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DESTRUCTION OF THE INSIDE PART OF A COAT OF A HARD CHROME CYLINDER USED FOR COMBUSTION ENGINES

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ABSTRACT

This paper had as a starting point the broken down through explosion suffered by the coat of a cylinder made of cast iron. The cylinder coat material must provide the necessary resistance to dynamic and static stresses and, especially, to wear, taking into account the operation in particularly unfavorable friction conditions. Analyzes have been made on the quality of the material in terms of chemical composition and microstructural analysis.

For comparison, the same investigations were carried out on samples taken from a cylinder coat with a good functioning (blank samples). This paper presents the analysis and conclusions regarding the chemical composition of the material from which the landmark chrome cylindrical coat was used for combustion engine, in order to determine the causes of its breakage and the excessive wear of the segments.

KEYWORDS: hard chrome coat, microstructural analysis, graphitizing elements.

1. Introduction

The cylinder is the organ inside which the piston moves and the engine fluid evolves. It is usually made in the form of a metallic bush, also called the drum sleeve. The drum liner material must provide the necessary resistance to dynamic and static stresses and specially to wear, taking into account the operation in particularly unfavourable friction conditions [1-2].

The most commonly used material is the grey cast iron alloyed with Cr, Ni, Mo, Ti, V, elements that increase wear resistance. More narrowly, aluminium alloys are used, although they are lighter and have a higher thermal conductivity, have a mechanical resistance and unsatisfactory corrosion. In some engines with special functional parameters, coat of Cr steel, nitrides steels and graphite steels are also used. The process of making the cylinder coats is casting (usually, centrifugal casting), followed by chunking, chrome plating, nitration or phosphating. Light alloys are chrome-plated or metallized, resulting both increased hardness and improved lubrication [1-2].

Common grey cast iron has the following characteristics: good casting properties, less solidification shrinkage than steels, high fluidity, which allows thin-walled parts to be made, complex shapes unreachable by mechanical methods, mechanical properties of strength and tenacity inferior to steels due to the presence of graphite. However, graphite also has positive effects if it shows the optimal amount, size, shape and distribution, ensuring good machining by cutting, high vibration damping capacity, lubricating properties under dry rubbing conditions, nipple insensibility, corrosion resistance in common corrosion environments [3-7].

The main element, which influences the structure of the cast iron, is the carbon. In grey iron for machine building, carbon is found within 2.6-3.8%. Lower limit decreases for alloyed alloys with strongly graphitizing elements, Si and Al.

Carbon is a graphitizing element that increases the amount of graphite in the grey cast iron structure and reduces the amount of perlite. Consequently, the increase in carbon content, by increasing the amount of graphite, leads to the decrease of the mechanical strength, hardness and tenacity of the cast iron. In white or mottled cast iron, the increase in carbon content increases the amount of cementite, hardness and brittleness [3-4, 7-8].

The quantity, size, shape and mode of graphite distribution with positive effects on the mechanical characteristics and area of the applications [3-8] can be obtained by changing the conditions of production or casting and by heat treatment.

2. Materials and experimental conditions

Samples were taken for analysis from a well-functioning of the cylinder coat, samples used as a control (A series), and samples from a cylinder coat breached by explosion (B series).

Since the carbon content in the two series of materials is the same (2.8%) and corresponds to that required by the manufacturer, analysis regarding the quantity of graphitizing, anti-graphitizing and carburizing elements from the chemical composition (the two series of materials with such different behavior in industrial practice) were imposed in order to determine the possible causes which led to the explosion breakdown.

Table 1 presents the chemical analysis for the graphitizing elements of the two series of materials determined by means of an X-ray fluorescence spectrometer from the material characterization laboratory. Table 2 shows the chemical analysis of the anti-graphitizing and carburizing elements determined by the spectrometer.

Table 1. *The chemical analysis for the graphitizing elements*

Series of samples	**The determined element**	
	Si [%]	**Cu [%]**
A Series (blank samples)	2.46±0.12	0.27±0,03
B Series	2.28±0.12	0.41±0,03

Silicon is found in grey cast iron within 1.5-2.5%. The lower limit drops to 0.5% Si in the white and upper castles it raises to 16% Si in alloy cast iron. Silicon dissolves in ferrite, and it hardens it. Ferrite from grey cast iron, also called silico-ferrite, has a tensile strength Rm = 350-500 N/mm^2 and hardness HB = 100-150 daN/mm^2, superior to steel. Silico-ferrites is included in the perlite (mechanically ferric + cementitious mixture), which is also harder and more resistant: Rm = 900-1200 N/mm^2, HB = 220-330 daN/mm^2. Silicon is a strongly graphitizing element, which increases the refractoriness of the cast iron. Silicon increases the amount of ferrite and graphite, reduces the amount of perlite, and thereby reduces the strength and hardness of grey cast iron [3-4, 8].

In the Maurer structural diagram of Figure 1, the influence of carbon and silicon content on the structure of cast iron is reflected [2]. It can be noticed that at the same carbon content (as in the case of the A and B series cast iron analyzed in the paper) but with the variation of the silicon content, the entire range of cast iron can be obtained: I - white cast iron; II - perlite-cementitious grey cast iron; III - grey pearls; IV - ferrite-perlite grey lichens; V - ferrite grey cast iron.

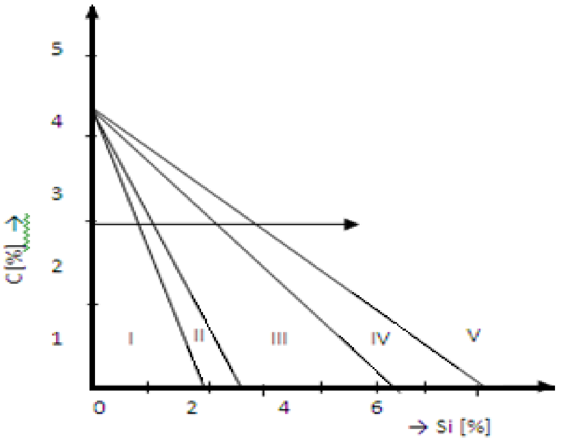


Fig. 1. *The Maurer structural diagram*

Analyzing the results in Table 1 for the two series of materials, it is obvious that if both series have the same carbon content (2.8%) and the series A, with good functioning, has the perlite matrix (sector III in Figure 1) implies that for series 2, the reduction in silicon quantity to 2.28% for the same thickness of the cylinder coat, can lead to structures with areas in sector II, or even I. In this case, these structures can lead to hardening of the cast iron and to an increase in the fragility of the pieces [4, 8]. For this reason, a rigorous microstructural study is required to correlate the chemical composition with the cast iron structure and properties derived from the structure.

Table 2 shows the chemical analysis of the anti-graphitizing and carburizing elements determined by the spectrometer.

Table 2. *The chemical analysis of the anti-graphitizing and carburizing elements*

Series of samples	**The determined element**		
	Cr [%]	**Mn** [%]	**Mo** [%]
A Series (blank samples)	0.35±0.03	0.53±0.04	0.43±0.01
B Series	0.54±0.02	0.35±0.05	0.19±0.01

The carburizing alloy elements Cr, Mn, Mo have anti-graphitizing action, and the non-carboniferous elements Si, Cu are graphitizing. The anti-graphitizing elements (Cr, Mn, Mo) are elements which either dissolve in cement [$(Fe, Mn)_3C$, $(Fe, Cr)_3C$], which stabilizes, or forms stable carbons, which facilitates cementitious germination (Cr_2C_3, Mo_2C). The carburizing elements, determined by Mn, Cr, Mo, are those that have higher affinity to carbon and, after interaction, they form stable carbides [3-4, 8].

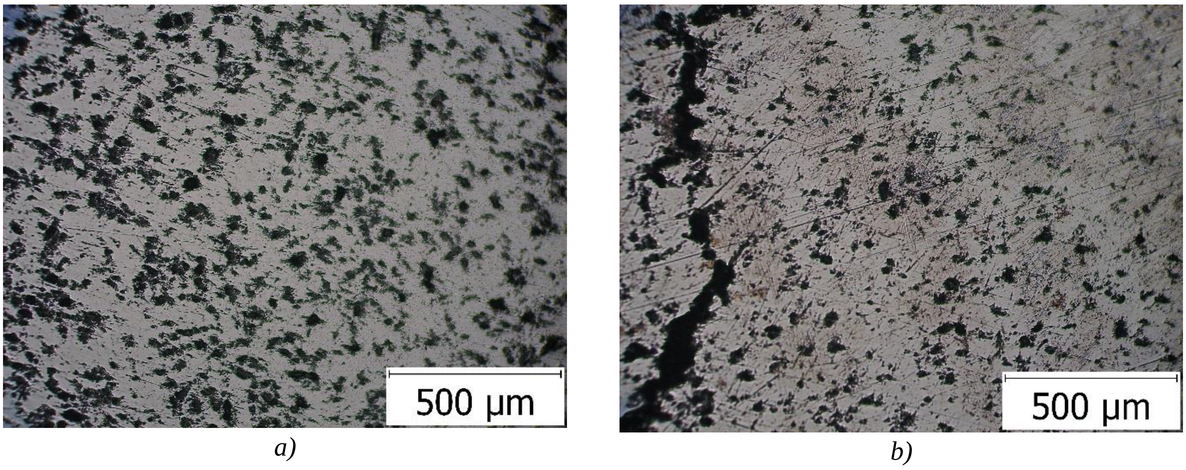
Manganese is dissolved in cement, increasing its stability, or in the form of sulphides. It is an anti-graphitizing element, which increases the amount of grey cast iron, i.e. the mechanical strength, hardness and wear resistance of the cast iron [3-4, 8]. Molybdenum is an alphagen element that partially dissolves in ferrite and cementite, the remainder forming carbides. In this way the characteristics of resistance and, to a certain extent, plasticity increase.

The alloying elements which partially dissolve in the cementite, partially form their own carbides, such as chromium and molybdenum, can form (especially when present in amounts exceeding solubility in cementite) EA_7C_3, $EA_{23}C_6$ or EA_6C type carbides with complex crystalline structure too, which dissolves relatively easily in austenite (on heating of alloyed steels or alloys) and type EAC, with cubic crystal structure or EA_2C, with hexagonal crystal structure (insoluble in austenite) [3-4, 8].

Carbides of alloying elements compared to iron carbide (cementite) are tougher and influence the properties of the material according to their quantity, size, shape, dispersion in the metal matrix. Thus, the primary carbons (as individual phases or as the constitutive phases of the eutectic mixture) can be arranged at the boundaries of the basic metallic mass in a mesh form and lead to an increase in the strength characteristics (mechanical strength and hardness), but diminish considerably plasticity and tenacity (in the case of chromium and manganese carbides). The fine-grained globular carbons (molybdenum carbides), uniformly dispersed, are desired phases in the base mass, as it provides a good complex of mechanical characteristics (with high values of both mechanical strength and hardness characteristics as well as plasticity and tenacity characteristics) [3-4, 8].

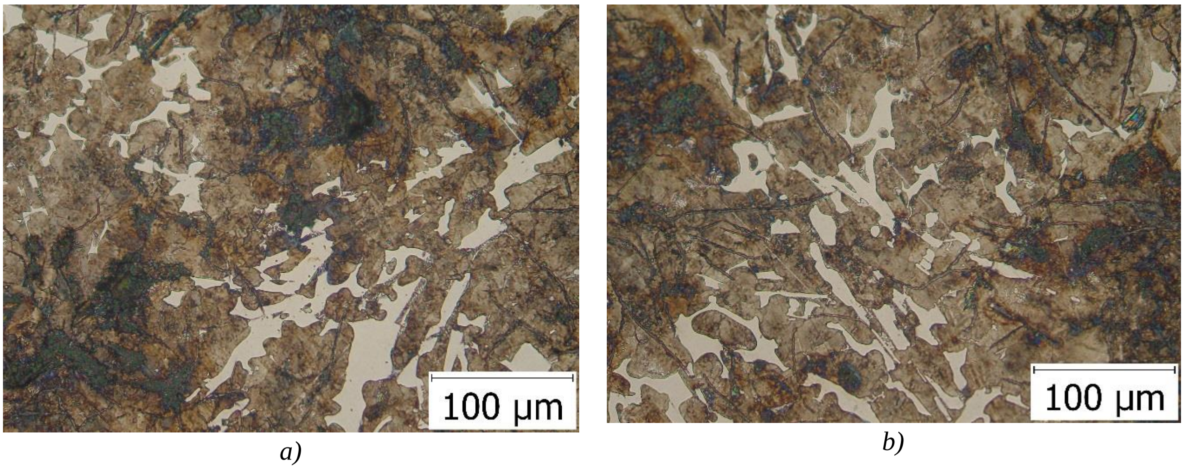
Analyzing the elements determined in Table 2, we can assume that considering the high carbon concentrations of the two series of cast iron and taking into account the quantities of graphitizing alloying elements (Si) as well as the quantities of carburizing alloying elements (Cr, Mn, Mo) it is possible that at their liquid cooling, the eutectic transformation to be realized, and small amounts of ledeburite (constituent specific to the structure of the white or spherical pigments, zones I and II in Figure 1) [9-12] to appear in their structure. Obviously, to the B Series with less silicon, a larger amount of carbon remains which is available to interact with the carburized elements. Depending on the carbon concentrations and alloying elements that characterize their composition, the ledeburitic formations in the structure of these steels can be dispersed coherently, in the form of an intergranular mesh (referred to as the ledeburitic skeleton), which can be primed and crack propagation pathways external requests [3, 8].

Starting from the analysis of the chemical composition of the material from which the hard chrome coat cylinder was made, destroyed by explosion and excessive wear of the segments, we determined the metallographic appearance on two polished samples (B series) but without metallographic attack from areas with and without cracks (Figure 2).



a) b)

***Fig. 2.** Microstructure of the material (B Serie) on polished probe (without metallographic attack). Magnification 100:1*



a) b)

***Fig. 3.** Microstructure of the material (B Serie) on polished probe and attacked metallographic) (with nital reactive); Magnification 100:1*

The shape, magnitude and dispersion of graphite in the base mass (dark grey colour) as well as white glowing micro-volumes suggesting the presence of free carbons have induced the idea that it could be a mottled cast iron (a part of carbon in free graphite form and another part in free form of carbides). Such an inappropriate structure would not be desirable considering the working properties of the cylinder coat landmarker.

On this purpose, the microstructures of the samples in the areas where the explosion cracks were propagated were studied in order to identify the structural constituents in the base mass (Figure 3).

The microstructures confirmed that the B series cast iron matrix is a perlite, but due to alloying amounts, it includes Alloyed carbides I (alloyed primary carbides), Alloyed carbides II (alloyed secondary carbides) with white colour and an atypical eutectic with both dispersed carbon forms in the matrix perlite, carbide and graphite, E [P + Graphite II + Alloyed carbides II + Graphite E], which explains the increased fragility of the piece breakdown through explosion.

3. Conclusions

The results obtained suggested the need for a thorough / rigorous, comparative (for the two A series and B series) microstructural analysis to explain the inappropriate behaviour, the destruction through explosion of the benchmark (B series), although the cast iron of the cylinder has the correct content of carbon. The beneficiary only requested the form of graphite and the perlite metallic matrix. The analysis of the authors has shown that for proper functioning it is necessary to specify not only the quantity of carbon but also the quantity of carbon in correlation with the alloy elements in order to achieve the correct physical-chemical constitution of the cast iron (structural constituents and constitutive phases).

References

[1]. Roşca R., Rakosi E., Manolache Gh., Roşu V., Elemente de tehnologia autovehiculelor, Editura “Politehnium” Iaşi, 2005.

[2]. Popa B., Băţagă N., Căzilă A., Motoare pentru autovehicule, Editura Dacia, Cluj-Napoca, 1982.

[3]. Levcovici M. S., Studiul materialelor I, Editura Fundaţiei Universitare “Dunărea de Jos”, Galaţi, 2002.

[4]. Potecasu F., Metalurgie fizică, vol. 1, ISBN-978 - 973-8151-48-1; ISBN-978 - 973-8151-49-9- Editura FRM, 2007.

[5]. ***, SR EN ISO 945-1:2009/AC:2010 ver.eng. Microstructura fontelor. Partea 1: Clasificarea grafitului prin analiză vizuală.

[6]. Ripoşan I., Sofroni L., Fonta cu grafit vermicular. Bucureşti. Editura Tehnică, 1984.

[7]. Sofroni L., Ripoşan I., Brabie, V. Chişamera M., Turnarea fontei, Bucureşti. Editura Didactică şi Pedagogică, 1985.

[8]. Potecasu F., Transformări structurale în materiale cristaline – e-book, platforma ugal, 2014.

[9]. Cojocaru- Filipiuc V., Ipoteze cu privire la obţinerea de materiale metalice pe baza tendinţei spre echilibrul chimic - aplicaţii la modificarea fontelor, Iaşi. Editura „Politehnium”, 2011.

[10]. Cojocaru-Filipiuc V., Remanent graphite and its implication in modification process of iron, Metalurgia Internaţional, Vol. XV No. 5. p. 57-62, 2010.

[11]. Jukov A. A., Fe-C. The stable and metastable equilibria. Giessereiforschung, p.106-112, 1992.

[12]. Dumitrescu T., Diagrama de echilibru stabil Fe-C, Ed Universitatea “Dunărea de Jos”, Galaţi, 1989.