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Examination of Electrical Resistance of Carburizers Used for Cast Iron Production

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Abstract

The publication presents the results of examination of selected carburizers used for cast iron production with respect to their electric resistance. Both the synthetic graphite carburizers and petroleum coke (petcoke) carburizers of various chemical composition were compared. The relationships between electrical resistance of tested carburizers and their quality were found. The graphite carburizers exhibited much better conductivity than the petcoke ones. Resistance characteristics were different for the different types of carburizers. The measurements were performed according to the authors' own method based on recording the electric current flow through the compressed samples. The samples of the specified diameter were put under pressure of the gradually increased value (10, 20, 50, 60, and finally 70 bar), each time the corresponding value of electric resistance being measured with a gauge of high accuracy, equal to 0.1μΩ. The higher pressure values resulted in the lower values of resistance. The relation between both the thermal conductance and the electrical conductance (or the resistance) is well known and mentioned in the professional literature. The results were analysed and presented both in tabular and, additionally, in graphic form.

Keywords: Cast iron, Foundry materials, Carburizers, Resistance.

1. Introduction

The question of ferrous alloy carburization during the metallurgical process of liquid cast iron production has an enormous importance in technologies using electric furnaces, especially the induction ones, in the melting process. The application of the induction crucible furnaces or the channel furnaces for melting enables unrestricted controlling of the chemical composition as well as of the temperature of the molten cast iron. The quality of carburizers determines the kinetic of their dissolving in liquid metal and the carburization process effectiveness measured by the ratio of carbon percentage increment in the alloy to the carbon percentage in the carburizer (taking into account the mass proportion factor). The effectiveness of carburizers can reach as much as 99% for the synthetic graphite and up to 90% for the petcoke [4]. On the one hand, the rate of dissolving the carbon from carburizer and the process effectiveness decide about the economy of the process, on the other hand, they create the optimum metallurgical conditions which enable to determine precisely the exact chemical composition of the cast iron over a period of time.

In their search for proper carburizers, foundries have to test them on their own by carrying out the trial melting operations to assess the carburization effectiveness (the yield), as well as the possibility of using a given type of material for the repetition work. Thus they are charged with costs of the risky production of uncertain materials. However, in the period of great competition, the search for the decrease of production costs is still of importance, so that cheaper materials, but of no significantly lower quality, would be welcomed.

The examination of carburizers is as a rule restricted to the determination of their chemical composition and finding the contamination content, which characterise the quality of a given material. Such examination is both time-consuming and expensive. Moreover, the microstructural examination of the carburizers are not always possible under the industrial conditions because of the lack of the special equipment, being often too expensive for a foundry.

Examples of the effect of various carburizers on the carburization process effectiveness are shown in Table 1, where one can easily notice the negative influence of contamination on the carburization process. On the other hand, the great differences in carbon yield values recorded for carburizers of practically comparable chemical compositions and similar contamination types can be seen. Such results ignite a lot of discussion if determination of the chemical composition alone is sufficient for an assessment of the carburizer quality.

Table 1.
Chemical composition of selected carburizers [1]

Substance	Graphite electrodes	High quality petroleum coke	Low quality petroleum coke	Coal tar pitch
	The substance content, mass %			
Carbon	> 99	99.5	94 – 98	95 – 98
Ash	0.1 – 0.4	0.1 – 0.5	0.2 – 1.0	0.5 – 1.0
Volatiles	0.3 – 0.5	0.1 – 0.2	0.5	–
Moisture	0.1	0.1 – 0.2	0.3 – 0.5	0.2 – 0.4
Nitrogen	< 0.05	< 0.07	0.2 – 1.2	0.7 – 1.0
Hydrogen	< 0.003	< 0.005	0.11 – 0.3	–
Sulphur	< 0.03	< 0.005	0.35 – 1.7	0.3 – 0.6

The characteristic structures of the commonly used carburizers are shown in Figure 1.

Thermal conductivity is another feature which can characterize carburizers. The results of its examinations can be found in some publications [6]. The present paper is focused on the electrical resistance and the electrical conductance of carburizers, each of them being the inverse of the other. It is well known that graphite is a good conductor of electric current. This can also result in its better – with respect to petcoke – thermal conductivity and thus influence positively the kinetics of graphite dissolution.

The development of new methods of quality assessment in order to verify carburizer material before it is used in the industrial production can prevent losses resulting from the off-composition casts and the necessity of correcting the carburizer material after such a cast. Therefore it can influence the cast iron quality and the time of its production, both of which contribute to the competitiveness of the final product. The present paper suggests a method of measuring the electrical resistance of the carburizer material samples prepared in the crumbled form in order to assess the possibility of using it in the cast iron technology. There was performed a comparative analysis of carburizers based on synthetic graphite or petcoke, regarded as the best materials for production of the synthetic cast iron based on steel scrap [5].

The synthetic graphite is obtained during the high-temperature treatment (graphitization) of coke (petroleum coke, coke of coal, or pitch coke) or anthracite. Heterogeneous graphitization occurs within the temperature range 2800-3000°C. Petcoke is produced by cracking at the temperature of 450-550°C, under the pressure of 0.1-0.7 MPa [3].

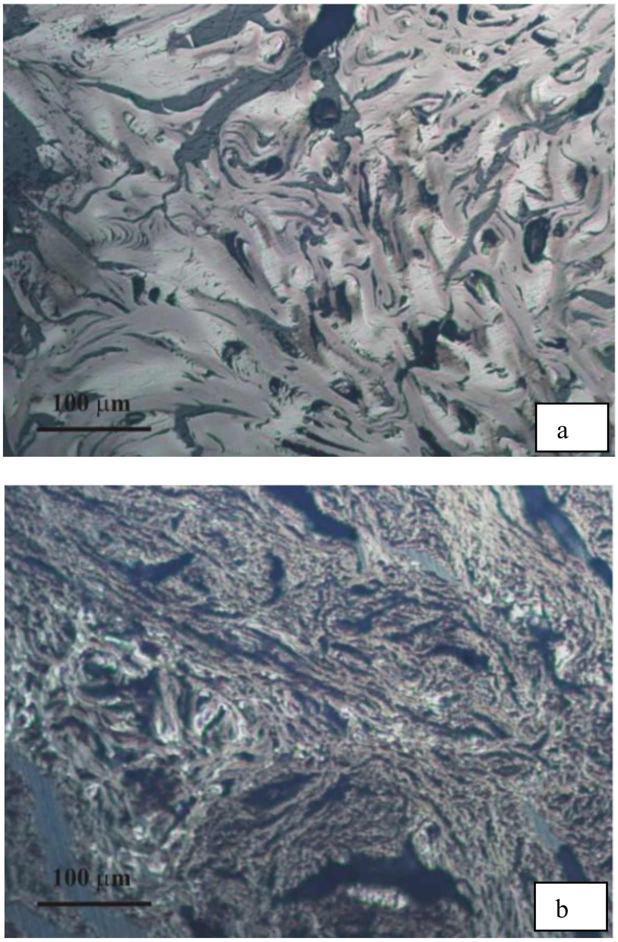

Fig. 1. Microstructures of synthetic graphite (a) and petroleum coke (b) [2]

2. The description of the research method

The electrical resistance examination was done for samples made of one of the three types of carburizers, namely the synthetic graphite, the petcoke A, and the petcoke B. The chemical compositions of the examined materials is presented in Table 2.

Table 2.
Chemical composition of selected carburizers

Substance	Synthetic graphite	Petroleum coke A	Petroleum coke B
	The substance content, mass %		
Carbon	99.4%	98.1%	98%
Ash	0.5%	0.23%	0.28%
Volatiles	0.1%	0.38%	1.08%
Sulphur	0.3%	1.07%	0.56%
Nitrogen	0.04%	0.97%	0.59%
Moisture	0.57%	0.69%	0.83%

The test samples were prepared from the fragmented carburizer. The research material was crushed with the rammer to the fine fraction, then sieved to separate the fraction of 0.125-1.0 mm. The material selected in this way was put into the previously prepared probe and compressed under the pressure of 10, 20, 50, 60, or 70 bar. To achieve the equal height of all the compressed specimens, various quantities of the sieved carburizer material were measured, in respect of the pressure to be applied.

The hydraulic press exerting pressure up to 100 bar was used for compression. The resistance measurements were taken by means of a MMR-630 high-accuracy resistance meter (micro-ohmmeter) made by Sonel company (measurement resolution of 0.1 μΩ). The electrical resistance of the prepared cylindrical specimens was measured along their diameter by putting the measuring probes at the opposite points of their lateral surface. The measurements were performed in the ambient temperature of 20°C, five read-outs being taken for each of the specimens. The scheme of the measurement is presented in Figures 2A and 2B.

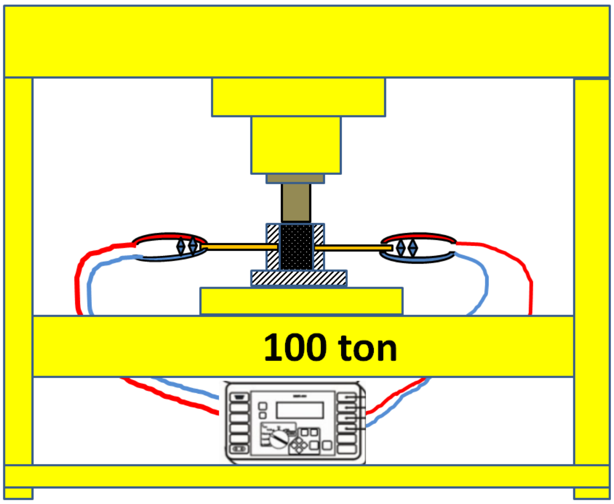

Fig. 2A Hydraulic press – 100T

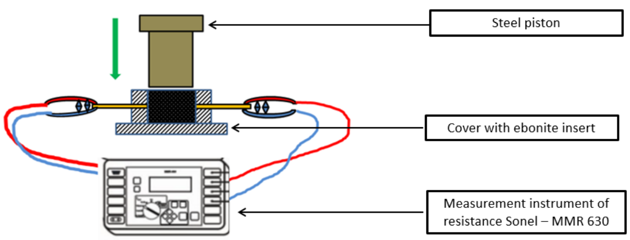

Fig. 2B The electrical resistance measurement scheme for the examined carburizers

3. Examination results and their analysis

The results of the electrical resistance measurements of the selected carburizers are presented in Tables 3-5 and Figs. 3-4.

Table 3.
Resistance measurement results for graphite carburizer

Pressure [bar]	Resistance [mΩ] Scrap from 0.125 mm to 1 mm						
	1	2	3	4	5	Average resistance	Standard deviation
10	13.7	12.2	12	12.1	13	12.60	0.654
20	7.69	8.1	7.98	7.81	8.1	7.94	0.163
50	5.29	5.23	5.28	5.26	5.38	5.29	0.050
60	4.94	4.9	4.92	4.91	4.97	4.93	0.025
70	4.68	4.69	4.71	4.66	4.74	4.70	0.027
Pressure [bar]	Resistance per unit length [mΩ/m] Scrap from 0.125 mm to 1 mm						
	1	2	3	4	5	Average resistance	Standard deviation
10	457	407	400	403	433	420.00	21.807
20	256	270	266	260	270	264.53	5.418
50	176	174	176	175	179	176.27	1.679
60	165	163	164	164	166	164.27	0.827
70	156	156	157	155	158	156.53	0.909

Table 4.
Resistance measurement results for petcoke B carburizer

Pressure [bar]	Resistance [mΩ] Scrap from 0.125 mm to 1 mm						
	1	2	3	4	5	Average resistance	Standard deviation
10	86.1	67.9	85	76.4	76.8	78.44	6.628
20	46.3	38.4	42.6	45.4	47.1	43.96	3.168
50	21.8	20.8	20.9	21	21.1	21.12	0.354
60	18.8	18	18.1	18.1	18.1	18.22	0.293
70	16.9	16.1	16.2	16.4	16.4	16.40	0.276
Pressure [bar]	Resistance per unit length [mΩ/m] Scrap from 0.125 mm to 1 mm						
	1	2	3	4	5	Average resistance	Standard deviation
10	2870	2263	2833	2547	2560	2614.67	220.933
20	1543	1280	1420	1513	1570	1465.33	105.590
50	727	693	697	700	703	704.00	11.813
60	627	600	603	603	603	607.33	9.752
70	563	537	540	547	547	546.67	9.189

Table 5.
Resistance measurement results for petcoke A carburizer

Pressure [bar]	Resistance [mΩ] Scrap from 0.125 mm to 1 mm						
	1	2	3	4	5	Average resistance	Standard deviation
10	39.1	39.5	36.9	38.7	35	37.84	1.675
20	22.6	20	22.5	21.3	23.1	21.90	1.119
50	11.5	11.4	11.6	11.6	11.6	11.54	0.080
60	10.2	10.3	10.4	10.4	10.5	10.36	0.102
70	9.4	9.6	9.7	9.8	9.7	9.64	0.136
Pressure [bar]	Resistance per unit length [mΩ/m] Scrap from 0.125 mm to 1 mm						
	1	2	3	4	5	Average resistance	Standard deviation
10	1303	1317	1230	1290	1167	1261.33	55.841
20	753	667	750	710	770	730.00	37.298
50	383	380	387	387	387	384.67	2.667
60	340	343	347	347	350	345.33	3.399
70	313	320	323	327	323	321.33	4.522

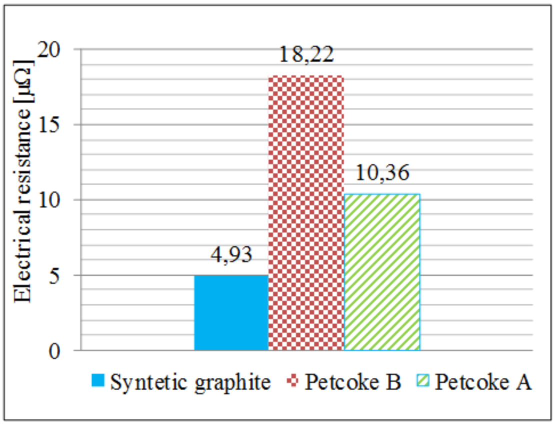

Fig. 3. Compared average resistance of carburizers at 60 bar pressure

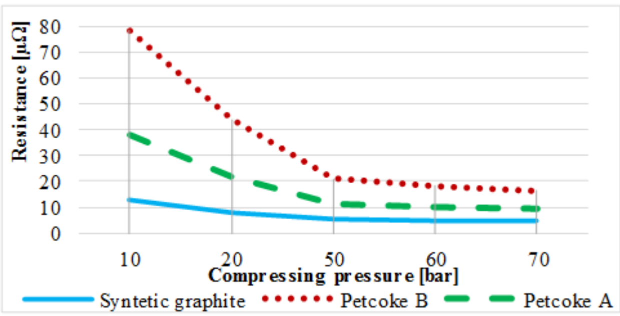

Fig. 4. The change of the resistance due to the applied compressing pressure for selected carburizers

The obtained results show that the electrical resistance of carburizers is different for various type of materials. The resistance decreases with an increase of pressure applied for compression of specimens, i.e. with the increasing compactness of the material.

4. Conclusions

The above presented results allow to draw the following conclusions:

- electrical resistance depends on the carburizer type and on the level of compactness of its structure (the density);
- synthetic graphite carburizer exhibited lower electrical resistance than carburizers made of petroleum coke;
- assuming that the relationship between the thermal conductance and electrical conductance (or electrical resistance) is known [6], the effectiveness of carburization can be assessed by measuring the electrical resistance of the carburizer, what enables to determine the carburizer quality already at the stage of delivery;
- the increased compressing pressure (the increased density) results in the decreased electrical resistance of the carburizer, but also contributes to the more stable (less scattered) results.
- the achieved results encourage further investigations in this direction and their application in practice. For example, the foundry staff can measure the electrical resistance of the carburizers presently used during melting process and, on this basis, compare them with other materials offered on the market. Such knowledge would allow both for better verification of carburizers before introducing them to the production process and for monitoring the changes in the material supplied to the foundry by even the same manufacturer over the time.

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