacts. The preferred from the group of chromium cast iron working in above-cited conditions are hypoeutectic cast irons consisting from the suitable matrix and usually about 30% carbides M_7C_3 type. Many investigations [8] confirms that the larger part of carbide phase decides about high resistance on the abrasive wear of chromium cast iron. However continuous raising of volume fraction of carbide phase (what is connected with the larger carbon content), joins with the passage to the group of hypereutectic chromium cast iron in which primary, large carbides appear. Practician do not prefer, and avoid outright this cast iron from the regard on considerable its fragility. It seems that hypereutectic chromium cast irons can establish the interesting group of casting alloys about the high resistance on the abrasive waste after solving the problem of their fragility, e.g. through the improvement of the morphology of primary carbides. According to authors [9÷2] the partial improvement of the morphology of primary carbides was got by the introduction of vanadium, titanium, niobium and cerium however in quantities considerably crossing the typical interventions of the modification. Whereas different authors [13÷15] getting the only insignificant improvement impact resistance and wear resistance they added silicon, boron, boron carbide.

The authors of the presented work conduct the systematic studies of wear resistance chromium cast iron resistance [16÷19]. They introduced the test of modification of hypereutectic chromium cast iron using the boron carbide, ferroniobium and ferroniobium with rare-earth mixture in the present article.
It was put in studies that the quantity of the single modifier should not cross 0,25%, and quantity sum should not cross introduced additions 0,5% of the mass of liquid cast iron.

2. Methodology and results of studies

Experimental studies were conducted on hypereuetectic chromium cast iron which contained basic elements about C = 3,5% and Cr = 25%. The aim of studies was to determine the influence of boron carbide, ferroniobium and ferroniobium with rare-earth mixture on the stereology of carbide phase in hypereutectic chromium cast iron.
Experimental melts were conducted in the induction crucible furnace about laying out indifferent and the capacity 20 kg. The plan of melts was introduced in Table 1.

Table 1.
Melts plan of studied chromium cast iron

Mark	%weight		modifier *X* %weight		
	C	Cr	B_4C	FeNb	FeNb + RE
wW0	3,5	25	-	-	-
wW1			0,25	-	-
wW2			-	0,25	-
wW3			-	-	0,2 + 0,2

The cast iron was subjected deoxidized with use of Al and FeCaSi before the modification. The tapping temperature of the cast iron was set on 1480°C. Liquid cast iron was cast to form-testers DTA-C and DTA-Is on the special research stand serving to registration of crystallization process (Fig. 1). Applied moulding materials of form-testers assure the various velocity of cooling castings. For example cooling and crystallization curves of studied cast iron were introduced on Figure 2. To see, that solidification time of casting ***Is*** in the tester DTA-Is is above twice longer than the solidification time of casting ***C*** in the tester DTA-C. Such differentiation was got by laying out the measuring cavity of the tester from isolating material (aluminosilicate). For the studied hypereutectic chromium cast iron average velocity in the range of primary crystallization carries out for the casting ***C*** – 0,6 K/s and for the casting ***Is*** – 0,3 K/s.

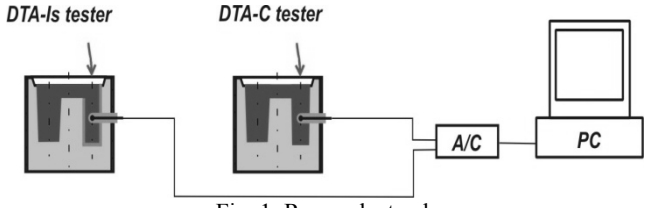


Fig. 1. Research stand

Obtained castings were used to metallographic investigations subsequently. The way of taking of metallographic samples from the casting ***C*** is showed on Figure 3 (for the casting ***Is*** similarly). Samples cut out on the laboratory cutter with strong cooling. Microsection was prepared according to the classic technique and deeply etched austenitic matrix using the nitrohydrochloric acid.
The pictures of the metallographic structure which was conducted the quantitative analysis of the stereology features of carbides were made for prepared microsection. The analysis was conducted using the programme NIS-ELEMENTS BR 3.10.

The obtained quantitative analyze of carbides used to preparing histograms of schedule of quantity of carbides belonging to the separate classes of the size on 1 mm^2.

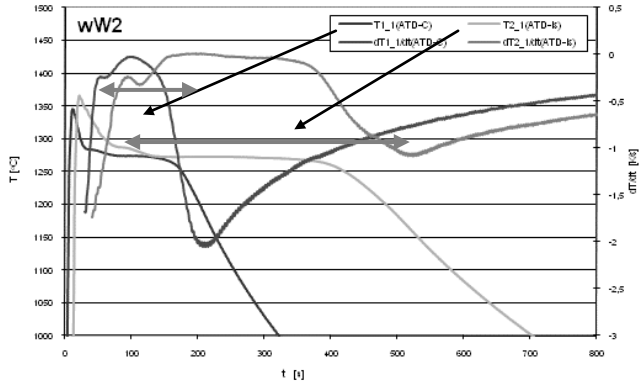


Fig. 2. The comparison of the times of primary crystallization of the studied chromium cast iron in testers DTA-C and DTA-Is

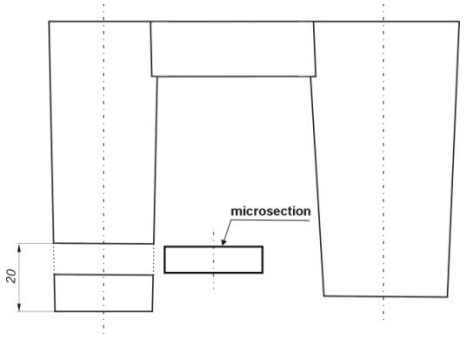


Fig. 3. Taking the test bar to investigations from the casting ***C***

Obtained histograms were described for the equations (1) [20]:

$$Na(P) = \frac{U^{\circ}Z^{\circ}exp\{Z[W - log(P)]\}}{\{1 + exp[Z(W - log(P))]\}^2} \quad (1)$$

where:
Na – quantity of particles on unit surface in 1/mm^2,
P – surface field of particle in μm^2,
U – coefficient of total quantity particles in μm/mm^2,
W – average logarithmic size of particles in μm,
Z – differentiation the size particles in 1/ μm.

The example pictures of metallographic structures are showed on Figure 4. Obtained histograms and the graphs of the function them describes the parameters U, W, Z and it statistical parameters are presented on Figures 5÷8.

a) b)

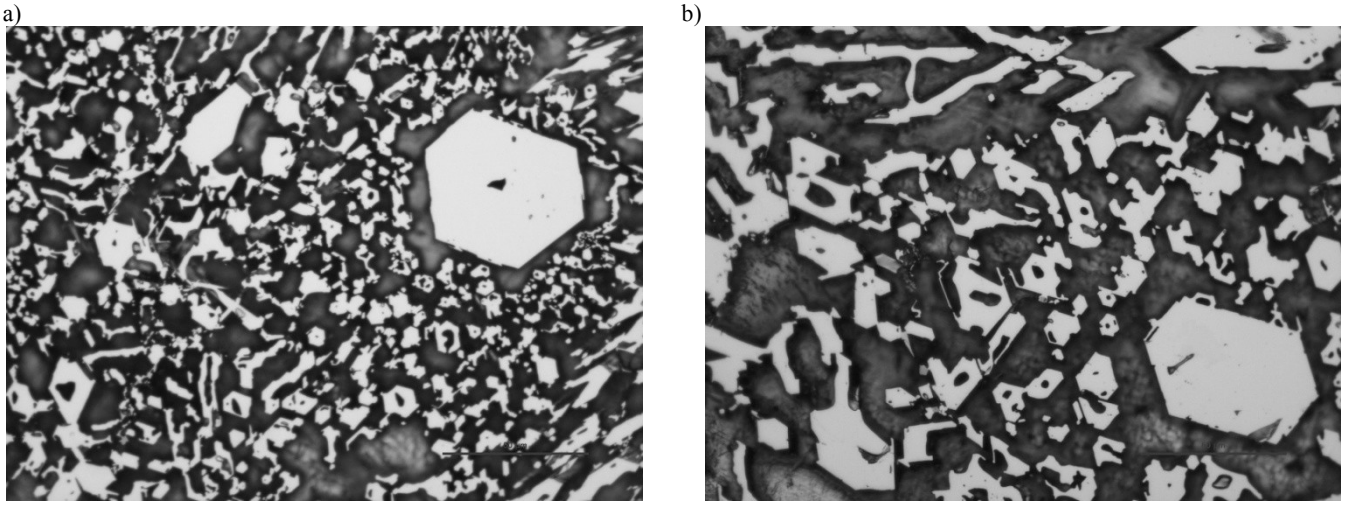
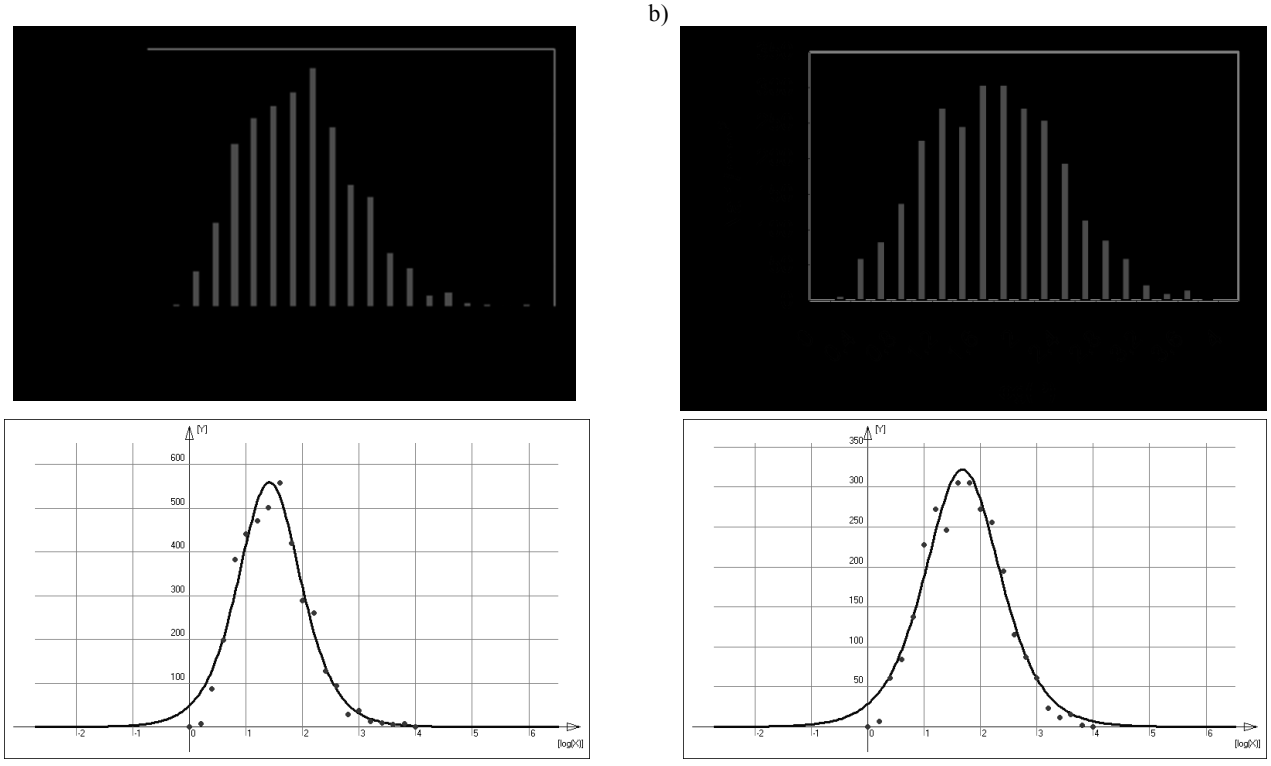


Fig. 4. The example structures of modified cast iron (FeNb); a) wW2- casting ***C*** x200, b) wW2-casting ***Is*** x200

a) b)

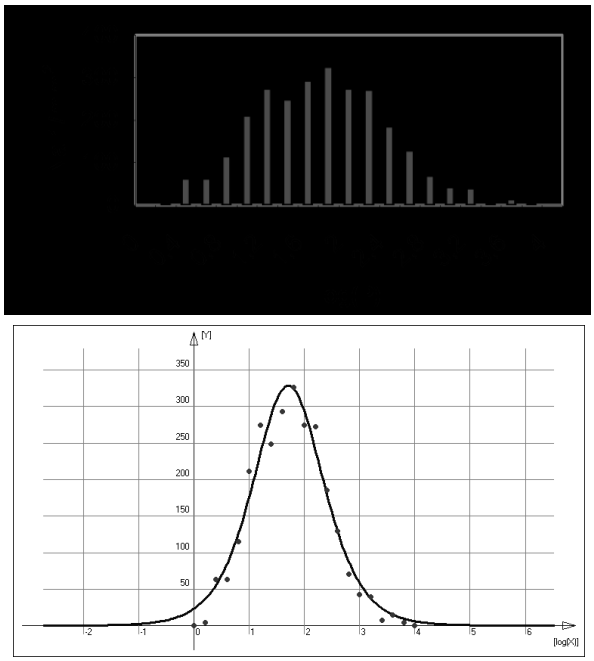


U = 834,49; W = 1,4143; Z = 2,6812
s.d. = 36,3; corr. = 0,9840; Fisher test = 59,0

U = 573,40; W = 1,6815; Z = 2,2436
s.d. = 21,0; corr. = 0,9848; Fisher test = 69,9

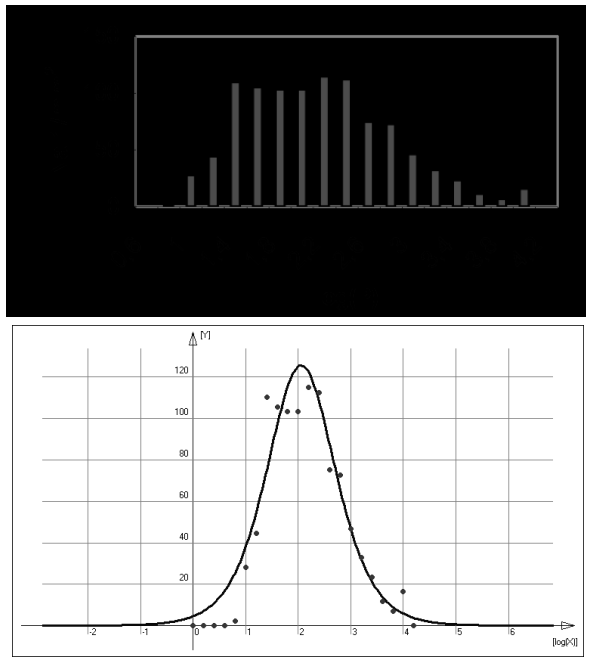
Fig. 5. The quantity distribution of carbides in the size classes; a) wW0 – casting ***C***, b) wW0 – casting ***Is***

a)



U = 561,35; W = 1,7093; Z = 2,3422
s.d. = 22,1; corr. = 0,9833; Fisher test = 62,9

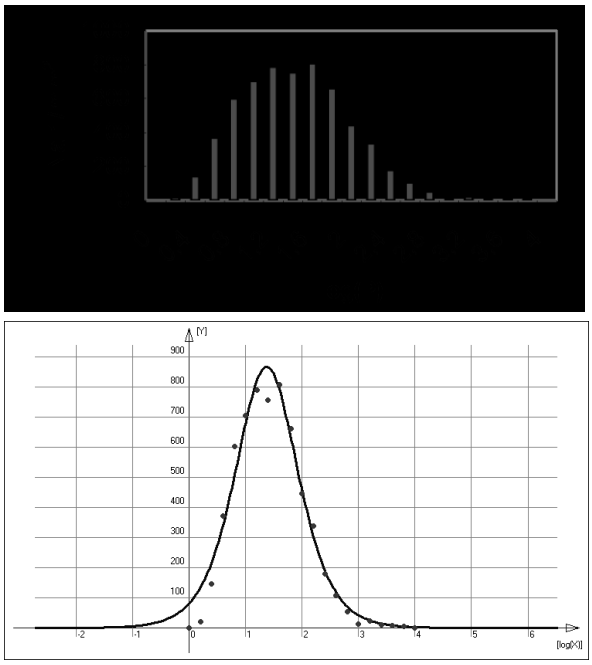
b)



U = 219,85; W = 2,0565; Z = 2,2857
s.d. = 13,0; corr. = 0,9597; Fisher test = 25,8

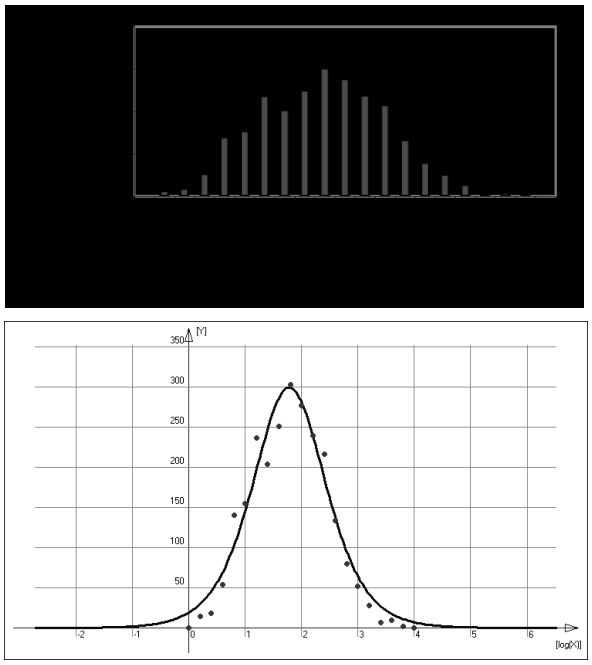
Fig. 6. The quantity distribution of carbides in the size classes; a) wW1 - casting ***C***, b) wW1- casting ***Is***

a)



U = 1285,9; W = 1,3738; Z = 2,6969
s.d. = 51,8; corr. = 0,9869; Fisher test = 69,2

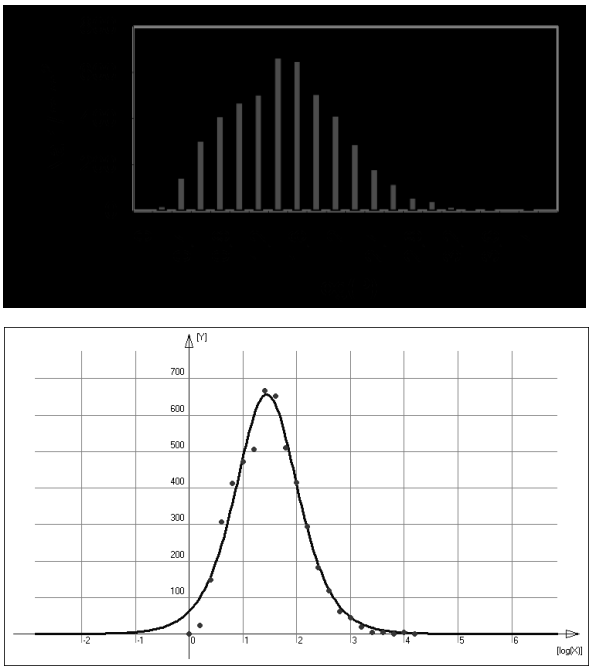
b)



U = 519,45; W = 1,7817; Z = 2,3055
s.d. = 22,4; corr. = 0,9800; Fisher test = 51,6

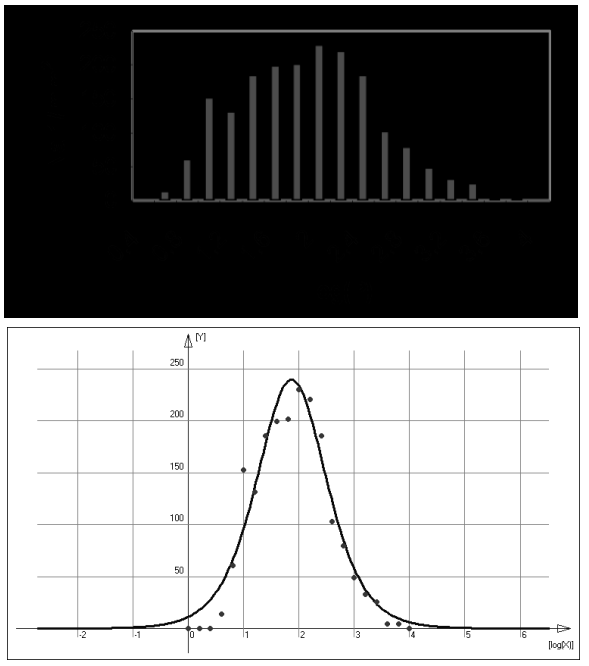
Fig. 7. The quantity distribution of carbides in the size classes. a) wW2 - casting ***C***, b) wW2 - casting ***Is***

a)



U = 1022,7; W = 1,4429; Z = 2,5670
s.d. = 36,2; corr. = 0,9885; Fisher test = 81,4

b)



U = 404,74; W = 1,8681; Z = 2,3687
s.d. = 20,3; corr. = 0,9742; Fisher test = 39,3

Fig. 8. The quantity distribution of carbides in the size classes; a) wW3 – casting ***C***, b) wW3 – casting ***Is***

3. Summary of studies

Conducted studies show that the kind of the applied modifier influences essentially on size and quantity of carbides. The obtained values of the parameters of the aproximation function of the quantity distribution of carbides testify about this. If we analyse the average size of carbide (represented by the parameter W of the curve) should affirm this, that for casingts ***C*** cooling in testers DTA-C the influence of applied modifiers is insignificant. The only addition B_4C effects almost the twofold growth of the average size of carbide from 26 μm^2 for sample unmodified to 51 μm^2 for the sample modified. In the case of castings cooling in isolated forms modifiers cause enlargement of the carbides. And again B_4C is the most wrongly which enlarges size of carbides from 48 μm^2 for sample unmodified to 114 μm^2 for the sample modified.

Analysing the quantity carbides in separate melts (represents by the parameter U on curves) we investigate to similar observations.

The addition of the modifier for except B_4C effects on the growth of the quantity carbides in the comparison with the state without the modification in unisolated castings. In the case of castings slowly cooling the modifiers do not enlarge quantities of carbides and B_4C reduces it considerably. For the matter of differentiation of the size carbides in castings cooling in unisolated forms additions B_4C and FeNb+RE reduce this differentiation. The additions of modifiers clearly enlarge the differentiation of the size carbides in castings about slowly cooling.

On the basis of conducted studies about the modification with boron carbide, ferroniobium and mixture of ferroniobium and rare-earth of hypereutectic chromium cast iron following conclusion were formulated:

1. Favourable actionof applied modifiers on carbide phase is observed only for castings, which were cooled in uninsolated forms.
2. Ferroniobium is most effective modifier reducing the size and enlarging the quantity of carbides.
3. Boron carbide is the modifier worsening the structure in hypereutectic chromium cast iron.

Acknowledgements

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