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STRUCTURE EFFECTS OVER BEHAVIOR OF GRAPHITE GRAY IRON IN RUNNING

Adriana PREDA[1], Minodora RÎPĂ[2], Florin MICULESCU[3], Gabriela DULEA[1]
[1] UZINSIDER ENGINEERING S.A. GALATI, [2] University "Dunărea de Jos" of GALATI
[3]POLITEHNICA- BUCHAREST
e-mail: research@uzineng.ro

ABSTRACT

The work aims at emphasizing the structure changes of graphite gray iron, as a result of make-casting conditions and their effects over behavior in running of several cast items. Researches consisted of complex characterization of several gray iron specimens sampled from damaged items comparatively to other suitable ones. Chemical composition, crack aspect, tensile strength, structure, kind, micro hardness of structural constituent were analyzed. Laboratory researches made by optical and electronic microscopy emphasized the showing up of some unsuitable structures with fragile structural constituents and areas unpurified by exogenous inclusions as well as degenerated graphite. All of these steady structural changes had a powerful fragility effect over the material. This fact was confirmed by mechanical characteristics and analysis of cracking area.

Results corroborating allowed finding the causes of graphite gray iron cast items damage as a result of a faulty make-casting technological management and incomplete heating treatment.

KEYWORD: gray iron, nodule graphite, dendrites.

1. Introduction

Graphite gray iron is an alloy of iron with more than 2.11% carbon used to make, by casting procedure, a large amount of items subject to wear and vibrations. This alloy is part of antifriction category materials. Its structure has to fulfill two basic running requirements like the favorable sliding behavior and the wear resistance [9]. Based on this aspect the antifriction materials have heterogeneous structure made of two or more constituents with different properties. Basic structure – the matrix has to have a fine granulation and phases uniformly spread in order to provide the hardness and resistance suitable for the running conditions. Graphite gray iron matrix may be made of ferrite (constituent with high plasticity), pearlite (constituent with low hardness and high breaking resistance) or ferrite and pearlite where the graphite formations are dispersed. [2].

Graphite is the phase with lubricating action and vibration damping capacity that provides the favorable behavior in running. It is the structural constituent with low density, very ductile that flows plastically and makes a cover that covers the harder phases from the matrix over the contact surface.

Therefore it is avoided the breaking and pulling away of hard grains from cavities which are able to act like abrasive particles, [5]. Graphite separations shape differs depending on the kind of wear and demand: vermicular, lamellar, rosette or nodular. Dimensions, shape and distribution of graphite separations have an important influence over the mechanic characteristics of gray irons as well as the behavior in running, [3].

Acting over the chemical composition, casting parameters and heating treatment result in getting the aimed characteristics. A categorical bill has the graphitizing elements like silica and magnesium that allow the alloy to solidify after the steady iron-graphite system. Kinds of wear where the graphite gray iron may be preponderantly involved are: the abrasive wear (bill crushers, rollers, grinding disks, crusher jaws); braking slide wear (with or without lubrication) characteristic for brake blocks, clutches, wheels on rails; rolling slide wear in case of traveling parts in engineering and passenger cars [8].

The items that are the subject of this research are "supporting arms of car wheels" cast in gray iron with nodular graphite. Such item is subject to brake sliding wear and powerful vibrations. Ferrite - pearlite gray

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iron with nodular graphite is suitable for this kind of loads: the matrix made of ferrite and pearlite dispersed in max. 15% lamellar shape, [8] provides the structural stability, good heating conductibility, good friction properties and average wear resistance taking into consideration the parts replacing requirement [8]. Nodular graphite with average compactness, uniformly spread, has a very good capacity in vibrations absorption.

2. Laboratory Experiments

Based on the theoretical considerations submitted, the herewith work intends to investigate three nodular graphite gray irons, apparently identical, but which stated a different behavior of cast items (fig. 1). From those specimens code 1, 2 and 3 tension specimens and metallography micro sections sampled. In case of damaged items code 2 and 3 the specimens were sampled from the cracking areas.

Fig.1. *„Arm – wheel support” - cracked piece.*

In order to find out the damage causes the following tests are performed: chemical and metallographical analysis, tensile test, cracking characterization, chemical composition over micro-areas by X rays as well as micro-hardness measurements on the structural constituents [1, 4, 6, 7].

Chemical composition analysis made by the DV-6 spectrometer with atomic emission (table 1) frames the materials in graphite gray nodular iron category.

Relatively large differences were found between contents of C and Si, the graphitizing element, as it follows: amount close to the bottom line of Si in case of sample code 1, a little bit over the upper limit of carbon of code 2 and over the upper limit of silica, in case of sample code 3. Tensile test performed as per SR EN 10.002/1/2002, in order to find out mechanical characteristics (table 2) emphasized the following observations: code **1** recorded high amounts of yield limit and crack resistance and a suitable elongation amount, fact confirmed by the small amount of Si and graphite as well; code **2** recorded an extremely high crack resistance (confirmed by the large content of C), yielding to permissible limit and a very low elongation. Against the high content of Si that had to provide a large quantity of graphite, therefore a high plasticity, code 3 acted very fragilly. Cracking section of probe code 3 (fig. 2) showed compactness defaults over more than 30% of surface.

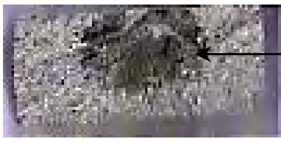


Fig. 2. *Crack section appearance of sample code 3.*

Table 1. *Chemical composition*

Sample code	Chemical composition, [%]				
	C	**Mn**	**Si**	**S**	**P**
1	3.13	0.31	2.14	0.016	0.019
2	3.78	0.18	2.24	0.016	0.044
3	3.34	0.20	2.80	0.016	0.050
Nodular graphite iron 450	3.1–3.7	0.15–0.30	2.0–2.7	Max. 0.02	Max. 0.12

Table 2. *Mechanical characteristics*

Sample code	Average amounts found		
	R_m [N/mm^2]	$R_{p0,2}$ [N/mm^2]	A_5 [%]
1	506	433	11.6
2	556	311	4.9
3	496	290	**7**
SR EN 1563-1999 for type EN-GJS-450-10	Min. 450	Min. 310	Min. 10

Metallographical analysis was performed by OLYMPUS optic microscope with automatic data acquisition as per SR EN ISO 945/2002.

Specimen microstructures analyzed (x100) sizes, are given in figures 3-a, b, c.

Specimen code 1 with suitable mechanical characteristics has an appropriate structure: matrix made by polyhedral grains, fine of ferrite and pearlite 10% percentage, dispersed like isles; nodular graphite with regular geometric shape, Gf6 standard scale, with variable diameter up to 25 μm, GNd1 scale and between 40-60 μm, GNd3 scale.

In case of specimens code 2 and 3 metallographical analysis emphasized several negative aspects concerning material cleanness and structure.

Specimen code 2 shows a brittle structure made of: ferrite-pearlite basic mass sintered by inter-dendrite area overlapped in exogenous inclusions, secondary cementite shows up dispersed (very hard constituent) in acicular shape and graphite is completely nodulized. On the specimen sampled from the damaged area of item code 2, several micro-crakes were found around which there are the exogenous inclusions crowds resulted from slag (fig.4).

Sample code 3 (fig. 3c) has per assembly a suitable structure (ferrite with fine polyhedral grains and 10% pearlite, nodular graphite with regular geometric shape, Gf6 standard of reference, with variable diameter over the part thickness between 25-40μm to GNd2 scale and 40-60 μm to GNd3 scale where isle area with contaminants (oxides and slag) show up.

For example (fig. 5) the macrostructure analysis of one sample from the damaged area was shown. In the thickness average of sample code 3, a powerful unpurified area, which caused the material fragilizing (fact confirmed by values of yelling and elongation limits) was found and constituted prime propagation of crakes during erection.

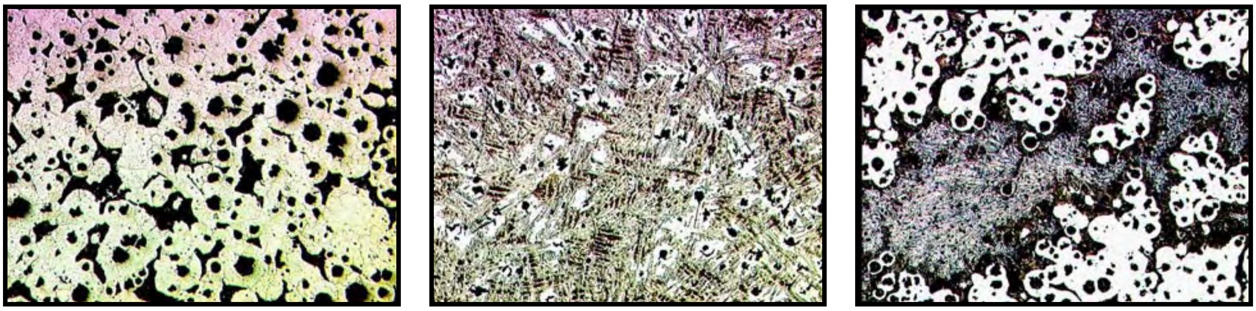
Results of mechanical characteristics and metallographical analysis were fulfilled by electronic microscope analysis and micro hardness measurements that confirmed the submitted data.

By ESEM-XL 30- PHILIPS electronic microscope the cracks of samples code 1, 2, 3, (figures 6-a, b, c) were analyzed and by X ray the chemical composition on the micro-areas with ferrite, graphite and impurities were found out.

In specimen code 1, cracking was ductile with a dark colored crack and inter-crystalline cleavage. Specific aspects of this crack may be seen (fig. 6a): curve lines and ferrite inter-crystalline detachment crests, as well as the black color bowls generated by graphite.

Specimen code 2 (fig. 6b) had a fragile cracking with a light color crack, silver and trans-crystalline cleavage. On the dendrites may be seen the material pulling out stages.

In case of specimen code 3 cracking has a mixed ductile-fragile character. In the inclusions area it was found out that dendrite arrangement in layers as well as evulsions generated by fragile inclusions framed by bowl type crests, was made by ferrite inter-crystalline detaching.



a) Specimen code 1 b) Specimen code 2 c) Specimen code 3

Fig.3. *Nodular graphite gray iron microstructure investigated. 2% Nittal attack.*

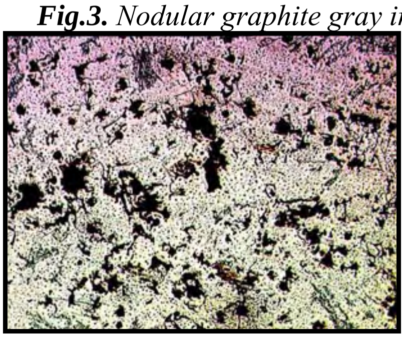
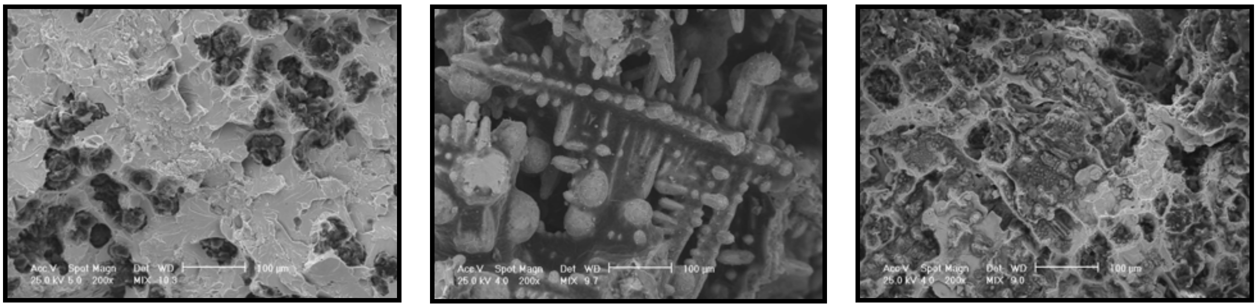


Fig. 4. *Unattacked specimen code 2(×100).*

Fig. 5*. Specimen code 3- 2% macro Nittal attack.*



a) Specimen code 1 b) Specimen code 2 c) Specimen code 3

***Fig.6**. Iron cracking surfaces micrographically investigated. (x200)*

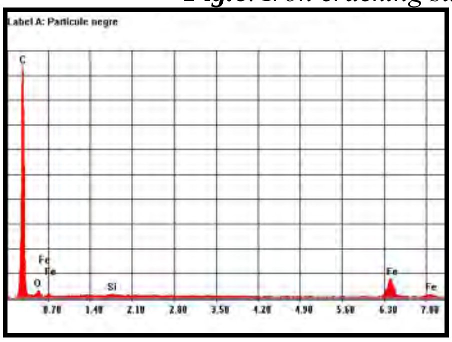


***Fig.7**. EDX spectrum- Specimen code 2.*

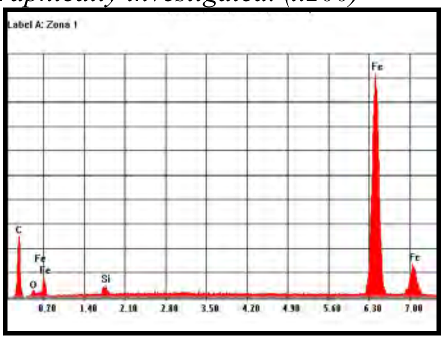


***Fig.8**. EDX spectrum- Specimen code **3**, area 1*

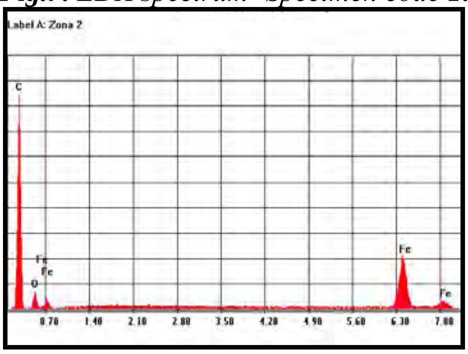


***Fig.9**. EDX spectrum- Specimen code 3, area 2.*

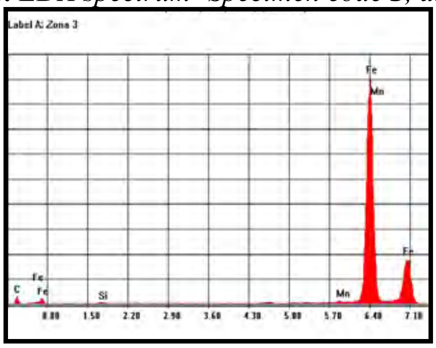


***Fig.10**. EDX spectrum- Specimen code 3, area 3.*

In figures 7, 8, 9, 10 are shown the EDX specters of chemical elements in inter-dendrite areas oversaturated by impurities, for specimens code 2 and code 3.

Local distribution of chemical elements emphasizes several oxides and silicates present into the unpurified inter-dendrite areas of specimen code 2 and code 3(fig. 7, 8, 9). It is noticed that crowds of oxides and exogenous inclusions (silicates) caused several lacks of composition (confirmed by the presence of antigrafitizant element Mn) that led to interrupting the grafitizing process over those areas (fig. 10).

Micro hardness values given by CV-400DAT2 micro-hardness testing machine may be found in table 3. They confirmed the existence and the nature of constituents identified in structure: plastic phase ferrite, harder phase pearlite, very smooth constituent graphite, cementite-Fe_3C very hard inter-metallic compound and areas with oxides, silicates and Mn which have variable hardness depending on local distribution of impurities.

***Table 3.** Micro hardness values*

Sample code	Average values of micro hardness [HV] recorded on each structural constituent; 50gf pressing force; 25 sec.				
	Ferrite	Pearlite	Graphite	Cementite	Zone with impurities
1	224	425	71	-	-
2	245	495	79	726	187
3	226	395	65	-	182[1]; 299[2] ; 495[3] ;

Note: Exponents 1, 2, 3, are suitable for the areas where the local chemical composition was determined.

3. Conclusions

Structural modifications recorded in gray irons analyzed (cast dendrites, acicular cementite, incompletely nodulized graphite, oxides and exogenous impurities overcrowded areas) generated an extremely fragile behavior of materials code 2 and 3, fact confirmed by the mechanical characteristics values.

According to the results, the mechanical characteristics and behavior in running of nodular graphite gray iron are more powerful influenced by technological make-casting management and heating treatment than the chemical composition of the material.

At the same chemical composition, the crowds of oxides and exogenous inclusions (silicates) caused structural inhomogeneities and the showing up of composition gaps (confirmed by the antigrafitizant element Mn presence) that get to interrupt the grafitizing process over those areas.

The submitted issues are the consequence of legal nonconformities connected to the conditions and technological parameters applied:

- bubbling and unsuitable protection of metallic bath during elaboration, as well as the incompletely slag exhausting, explain the oxides and exogenous existence in the iron;
- the too large speed when parts solidifying in mold allowed the secondary cementite precipitating;
- Insufficient treatment holding temperature and time led to the cast dendrite structure keeping.

Unsuitable structures and mechanical characteristics found in nodular graphite gray iron codes 2 and 3, resulted because of the deficient technological make-casting management, neglected and incomplete heating treatment. They caused the items cracking even during assembly.

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