

Obtaining of High Cr Content Cast Iron Materials

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Abstract. We have obtained, through the classic casting process, 3 highly chromium-based experimental alloys proposed for replacing the FC 250 classical cast iron in braking applications. Casting was carried out in an induction furnace and cast into moulds made of KALHARTZ 8500 resin casting mixture and HARTEC hardener at SC RanCon SRL Iasi. It is known that the microstructure of the cast iron is a combination of martensite with a small amount of residual austenite after the heat treatment of the ingot. In the case of high-alloy chromium alloys, the performance of the material is due to the presence of M₇C₃ carbides distributed in the iron matrix. Resistance to machining and deformation is based on alloy composition and microstructure, while abrasion resistance will depend on properties and wear conditions.

1. Introduction

Friction between two dry surfaces in contact and moving relative to each other is known as Coulomb friction and even if it is a phenomenon that occurs several times a day the frictional force can only be estimated from previous experience and experimental results [1].

In the case of braking systems (for any type of vehicle using braking systems) the contact surfaces are often covered with different materials to result in a sliding process and are not just two metallic materials sliding over each other. The metallic surface will be affected by abrasion, adhesion of compounds other than the base material, or deformation of the material during sliding, which will create metallic fragments of material as well as other particles [2].

Any metal friction surface, even if it appears geometrically fine at a macroscopic level, is quite rugged on a microscopic scale, with a large distribution of roughness along it. An explanation of friction formation is the interaction of microscopic asperities of two surfaces, but when two such surfaces are forced to slide one on the other, it is very difficult to specify where and how contact occurs between them.

Even if, from the point of view of an engineer, it can be assumed that a coefficient of friction between two surfaces, especially metallic, sliding one at the other, can be considered constant in the applicative work with the braking systems, it is very important to understand that this coefficient is variable and it is very useful to understand why [4,5]. There are several reasons why the braking performance of a vehicle can change over time and any damage can be recognized by the user through a reduction in braking parameters such as distance or vehicle stopping time [6-8].

Alloy cast iron with a high percentage of chromium are recognized as having a high wear resistance and have been widely used for wear-affected parts operating under extreme conditions. Exceptional wear resistance of Cr-rich castings results primarily from the high percentage of M₇C₃ carbides formed in the ferrous matrix with M = Fe, Cr and which have the role of preventing graphite formation and generally stabilize carbides [14].



The chromium content is depending on the destination of the cast iron, being 11 ... 30% for the wear resistant cast iron, 15 ... 25% and 29 ... 35% for the high temperature cast iron and 20 ... 35% for the cast iron corrosion. Typically, molybdenum is present in these cast irons at a maximum of 30%. If the chromium content is less than 9.5%, the presence of Carbide (Fe, Cr) $3C$, with orthorhombic network, as part of eutectic colonies, is found in the structure. In this paper we present some preliminary results, chemical and microstructural insights, obtain on three experimental cast-iron materials.

2. Experimental details

Experimental samples with varying percent chromium ($\approx 11, 14, 22$ wt%) were obtained in the form of further heat treated ingots and experimental samples. For the present study, in addition to a class 250 FC cast iron, three types of chromium alloy cast iron were developed at SC Rancon S.R.L. Iași in the induction furnace and cast into moulds made from Kalhartz 8500 resin binder and Harter hardener. The chemical composition of the three materials was determined on the Foundry-Master 01J0013 Spectrometer.

Their hardness was measured on the Wilson Wolpert Model 751h hardness meter (equipped with the SIM Iasi faculty) with a diamond-shaped cone penetrator with a load force of 150kgf and a standard pushdown time of 12 seconds. At micro-scale chemical composition was realized using an EDS detector (Bruker XFlash – EDAX type) in order to establish some chemical details from the cast iron materials. For microstructure, after mechanical grinding and polish plus chemical etching (with nital at room temperature, 4% alcohol solution of nitric acid (HNO_3)) the structure was observed by scanning electron microscopy (VegaTescan LMH II SEM with SE detector at 30 kV).

3. Experimental results

The three experimental materials obtained by the classical method of industrial casting are referred, in the present work, as the alloy A, B and C, these having the possible applications for producing different automotive parts such as brake discs. The chemical composition of the three materials is shown in table 1. At the same time we also analysed a standard material used for industrial automotive brake discs, a classical cast iron, FC 250 which we named the sample D or the initial sample. The chemical composition is presented as a percentage by weight (wt%) and was performed after 5 measurements by optical spectroscopy on a 4 mm^2 area for each determination.

Chromium, in quantitative terms, varies in the casting of the oligo-element (less than 0.3%) to the alloy element quality (over 0.3% - the bibliographic source [15] indicates cast iron with a maximum of 36% - 45% Cr [16] materials were also experimentally analysed. Chromium is an anti-graphitizing on a scale, in an ascending order of the anti-graphitizing (whitening) effect, the order being: W, Mn, Mo, Sn, Cr, V, B etc. As an anti-graphitizing chromium increases the number of eutectic cells and the proportion of pearlite in the case of grey cast iron.

Table 1. Chemical composition of experimental alloys.

Alloy	C wt%	Si wt%	Mn wt%	P wt%	S wt%	Cr wt%	Mo wt%	Ni wt%	Cu wt%
A	2,76	0,64	0,65	0,03	0,067	11,2	0,27	0,3	0,16
B	2,48	0,65	0,53	0,03	0,078	14,7	0,38	0,38	0,18
C	2,64	1,11	0,66	0,03	0,056	20,9	0,11	0,16	0,1
D	3,1	1,2	1,0	0,03	0,04	-	-	-	-

For a better evaluation and characterization of the alloys tested, their hardness was measured on the Wilson Wolpert Model 751h hardness meter (equipped with the SIM faculty) with a diamond-shaped cone penetrator with a loading force of 150 Kgf and a standard push time of 12 Seconds, the results are shown in table 2.

Table 2. Hardness values of the experimental materials.

Alloy	Hardness in 3 points (HRC)			Mean value of hardness (HRC)
A	56,7	55,4	56,3	56,1
B	58,9	57,5	58,8	58,4
C	43,2	42,2	45,3	43,6
D	57,3	57,8	56,7	57,3

Experimental alloy micro-hardness values show close average values for samples A, B and D (i.e., the one alloyed with 11 and 14 wt% Cr respectively the initial sample) and a lower value for sample C, the sample containing a higher percentage of chromium (21 wt%).

The chemical analysis of the constituents of material C was performed on the Bruker EDAX equipment by analyzing at various points on the micrograph. Three areas for chemical analysis were selected, showing microstructural differences due mainly to their chemical differences, figure 1.2 a).

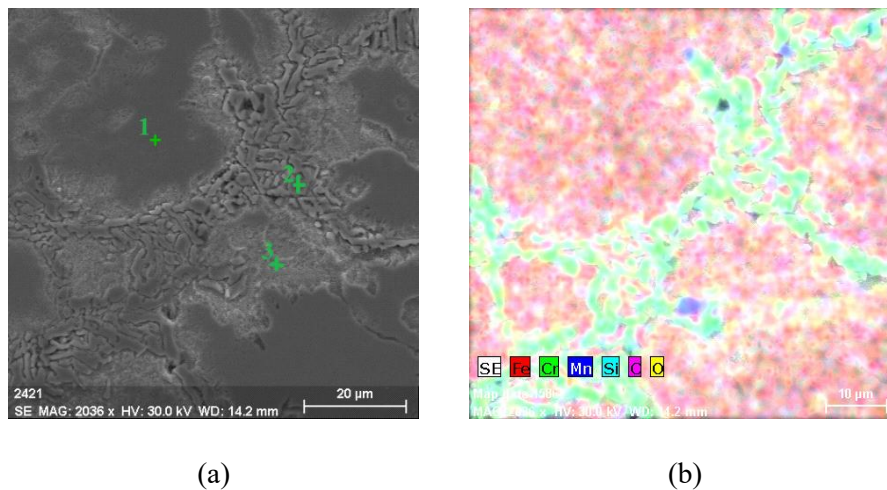


Figure 1. Alloy C (a) Surface micrograph of experimental material C with selection of micro-zones (1-3) for chemical analysis and (b) distribution of Fe, Cr, Mn, Si, C and O chemical elements on a specific surface.

Figure 1 b) shows the distribution of Fe, Cr, Mn, Si, C and O on the surface of the metallic material. table 3 shows the chemical compositions characteristic of the 3 points selected in figure 1 a). At point 1, the iron composition of iron-based matrix composed of Fe, Cr, Si and C. The selected area of point 2 shows the Cr-based compounds in dendrite like forms mostly Cr-based carbides and Fe. The area selected by point 3 is a transition zone between the dendrites with a higher percentage of chromium and the matrix of the iron-based material. There is a slight oxidation of the compounds with more chromium and especially of the interface between the carbides and the ferrous matrix (the main cause being due to the chemical attack made to highlight the metal alloy microstructure).

Table 3. Chemical analysis of alloy C by weight percent (wt%) and atomic percent (%).

Area (Fig. 1 a))	Fe		Cr		C		Si		O	
	wt%	at%	wt%	at%	wt%	at%	wt%	at%	wt%	at%
Point 1	76,9	63,5	16,9	14,8	5,1	19,6	1,2	1,9	-	-
Point 2	39,7	32,7	55,3	48,9	4,03	15,4	-	-	1	3
Point 3	74,1	64,9	21,5	20,3	2,5	10	0,9	1,6	1,1	3,2
EDAX Error	1,8		0,5		0,8		0,1		0,6	

The chemical composition obtained in point 3 is very close to the general chemical composition shown in Table 1 representing, at least in terms of carbon, a mediation between the two main component phases. It is known that the microstructure of the cast iron is a combination of martensite with a small amount of residual austenite after the heat treatment of the ingot. In the case of chromium-high alloy castings, the performance of the material is due to the presence of carbons of the M7C3 type distributed in the iron matrix [10]. Resistance to machining and deformation is based on alloy composition and microstructure, while abrasion resistance will depend on properties and wear conditions.

The microstructural material is characterized in figure 2 at two amplification powers showing a homogeneous dendrite tree structure distributed in the iron matrix.

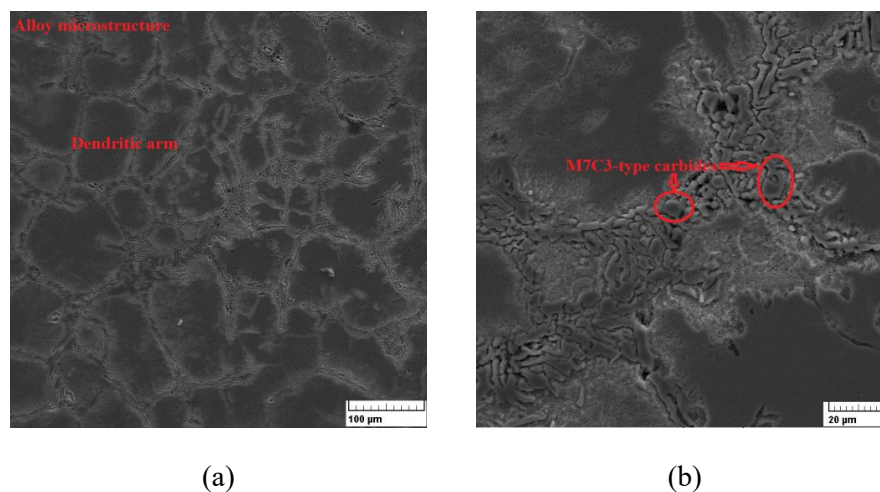


Figure 2. SEM Microscopes (a) Arboreal spacing of homogenous dendrites distributed and (b) distribution of carbides in the ferrous matrix.

The distribution of M7C3 carbides and secondary carbides, in a much lower percentage, demonstrates the significant effects of Si and Cr on dendrite sparing. Since the cast iron chromium ratio is greater than 9.5%, carbon (Cr, Fe) 7C3 is also present in the structure, along with carbon (Fe, Cr) 3C, the latter determining cylindrical and conical eutectic colonies, figure 2b). Carbon (Fe, Cr) 7C3 has a triangular network and develops in the direction of the longitudinal axis of the cylindrical or tapered column of the eutectic colony.

4. Conclusions

We have obtained, through the classic casting process, 3 highly chromium-plated experimental alloys to replace the FC 250 classic cast iron in braking applications. Casting was carried out in an induction furnace and cast into moulds made of KALHARTZ 8500 resin casting mixture and HARTER hardener at SC RanCon SRL Iasi. The experimental results show a very good chemical and microstructural homogeneity of the made materials.

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