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Carbides in Nodular Cast Iron with Cr and Mo

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Abstract

In these paper results of elements microsegregation in carbidic nodular cast iron have been presented. A cooling rate in the centre of the cross-section and on the surface of casting and change of moulding sand temperature during casting crystallization and its self-cooling have been investigated. TDA curves have been registered. The linear distribution of elements concentration in an eutectic grain, primary and secondary carbides have been made. It was found, that there are two kinds of carbides: Cr and Mo enriched. A probable composition of primary and secondary carbides have been presented.

Keywords: Innovative material and casting technologies, Carbidic nodular cast iron, Thermal derivative analysis (TDA), X-ray microanalysis

1. Introduction

Carbidic nodular cast iron is the material which ensure higher wear resistance than cast iron with analogical metal matrix without carbides. Carbides as-cast condition can be obtained when Cr and Mo elements are synergic added. Ni and Cu supplement provides obtaining martensitic microstructure and increase the propensity to cast iron graphitization. In works [1 ÷ 3] the possibility obtaining carbidic nodular cast iron was presented. The aim of this paper is testing of castings cooling rate in the centre of their cross-section and on the surface, change of moulding sand temperature during casting crystallization and its self-cooling and carbides identification.

2. Research methodics

Cast iron was melted in 0,5Mg high-frequency induction furnace. As a nodulizer FeSiMg10 foundry alloy was used and as an inoculant – SB5. The chemical composition of cast iron is presented in table 1.

Table 1.
Chemical composition of examined cast iron

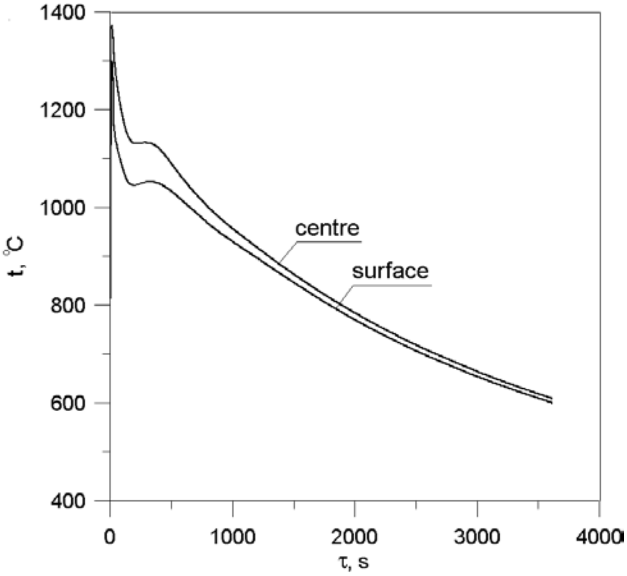
Chemical composition, %						
C	Si	Mn	Cr	Cu	Mo	Ni
3,46 ÷ 3,60	2,45 ÷ 2,57	0,28 ÷ 0,55	0,68 ÷ 1,23	0,97 ÷ 1,39	0,30 ÷ 0,52	3,60 ÷ 4,80

Castings of type „Y”: 4, 12, 25, 50 and 75mm wall thick were made. Curves of cooling rate in the centre of cross-section and on the surface of castings, change of moulding sand temperature at the distance of a: 5, 15 and 30mm from casting surface were registered. Curves of thermal derivative analysis (TDA) were registered too. Microstructure photographs were made by using Hitachi S-3000N scanning electron microscope. X-ray microanalysis was made by using Pioneer ESD detector and Ventago software in order to make an identification of a distribution of elements concentration within an eutectic grain and in carbides.

3. Results

Example curves of temperature change of casting 25mm wall thick are shown on figure 1 (a, b).

a)



b)

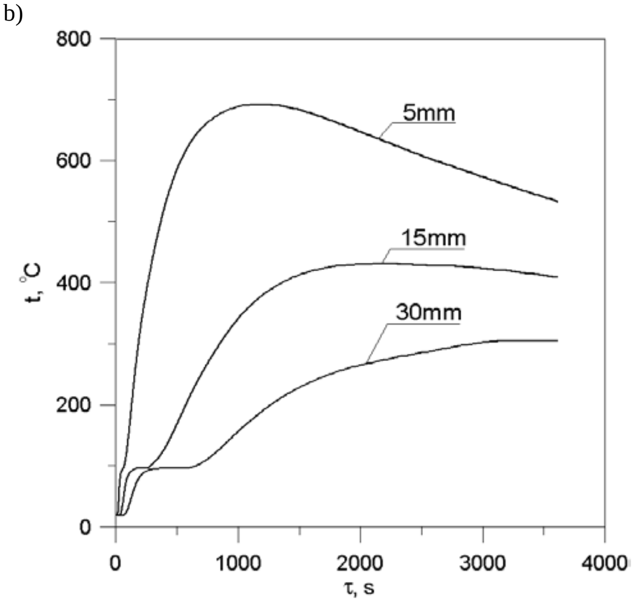
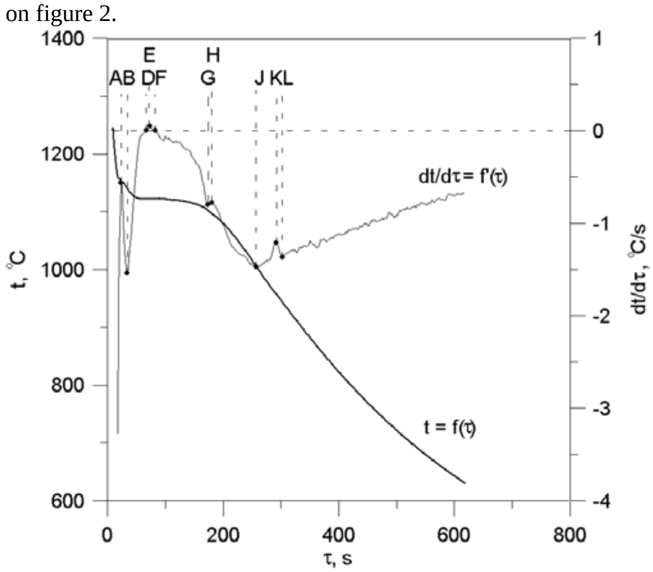


Fig. 1. Curves of cooling rate of the centre and surface of casting (a) and temperature change in moulding sand (b) at a distance of a: 5; 15 and 30mm from the surface of mould cavity

Result from them, that the difference between crystallization temperature of cast iron in the centre of cross-section and on its surface amounts about 100°C. During further cooling this difference decreases and as an example amounts to 9°C after 1 hour. On cooling curves there is not the thermal effect from austenite → pearlite transformation. It testifies, that an austenite transform in lower temperature. After ending of a crystallization process of cast iron the centre of casting cool down at the rate of 0,30°C/s and the surface - 0,19°C/s.

From fig. 1 (b) results, that the mould heats the most intensively at the distance of a 5mm from the casting surface and the most slowly at the distance of a 30mm. On all three curves in temperature of about 100°C there is a temperature hold, the shortest at the distance of a 5mm and the longest - 30mm from the surface due to a desiccation of damp moulding sand.

Example TDA curves of carbidic nodular cast iron are shown on figure 2.



Point	τ, s	t, °C	dt/dτ, °C/s
A	23	1153	-0,56
B	33	1142	-1,54
D	67	1122	–
E	73	1122	0,05
F	83	1122	–
G	174	1102	-0,80
H	180	1097	-0,78
J	257	1005	-1,48
K	292	957	-1,21
L	302	944	-1,37

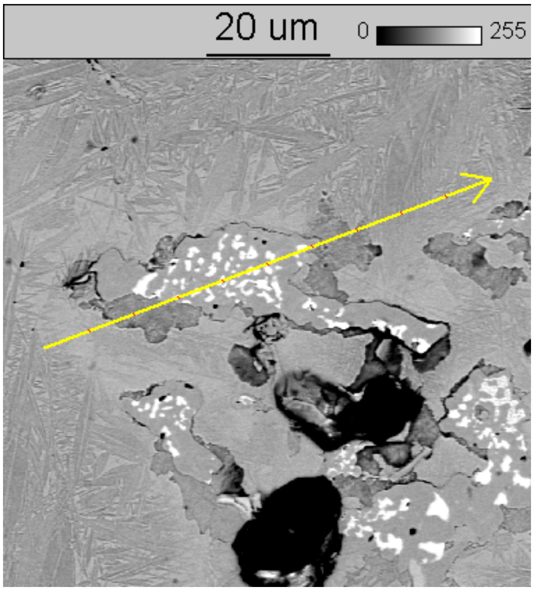
Fig. 2. Example TDA curves of carbidic nodular cast iron with: 3,54% C; 2,50% Si; 0,35% Mn; 1,4% Cu; 0,80% Cr; 0,30% Mo; 4,80% Ni

On TDA curves there are thermal effects described with A ÷ L characteristic points derive from the crystallization of:

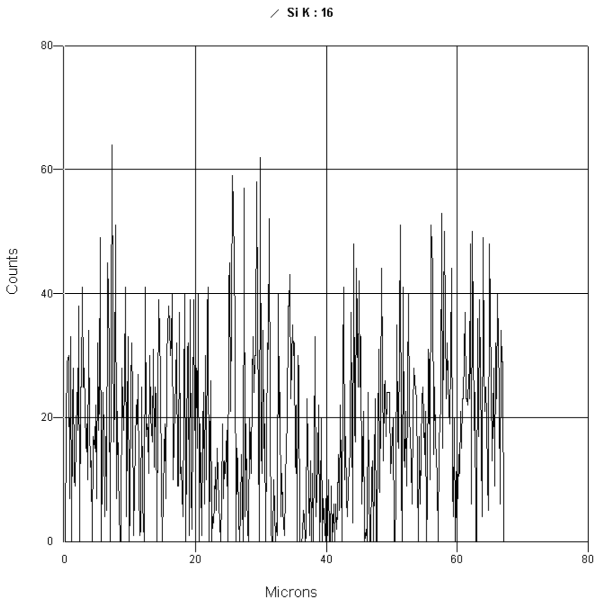
- AB – spheroidal graphite,
- BDEFG – graphite eutectic,
- GHJ – primary carbides,
- JKL – secondary carbides.

On figure 3 (a ÷ g) the microstructure (a) and the linear distribution of elements concentration (b ÷ g) within primary carbides in cast iron with: 3,54% C; 2,50% Si; 0,35% Mn; 1,4% Cu; 0,80% Cr; 0,30% Mo; 4,80% Ni are presented.

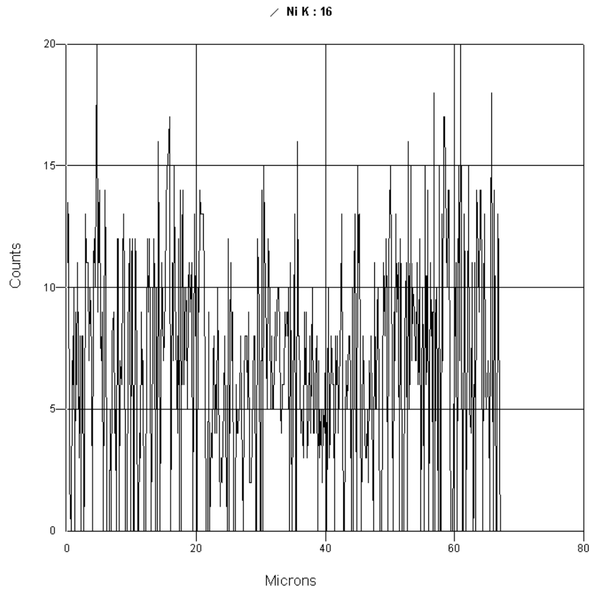
a)



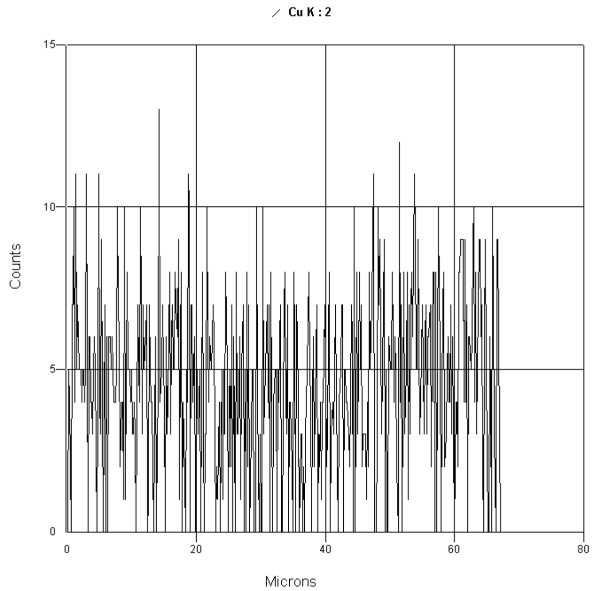
b)



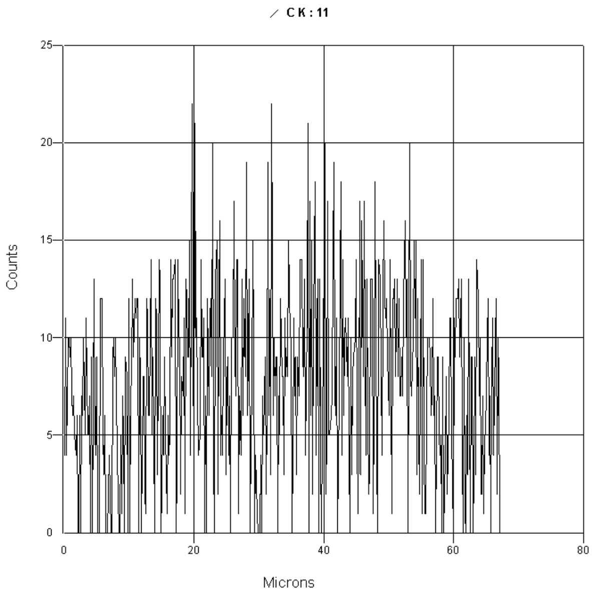
c)



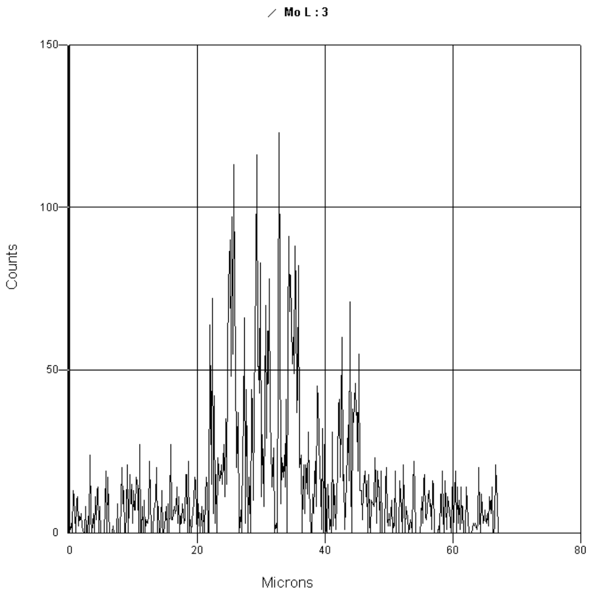
d)



e)



f)



g)

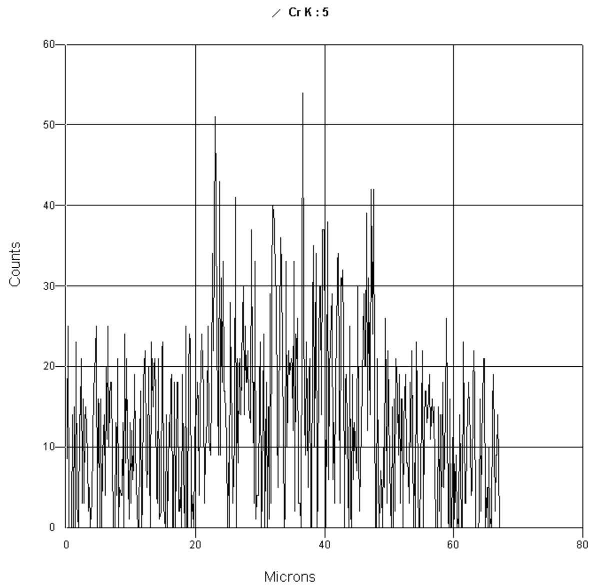
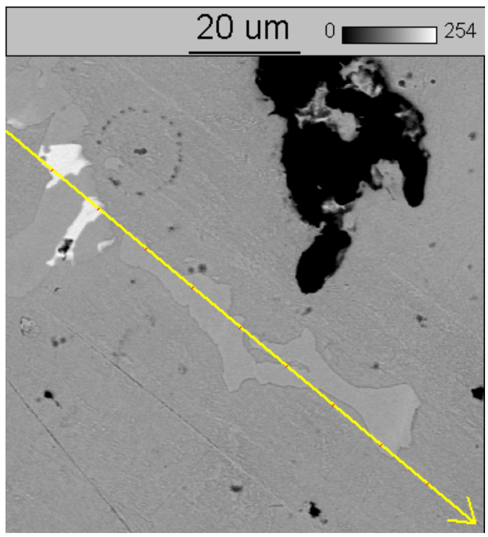


Fig. 3. Microstructure (a) and the linear distribution of: Si, Ni, Cu, C, Mo and Cr concentration (b ÷ g) in primary carbides

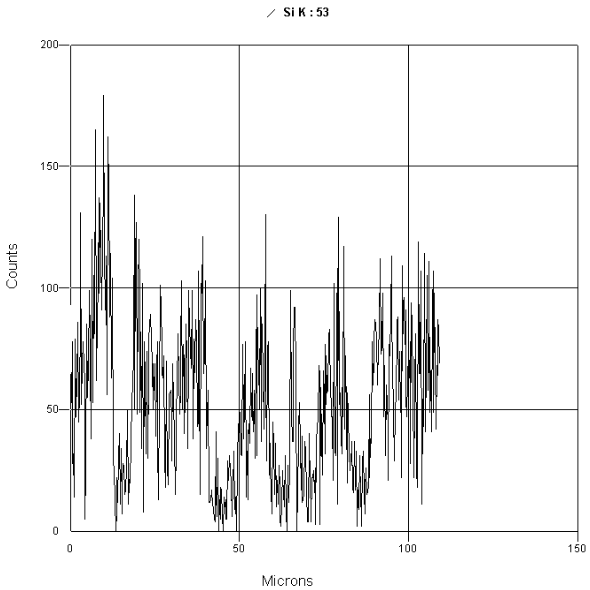
From fig. 3 results, that there are two kinds of primary carbides: “light” Mo enriched and “grey” Cr enriched. From fig. 2 results, that these carbides crystallized at the end of eutectic crystallization. According to data in work [4], in Fe alloys with no more than 3% Mo carbides $(Fe,Mo)_3C$ can crystallize. Because of the fact, that in tested cast iron there is Cr too, these carbides are supposed to be carbidic eutectic of $(Fe,Mo)_3C$ + $(Fe,Cr)_3C$ type. The concentration of alloy elements which are conductive to graphitization, i.e. Ni and Cu in metal matrix is weak (fig. 3 c, d).

On figure 4 (a ÷ g) the microstructure (a) and the linear distribution of elements concentration (b ÷ g) in cast iron with: 3,48% C; 2,48% Si; 0,40% Mn; 1,20% Cu; 1,22% Cr; 0,80% Mo; 3,60% Ni are presented.

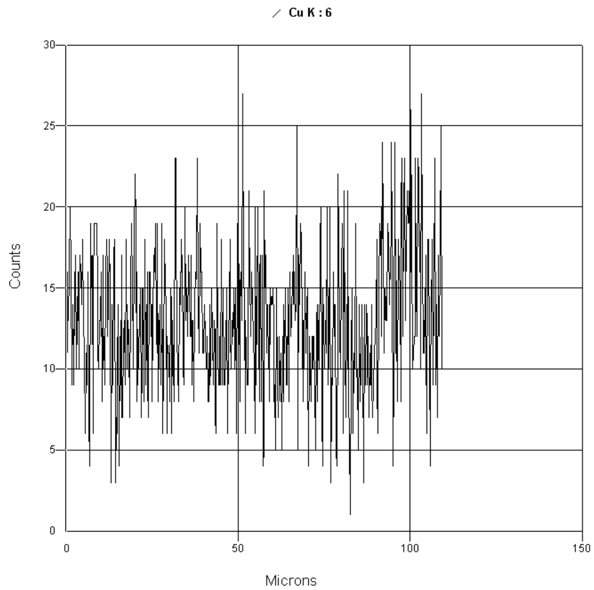
a)



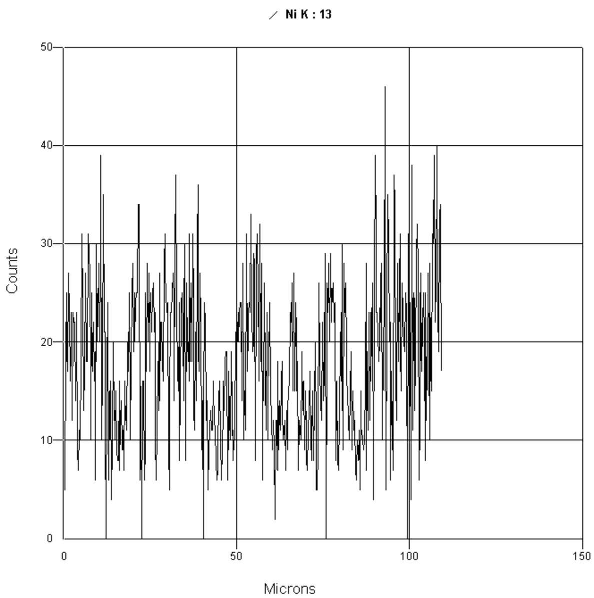
b)


Si K : 53
200
150
100
50
0
Counts
0
50
100
150
Microns

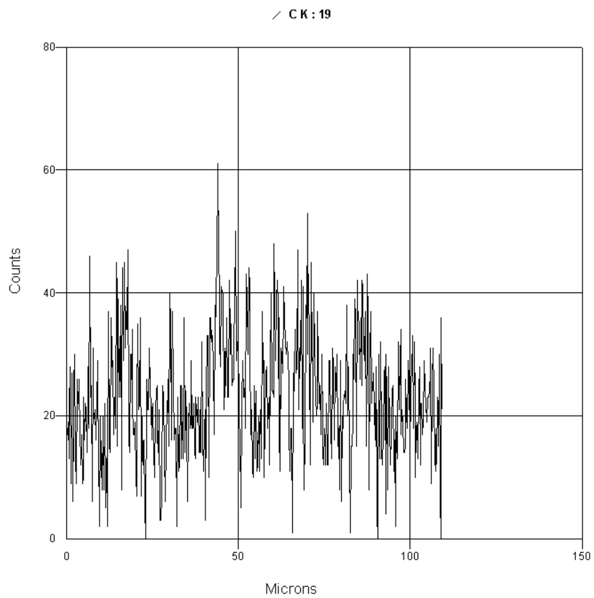
d)


Cu K : 6
30
25
20
15
10
5
0
Counts
0
50
100
150
Microns

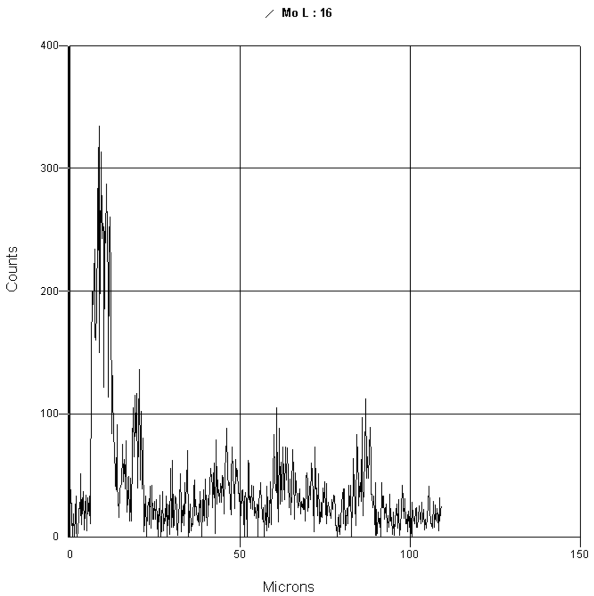
c)


Ni K : 13
50
40
30
20
10
0
Counts
0
50
100
150
Microns

e)


C K : 19
80
60
40
20
0
Counts
0
50
100
150
Microns

f)



g)

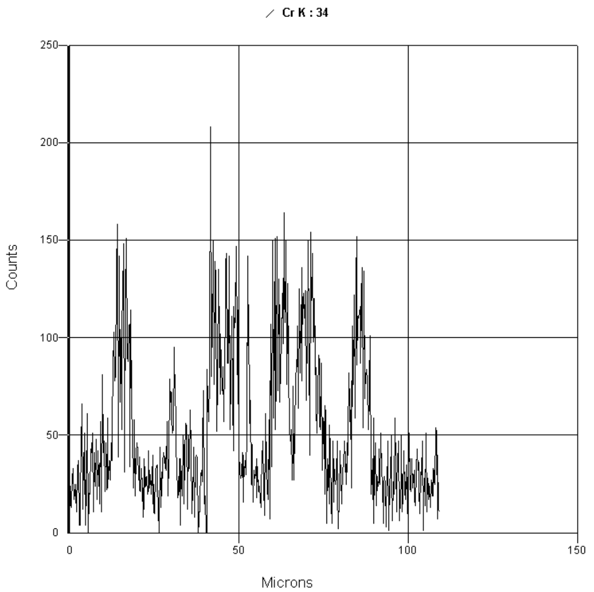


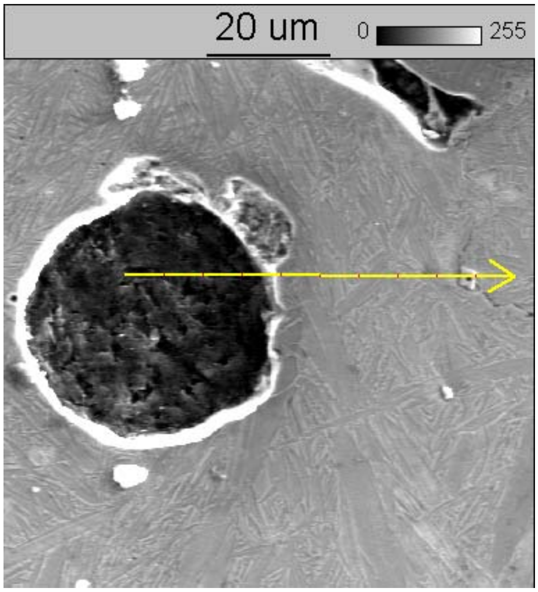
Fig. 4. The microstructure (a) and the linear distribution of: Si, Ni, Cu, C, Mo and Cr concentration (b ÷ g) within primary carbides

Result from it, that there are two kinds of carbides: „light" type $(Fe,Mo)_3C$ and "grey" type $(Fe,Cr)_3C$. Increased concentration of Mo is also on the boundary of metal matrix-carbide. This fact can be due to a release of fine secondary carbides after ending of eutectic crystallization. From fig. 4 (g) results, that Cr comes within carbide and metal matrix is weak with it.

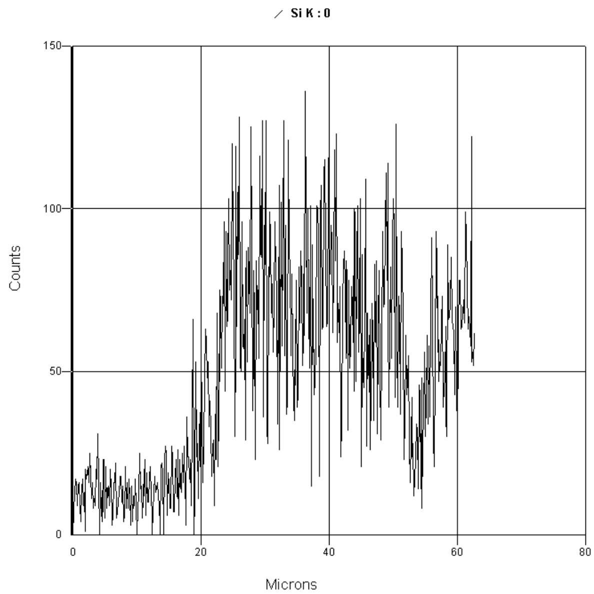
From fig. 3 and 4 (e ÷ g) result, that the stoichiometric ratio inside carbides are similar, i.e. their phase composition is not change within testing chemical composition of cast iron.

On figure 5 (a ÷ g) the microstructure (a) and the linear distribution of elements concentration (b ÷ g) within eutectic grain in cast iron with: 3,54% C; 2,50% Si; 0,35% Mn; 1,4% Cu; 0,80% Cr; 0,30% Mo; 4,80% Ni are presented.

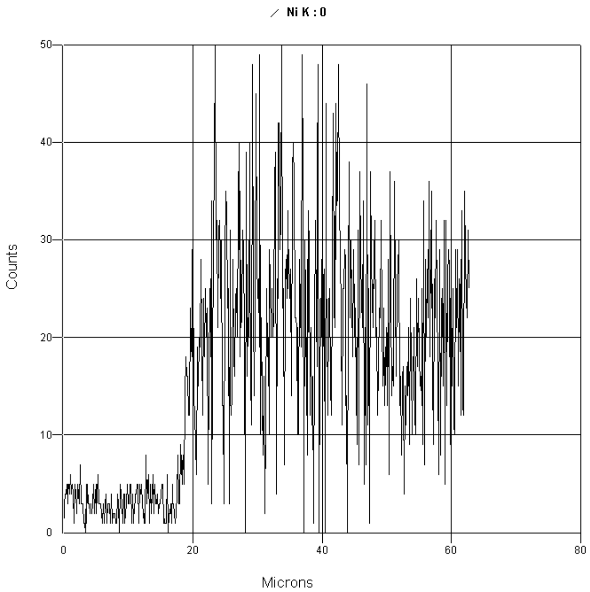
a)



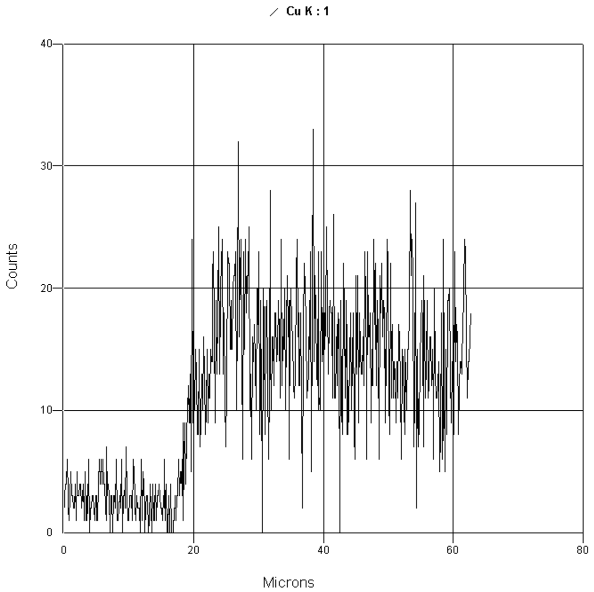
b)



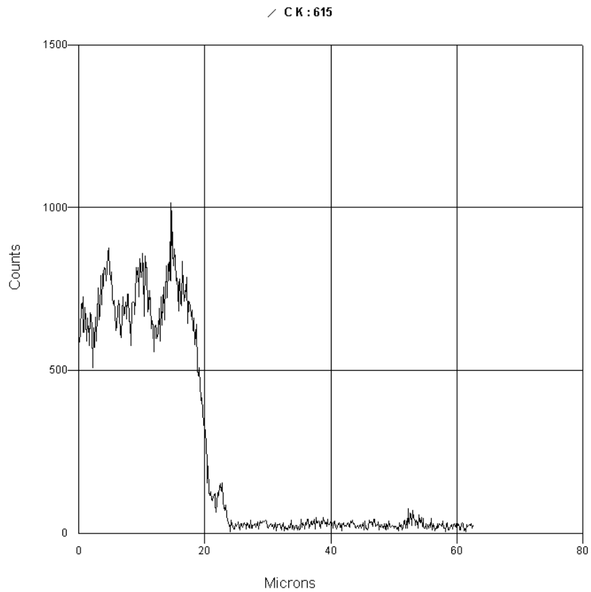
c)


Ni K : 0
Counts
Microns
0
10
20
30
40
50
60
80

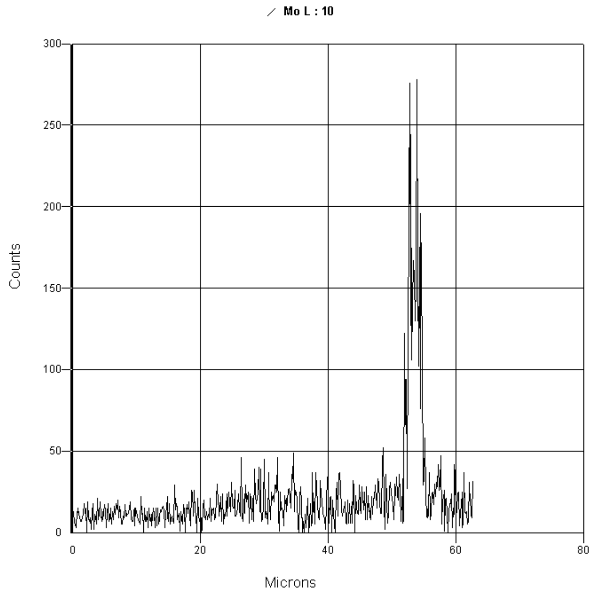
d)


Cu K : 1
Counts
Microns
0
10
20
30
40
60
80

e)


C K : 615
Counts
Microns
0
500
1000
1500
20
40
60
80

f)


Mo L : 10
Counts
Microns
0
50
100
150
200
250
300
20
40
60
80

g)

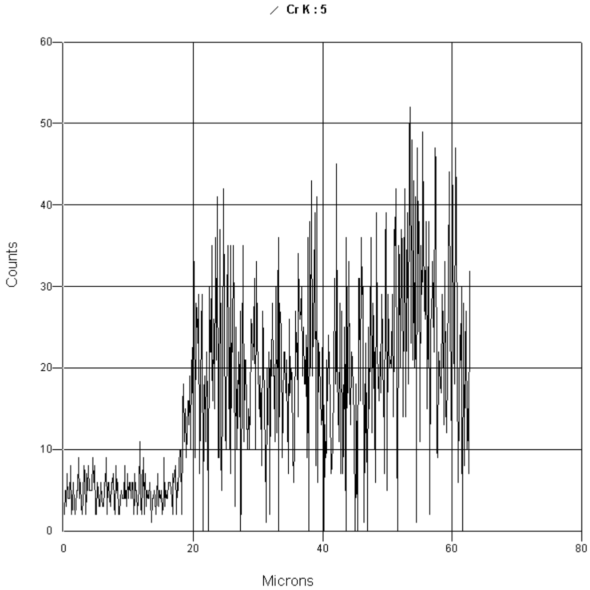


Fig. 5. The microstructure (a) and the linear distribution of: Si, Ni, Cu, C, Mo and Cr concentration (b ÷ g) within the eutectic grain

Results from it, that Si, Cu and Ni concentration within the eutectic grain is maximum close to the graphite separation and minimum close to the grain boundary. This is the typical distribution of elements, which are conductive to graphitization [5]. Cr and Mo concentration (fig. 5 f, g) is changing inversely, as elements, which counteract the graphitization. On the grain boundary there is the secondary carbide type Mo_2C. These carbides there were in the whole testing area.

4. Conclusions

The results have indicated the following:

- common addiction of Cr and Mo elements provide obtaining primary and secondary carbides in metal matrix of nodular cast iron,
- there are two kinds of primary carbides, the most probable $(Fe,Mo)_3C$ i $(Fe,Cr)_3C$ type, and the secondary – Mo_2C type.

Acknowledgements

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