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The Tendencies of Piece Casting from Modified Irons

In this paper we have presented the metalographic studies made on the grey cast irons treated with complex modifying substances, type FeSiMgRE (Mg alloy) and their influence on the compactness degree of graphite separations. For research and experiments, a melt of grey iron was produced in an induction furnace of a capacity of 5to, starting with a metallic charge made from 100% synthetic pig iron. We realized eight practical charge made modification, by using different combinations of modifying substance and in different concentrations. The addition of carbon to the melt was performed using electrode graphite powder in the metallic charge.

Key words: *Synthetic pig iron, compactness degree graphite.*

1. Introduction

In order to analyze and study the influence of compound modifiers, from the Mg alloy category (FeSiMgRE - RE: Ce, La, Nd, Pr) (Mg alloy) on the compactness of graphite separations in cast irons, we proceeded with the elaboration of a melt of cast iron in an induction furnace with a capacity of 5,0t, of a law frequency. The metallic charge with which we started was composed entirely of synthetic pig iron. The synthetic pig iron was produced in an arc electric furnace (with a capacity of 6t) by the remelting of scrap iron waste, rigorously selected from the point of view of accompanying elements content (Cr, Ni, Mo, Sb, As etc.). Thus, we paid attention that, in the synthetic pig iron, the contents of antinodulizant and antighaphitizant chemical elements, to be as small as possible so that the process of modification would not be negatively influenced. In order to obtain a growth of the carbon content in the melt, in the induction electric furnace, we added in the charge, and even in the metallic bath, graphite dust, resulted from processing through turning of graphite electrodes.

The treatment of cast iron in a liquid state, in order to obtain the modification of graphite separations, was realized in next technological variants:

♦ For the compactness modification of graphite separation we used two types of complex modifiers, from the Mg alloys category, with slightly different chemical compositions:
* Mg I alloy - FeSiMgRE I (5,4%Mg; 2.0%Ca; 65,0%Ce, from 5,7%RE);
* Mg II alloy - FeSiMgRE II (5,9%Mg; 2,1%Ca; 52,5%Ce, from 6,5%RE).
♦For the graphite modification, we used two types of substances from the Si alloy category, with different chemical compositions:
* FeSi75 (75%Si);
* FeSiSr (45%Si; 0,8%Sr).

Obs. The concentrations of chemical elements from the modifiers were approximated.

The technology of treatment in a liquid state of grey cast irons for the obtaining of graphite separations compactness, is realized with the help of the Sandwich procedure, in a pot with a capacity of 1000kilos, and the technology of graphite modification was realized by the application of the addition of the modifier procedurein "the spray" of liquid cast iron, in the discharge of the liquid cast iron from the modifying, nodulizing pot in another one, with a capacity of 400kilos.

Thus, the experiments were made on a single charge of grey cast iron, elaborated in an induction furnace. From a technological point of view, the experimental procedures of modification of grey cast irons are presented in the following manner:
a. – from the melt of elaborated grey cast iron, a quantity of 600kg of liquid cast iron is subjected to a modification of spheroid of the graphite separation, by using a higher quantity of Mg I alloy (~1,6%);
- 300kilos of cast iron thus treated, is subjected to a graphite modification with FeSi75 (melt 1);
- 300kilos of cast iron is treated for the modification of graphite with a quantity of FeSiSr, identical with the quantity of FeSi (used in the anterior stages) (melt 2).
b. – from the same melt elaborated from cast iron, another quantity of liquid cast iron of 600kg is subjected to nodulizing modification with a lower quantity of cu o Mg I alloy (~1,0%);
- for the graphite modification we preceded in the same manner as in the anterior case, by using the same quantities of graphitization modifiers: FeSi75 and FeSiSr (melt 3, respectively melt 4).
c. - 600kilos of liquid cast iron was subjected to a nodulization modification with a higher quantity of Mg II alloy (~1,6%);
- the graphitization modification was realized the same way as in the anterior cases, by using the same quantities of modifying substances of the same type: FeSiSr and FeSi75 (melt 5, respectively melt 6);
d. – a quantity of 600kilos of liquid cast iron is subjected to a nodulization modification with q lower quantity of Mg II alloy (~1,0%);
- for the graphitization modification the procedure is the same as the one presented at point „c" (melt 7, respectively melt 8).

2. Experiments results.

Table 1

Chemical composition of grey cast iron in a liquid state [%]

C	Si	Mn	P	S	Cr	Ni	Mo	Al
3,57	2,23	0,193	0,0563	0,0127	0,076	0,044	0,00691	<0,0003

Co	Co	Cu	Nb	Ti	V	W	Pb
0,00142	0,00142	0,27	0,0045	0.00875	0,0084	0,0056	0,00064

Sn	As	Bi	Ca	Sb	B	Zr
0,00745	0,00362	0,0024	0,0093	0,00196	0,00079	0,00125

Table 2

Variants of grey cast irons modification and quantities of modifier [%]

Melt no.	Modification variant			
	Spheroid modification		Graphitization modification	
	Type of modifier	Quantity [%]	Type of modifier	Quantity [%]
1	Mg I alloy	1,6	FeSi75	0,8
2	Mg I alloy	1,6	FeSiSr	0,8
3	Mg I alloy	1,0	FeSi75	0,8
4	Mg I alloy	1,0	FeSiSr	0,8
5	Mg II alloy	1,6	FeSiSr	0,8
6	Mg II alloy	1,6	FeSi75	0,8
7	Mg II alloy	1,0	FeSiSr	0,8
8	Mg II alloy	1,0	FeSi75	0,8

Table 3

Chemical composition of grey cast irons melts after the modification [%]

Melt no.	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	Mg
1	3,76	2,18	0,194	0,0447	0,0145	0,0696	0,0366	0,00630	0,252	0,0613
2	3,60	2,71	0,193	0,0414	0,0103	0,0686	0,0400	0,00665	0,259	0,0669
3	3,30	2,09	0,216	0,0393	0,0105	0,1110	0,0695	0,01530	0,135	0,0201
4	3,53	2,22	0,213	0,0421	0,0135	0,1100	0,0944	0,01580	0,135	0,0317
5	3,58	2,00	0,235	0,0657	0,0158	0,0213	0,0056	0,00180	0,006	0,0600
6	3,47	2,13	0,244	0,0577	0,0092	0,0202	0,0066	0,00190	0,005	0,0455
7	3,46	1,74	0,265	0,0547	0,0153	0,0205	0,0055	0,00150	0,005	0,0249
8	3,44	1,70	0,268	0,0562	0,0144	0,0202	0,0059	0,00160	0,006	0,0260

Keeping in mind that only one melt of grey cast iron was elaborated and subjected to some treatments in a liquid state with different compactness

substances of graphite and graphitization separation, the content of accompanying chemical elements is a low one and slightly varies from one melt to another. Thus, we have the following contents: Al = 0,0162÷0,0078%; Co ≈0,001%; Nb = 0.0463÷0.0325%; Ti = 0.0124÷0.0077%; V = 0.00875÷0.00705%; W = 0.00601÷0.00293; Pb = 0.00744÷0.00065%; Sn = 0.00726÷0.00266%; As = 0.00303÷0.00266%; Bi = 0.00300÷0.00156%; Sb = 0.00275÷0.00078%; B = 0.000095÷0.000050%; N = 0.0240÷0.0006%; Ca = 0.00920÷0.00005%; Zr = 0.0003÷0.000011%.

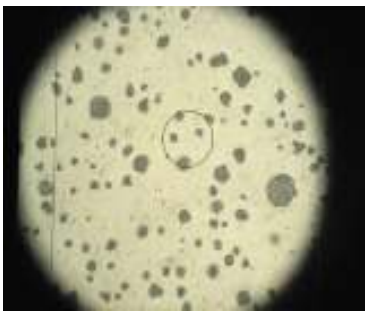
For the realization of the metallographic structure study of the cast melts from modified cast irons, from every cast melt (ϕ30x300) we tested samples with sizes of ϕ30x10.

Table 4

Characteristics of the metallographic structures of modified grey cast irons

Melts no.	Matrix		Graphite separations			
			Surface occupied [%]	Shape	Nodules no./ mm^2	Nodule diameter [μm]
1e	P80/F20	10 ÷ 30	> 12	N	~ 125	40÷60
1m	P94/F6	2 ÷ 10	~ 8	N	~ 75	40÷60
2e	P80/F20	10 ÷ 30	> 12	N	~ 150	25÷40
2m	P80/F20	10 ÷ 30	> 12	N	~ 125	40÷60
3e	P60/F40	30 ÷ 50	> 12	15%N 80%V 5%C	~ 25	40÷60
3m	P60/F40	30 ÷ 50	> 12	15%N 85%V	~ 25	40÷60
4e	P60/F40	30 ÷ 50	> 12	50%N 50%V	~ 50	25÷40
4m	P60/F40	30 ÷ 50	> 12	25%N 75%V	~ 25	40÷60
5e	P80/F20	10 ÷ 30	> 12	N	~ 100	25÷40
5m	P60/F40	30 ÷ 50	> 12	N	~ 100	25÷40
6e	P80/F20	10 ÷ 30	~ 6	90%N 5%V 5%C	~ 125	25÷40
6m	P94/F6	2 ÷ 10	~ 8	N	~ 125	25÷40
7e	P80/F20	10 ÷ 30	> 12	N	~ 125	25÷40
7m	P60/F40	30 ÷ 50	> 12	N	~ 125	<25
8e	P60/F40	30 ÷ 50	> 12	N	~ 100	<25
8m	P80/F20	10 ÷ 30	> 12	N	~ 150	25÷40

Notes: 1. N - nodular graphite; V - vermicular graphite; C - „coral" graphite.
2. e - exterior area of the sample; m - middle area of the sample.



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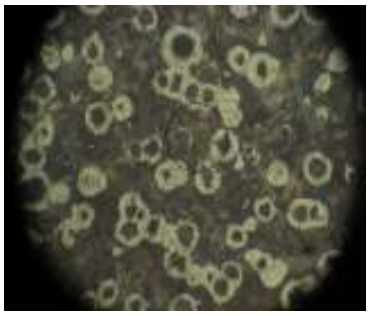

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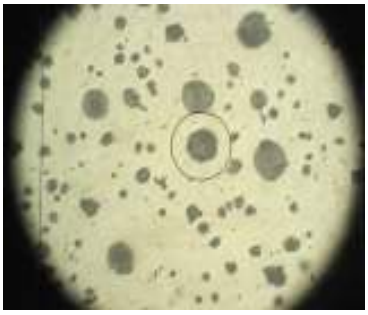

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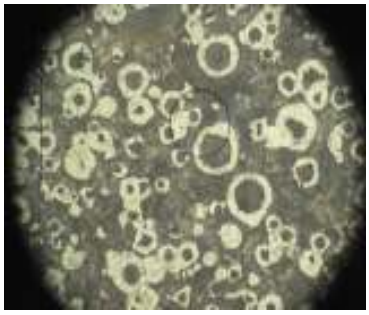

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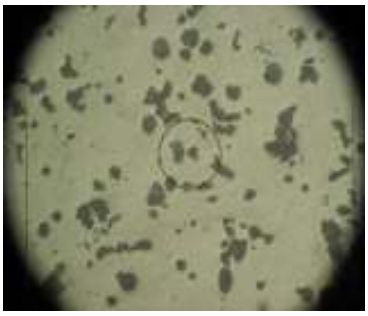

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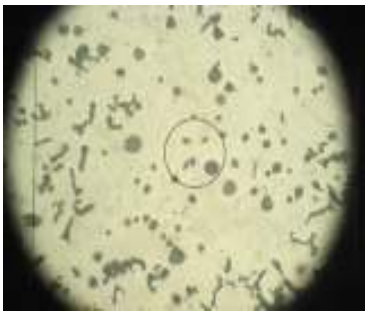

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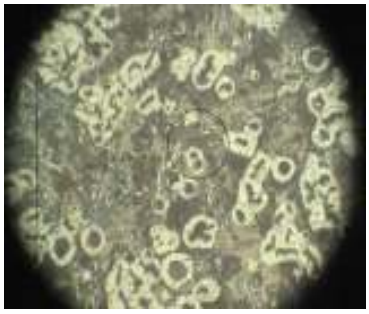

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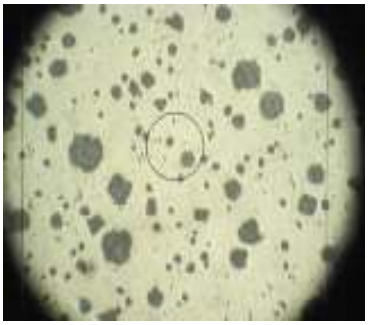

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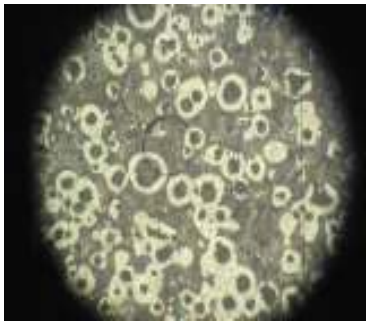

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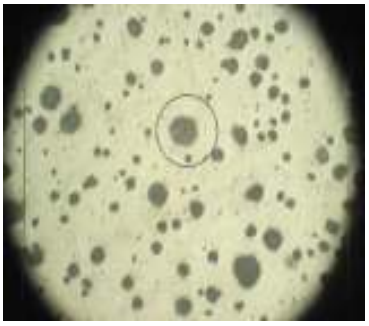

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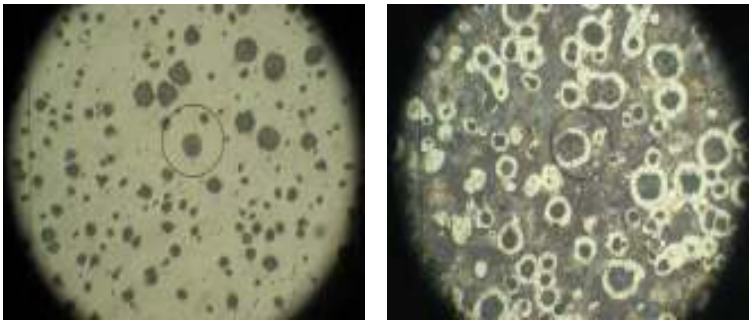

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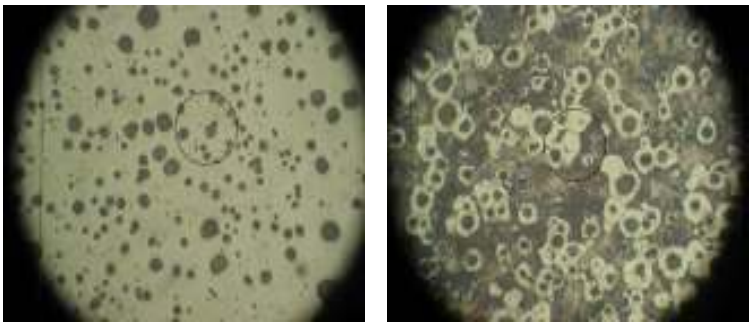

8. 8e.

Figure 1. Metallographic structure of modified grey cast irons (100X) (e – Nital etched of the sample, 4%)

Table 5

Mechanical properties of the cast modified irons

No. melt	Tensile strengh, R_m, [MPa]	Yield strengh, R_{p02}, [MPa]	Elongation, A_5, [%]	Hardness Brinell [HB]
1	580	344	2,2	229
2	611	395	7	223
3	318	293	1,8	179
4	452	350	4,2	179
5	599	369	9,2	207
6	554	331	6,6	179
7	567	369	7,8	197
8	510	331	6	187

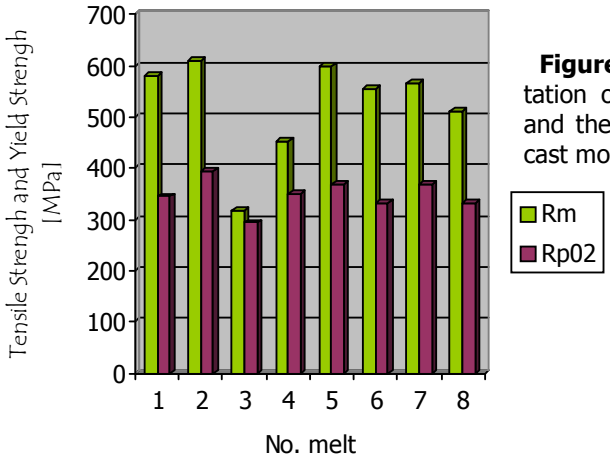

Figure 2. The graphic representation of the tensile strengh, R_m, and the yield strengh, R_{p02}, of the cast modified irons.

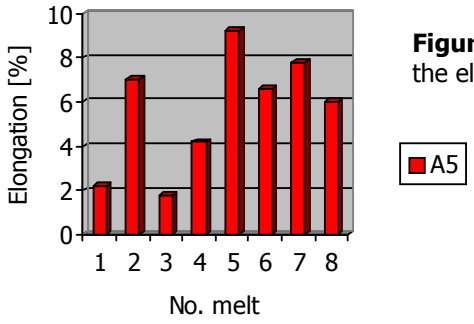

Figure 3. The graphic representation of the elongation of the cast modified irons.

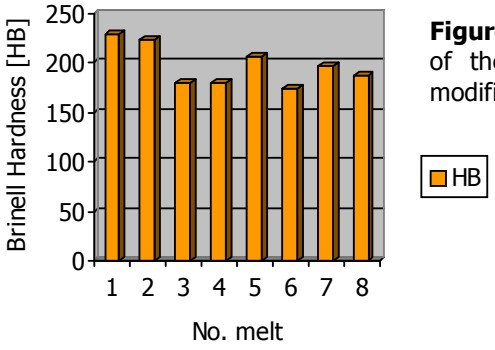

Figure 4. The graphic representation of the Brinell hardness of the cast modified irons.

In table 6 we can see the values of the Vickers hardness measured on the grains of the matrix constituents. Because the matrix is mainly pearlitic and the ferrite grains are very small from the size point of view, in most of the samples the Vickers hardness values were determined only on the pearlite grains.

Table 6

Harness values, determined on the constituents of the basic metallic mass

Melt no.	Vickers Hardness, on the constituent, [HV_1]	
	Pearlite	Ferrite
1	248; 245; 257	-
2	237; 239; 242	-
3	286; 276; 286	185; 185; 181
4	257; 269; 283	165; 174; 162
5	234; 229; 224	-
6	269; 251; 239	-
7	245; 229; 229	-
8	269; 260; 263	-

3. Conclusion

The research made on the metallographic structure of modified cast iron was made on two different areas of the melts surfaces: middle area (i) and exterior area (e), the results of the study being presented in table 4 and figure 1.

According to the analyses of metallographic structures of compact graphite cast irons melts a few ideas can be exposed:

● If on the cast samples from the melts of modified cast irons 1, 2 and 5÷8 - we observed spheroid graphite separation (graphite nodules), on samples 3 and 4 vermicular graphite separations were underlined (80…85%, respectively 50…75%, from the total of graphite separation from the surfaces analyzed), with a growth of percentage of graphite vermicular separations to the middle of the samples, respectively on the exterior area of sample 6 (~5%). But, in general, all cast irons studied present a predominance of graphite nodular separations (Fig. 1).

● We also observed the type „coral" graphite separations on the exterior areas of samples 3 and 6 (~5%), which on the basis of some researchers affirmations in the domain, on a number of times can be assimilated with degenerated separations of nodular graphite (even with separations of vermicular graphite) (FIG. 1-3, 3e, 6, 6e).

● Thus, the study of metallographic structures study, of the 8 samples has underlined an unprecedented fact regarding the usual graphite separations

obtained, we may say even predictable, regarding the concentrations of Mg alloys used in the compacting treatment of graphite separations. Thus, melts 1…4, were treated with Mg I alloy, and alloy created and made by the producer for the purpose of producing nodular graphite cast irons, while cast irons melts 5…8, were treated with Mg II alloy, created and made by the producer for the purpose of producing vermicular (compact) graphite cast irons, both types of compact graphite cast irons being destined to part casting. We must also mention the fact that in the two types of Mg alloys, the contents of the same chemical elements are almost the same, the difference of higher contents for Mg II alloy, with approximately 0,5% for Mg, with approximately 0,7% for RE, but lower with approximately 12,5% RE in the same Mg II alloy.

• In these conditions, we may stipulate that the precision of the specialty literature in the domain and the use of lower quantities of Mg alloy (reduced addition of Mg) in the treatment of cast irons may lead to the apparition of vermicular graphite next to the nodular graphite (graphite separations considered as having the highest degree of compactness).

• On the other side, the matrix of the cast irons studied if considered to be perlito-ferritic, the concentration of ferrite growing (with little exceptions) towards the middle of the samples studied and the quantity of graphite on the surfaces analyzed is studied for concentrations over 12%. Of course, in both situations (the rapport of constituents of the matrix and the quantity of graphite quantity, on the surfaces studied), may appear small anomalies that intervened in the modification and cooling of cast samples, in this phase of this research, were not approached.

• Regarding the analysis of the number of graphite nodules/mm^2 on the surfaces studied, we mention the fact that this is situated at medium values of 100 nodules/mm^2, the exceptions being (as we already know) observed in melts 3 and 4. Also, graphite nodules (in all cases) are characterized by sizes (diameters) of 25…60μm, being different from a size point of view.

• Regarding mechanical properties obtained on cast mechanical samples, from eights melts of modified grey cast irons, we can underline a series of particularities in connection to these results. These aspects represent the results of modification variants applied to the treatments of melts, with an accent on the chemical composition of modifying substances also used for the influence of nodulization and graphitization modifications of graphite. Thus:

• The technological samples cast from melts 1÷2 and 5÷8, characterized, from a structural point of view, by a matrix, mainly pearlitio-ferritie (over 80% pearlite, in general) and by separations of graphite from the "nodules" type (with different sizes - Table 4) that occupy a surface of over 12% of the grey cast irons surface already studied, have determined the obtaining of greater values of the breaking resistance (over 550MPa), but, specific to non-alloy nodular graphite cast irons (Fig. 2).

• The same conclusion are reached in the case of flow limit, the resulted value of which respects the same proportion for the eight samples.

● Regarding the values of elongation for the eight technological samples, we can observe that this is characterized by lower values for samples 1÷4 that were modified through nodulization with the Mg I alloy, in comparison to samples 5÷8 which were treated for the modification through compactness of graphite separations, in the same conditions, with the Mg II alloy and that are characterized by higher values of the elongation. We have to mention the fact that for the graphitization modification, in both cases, we used the same types of (Si alloys), their adding in the melts being made in the same conditions (see § 1).
● Thus, better values of the elongation of modified grey cast irons are obtained in the case where the treatment is realized in a liquid state with the Mg II alloy (!) in the conditions in which, in the structure nodular graphite separations are.
● A different situation is observed for samples 3 and 4 which, from a structural point of view are characterized by graphite vermicular separation (preponderant), even if these melts have been treated with the Mg I alloy. For this kind of graphite vermicular separations, we can (sort of) consider that the values of the mechanical properties are situated in reasonable limits and that, still, these can not be compared, in such conditions, with values of mechanical trials for nodular graphite cast irons.
● For melts 3 and 4, we realized, with greater difficulty, the determination of the Vickers hardness on the ferrite grains; the determinations was realized because the two melts presents a specific structure of vermicular graphite cast irons, different from the other metallographic structures of the melts that are specific to nodular graphite.
● Regarding these hardness values, we can observe that the melts presents values of the Vickers hardness for the pearlite grains close form a value point of view, with the exception of melt 3, characterized by grater values of harness on the pearlite grains, in comparison to the rest of the melts. This exception was caused by the presence of smaller concentrations ledeburite (mainly in the middle of the sample) (max. 5%), underlined in a more detailed metallographic study and which lead in an inevitable manner to the growth of the Vickers hardness on the pearlite grains. Only after such a metallographic study we could find an explanation for the different values of Vickers hardness.
● Thus we may conclude that by treating grey cast irons in a liquid state (in the given conditions) only with the Mg I alloy, we may obtain vermicular graphite cast irons.
● On the basis of the experiments results made in industrial conditions and on the structural analysis of modified grey cast irons with types of Mg alloys, at this level of study we may affirm that the two types Mg alloys may be used with good results in the producing of nodular graphite cast irons and in vermicular graphite cast irons, everything depending in the industrial practice on the adding of modifier for the compacting of graphite separations used.

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