

## ARCHIVES of FOUNDRY ENGINEERING

ISSN (1897-3310) Volume 8 Issue 4/2008

55 - 60

11/4

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

# The sort of carburization and the quality of obtained cast iron

K. Janerka\*, D. Bartocha

Department of Foundry, Silesian University of Technology, Towarowa Str. 7, 44-100 Gliwice, Poland \*Corresponding author. E-mail address: krzysztof.janerka@polsl.pl

Received 15.07.2008; accepted in revised form 20.07.2008

#### Abstract

In the production of cast iron, the pig iron's amount in charge material is more and more often limited, and replaced by steel scrap. That extorts the necessity of know-how the carburization and one is looking for carburizers, which ensure obtaining big carbon increment as quickly as possible with the high repeatability and the ones which ensure getting the adequate quality of cast iron. The object of presented research was definition of the influence of charge materials' sort on the structure, course of solidification, and the effectiveness of process. The cast iron melts, which are presented below, are made only on the basis of steel scrap with portion of graphitoidal, coke and anthracite carburizers, which were added to the charge in solid. In the article one compared the carburizers in respect of their structure, chemical constitution and the effectiveness obtained during the carburization of liquid metal. The melting of cast iron, based on the special pig iron, was carried out as well. The course of melts, chemical constitution of obtained cast iron and its structure were presented. The comparison between quality distribution and the volume fraction of graphite in classes of size for the individual melts were achieved and the TDA curves were inserted.

Keywords: Theoretical bases of foundry processes, Cast iron, Carburization, Carburizers, Effectiveness of carburization

### **1. Introduction**

The process of cast iron melting in foundries, more and more often takes place in the basis of steel and process scrap, and eliminates the pig iron from charge. It reduces the costs, but causes the necessity of metal carburization. One can find the problems of carbon dissolution in liquid iron in many articles [1,2,3,4]. There are also known publications about the influence of carburizer's sort on its assimilation rate by liquid metal [5,6,7,8]. The researches evaluating the pneumatic addition of graphitoidal material to the liquid metal [9,10,11] and the influence of graphitoidal carburizer on the quality of cast iron [12,13] were also introduced into practice in the Department of Foundry, Silesian University of Technology. The results of researches presented in this work, concerned the assessment of quality of synthetic cast iron obtained by using graphitoidal, coke and anthracite carburizers. Analyzed materials differ from each other not only in chemical constitution, but also in crystallographic structure, which can have influence on generating of cast iron structure, its shape and spacing of graphite grains.

Significant differences occur in thermo-physical properties of these materials (specific heat, thermal conductivity), which decide about the rate of particles heating, and as the consequence of it – about their dissolution. The carburizers are naturally (anthracite, natural graphite) or synthetically (cokes, electro graphite) occurring. Cokes structure depends on the quality of charge and heat treatment. One can distinguish the following structures of petroleum coke: acicular, fibrous and leaf-rotational. In turn, the electro graphite is obtained as the result of high-temperature heat treatment of pitch coke and petroleum coke and anthracite (calcination, graphitization).

#### 2. The carburizers

Within a framework of study, the experiments of metal carburization by addition of carburizer in the charge solid by using natural and synthetic graphite, anthracite, petroleum coke A and petroleum coke B. Petroleum cokes came from different producers. The chemical constitution and sorts of carburizers used in these researches are presented in Table 1.

Table 1.			
The comp	position of carl	ourizers used	in researches

Sort of material	C [%]	S [%]	Volatile matter [%]	Ash [%]
natural graphit (GN)	85	0,08	3,0	11,0
synthetic graphite (GS)	99,1	0,30	0,2	0,4
anthracite (ANT)	95	0,30	1,0	4,0
petroleum coke A KNA)	98	0,50	0,7	0,65
petroleum coke B (KNB)	98	0,60	1,0	0,6

One made the microsections and took pictures of used carburizers structure – the carburizers are presented in figures from 1 to 5.



Fig. 1. Natural graphite, magnification x200



Fig. 2. Synthetic graphite, magnification x200



Fig. 3. Anthracite, magnification x200



Fig. 4. Petroleum coke A, magnification x200



Rys. 5. Petroleum coke B, magnification x200

If we analyze the obtained images of carburizers structure used in researches, one can say that they differ from each other considerably. Natural graphite has its own "metallic" surface with few pores. Anthracite has similar structure, except that the amount of pores is noticeably bigger, but they are spaced uniformly. Synthetic graphite has "metallic" surface with big amount of unevenly spaced pores, which have different shapes. Petroleum cokes are characterized by porous, leaf-rotational structure. They are typical of the lowest level of graphitization in comparison with cokes of fibrous or acicular structure.

### 3. The course and results of researches

During realization of researches, one has made 10 cast iron melts. Some of meltings were carried out only on the basis of steel scrap and the carburizers as natural and synthetic graphite, anthracite and petroleum coke. Two of melts were made of special pig iron (melt designation – SUR). Charge materials are added to the furnace in portions, which had been calculated and weighed before. The mass of steel scrap containing 0,1%C was oscillated about 10 kg. The carburizers were added in different amounts, which followed from the intention of obtaining similar increments of carbon content in cast iron. In every melts the content of silicon were completed by addition of FeSi75 on the surface of liquid metal after melting the charge. The carburization was carried out in the induction, average frequency, crucible furnace, with capacity of 20 kg.

The results of chemical analyses of obtained cast iron are presented in Table 2.

Table 2.

-					1	···· · · · · · · · · · · · · · · · · ·		
	Sign of melt	С %	Si %	Mn %	Р%	S %	Cr %	Cu %
	GN-2	3,21	2,16	0,38	0,026	0,028	0,089	0,278
	GS	3,17	2,13	0,44	0,018	0,023	0,079	0,285
	ANT-1	2,84	2,14	0,49	0,035	0,071	0,066	0,293
	KNA-2	3,25	2,12	0,49	0,023	0,038	0,080	0,279
	KNB	3,16	2,14	0,48	0,022	0,032	0,068	0,291
	SUR-2	3,34	1,98	0,33	0,045	0,035	0,033	0,085

Chemical constitution of cast iron, obtained as the result of carburization of liquid metal by the addition of carburizer to charge in solid

In the process of carburization, the important problem is the assimilation of carbon by liquid metal. It depends on many factors, for example from the sort of carburizer. Because in realized melts one tried to maintain the constancy of melting conditions and chemical constitution of charge materials, a sort of carburizer has the deciding influence on the effectiveness of process.

For particular melt the effectiveness of carburization was calculated from the dependence (1) and inserted in Table 3 and in the Fig. 6.

$$E = M_m \frac{C_k - C_p}{M_n C_x} \cdot 100\%$$
<sup>(1)</sup>

where:  $M_m$  – mass of metal charge [kg],  $M_n$  – carburization mass [kg],  $C_p$  – initial carbon content in charge or liquid metal (before carburization)[%],  $C_k$  – final carbon content after carburization [%],  $C_x$  – carbon content in carburizer [%].

#### Table 3.

The calculation results of carburization effectiveness

No of melt	$M_{\rm m}$	$M_n$	$C_p$	$C_k$	$\Delta C$	Е
GN-1	10,2	0,420	0,1	2,79	2,69	76,85
GN-2	10,03	0,075	2,79	3,21	0,42	66,08
GS	10,22	0,361	0,1	3,17	3,07	87,79
ANT-1	10,37	0,376	0,1	2,84	2,74	79,54
KNA-1	10,26	0,365	0,1	2,91	2,81	80,59
KNA-2	10,09	0,050	2,91	3,25	0,34	70,00
KNB	10,32	0,385	0,1	3,16	3,06	83,69



Fig. 6. The effectiveness of carburization for carburizers used in researches

The effectiveness of carburization was changing in realized investigative process, from 66 to 87,8%. The highest effectiveness was obtained by carburization with synthetic graphite, and the lowest – by using the natural graphite. The grade of carbon assimilation for petroleum cokes totaled 80,6 and 83,7%. By melts GN-2 and KNA-2, where carburization was carried out on the level of 2,8%, one can notice 10% decrease of effectiveness.

While the researches were carrying out, picture of microsections were taken (magnification 200x), in the aim of comparison between structure of obtained cast iron by addition of different carburizers and cast iron melted on the basis of pig iron. The picture of structure are presented in the figures from 7 to 12.





Fig. 7. Cast iron carburized by natural graphite (GN-2)



Vv [%] Na [1/mm2]



Fig. 8. Cast iron carburized by synthetic graphite (GS)



Vv [%] Na [1/mm2]



Fig. 9. Cast iron carburized by anthracite (ANT-1)



🗖 Vv [%] 🔳 Na [1/mm2]



Fig. 10. Cast iron carburized by petroleum coke A (KNA-2)







Fig. 11. Cast iron carburized by petroleum coke B (KNB)



Vv [%] Na [1/mm2]



Rys. 12. Cast iron melted on the basis of pig iron (SUR-2)

During analyzing the amount of graphite in the structure  $(N_A)$ , one can claim, that the highest parameters are typical for the melt with portion of petroleum coke A (KNA), and the lowest parameters – for the melt with synthetic graphite (GS). In turn, while analyzing percent participation of graphite volume  $(V_v)$ , one should claim that the highest parameters are obtained for the cast iron carburized by synthetic graphite (GS), and the lowest for the one carburized by petroleum coke B (KNB). If one accepts, that the cast iron obtained in melting with the portion of pig iron is the model melt, one can notice, that the most similar to the standard one are cast irons from the meltings KNA-2 and KNB, if we look at the amount of graphite in particular classes. Percent part in structure of graphite with particular volume is the most similar to cast iron melt GS.

Within a framework of every melt, the TDA test was carried out. Some parts of obtained results are presented on the figures from 13 to 16.



Fig. 13. TDA graph for grey cast iron melt, carburized by synthetic graphite (GS)



Fig. 14. TDA graph for grey cast iron melt, carburized by petroleum coke A (KNA-2)



Fig. 15. TDA graph for grey cast iron melt, carburized by petroleum coke B (KNB)



Fig. 16. TDA graph for grey cast iron melt, obtained on the basis of pig iron (SUR-2)

During the analysis of self-cooling curves obtained in TDA test, one can notice the appearance of some thermal effect for the cast iron carburized by petroleum coke A and petroleum coke B, if we look at derivational curve, in the temperature range from 1080 to 1130°C. It is not visible for TDA curves for the cast iron carburized by graphite, anthracite and cast iron from pig iron. The change of crystallization curve's course is caused by thermal phenomenon, which appears only in the solidification time for cast iron carburized by petroleum coke. If one want to explain the appearance of these phenomena, analysis of nitrogen content in cast iron and phased researches can be useful. The beginning of nucleation and crystallization for particular melts appears in similar thermal range. The end of cast iron crystallization occurs in temperature close to 1100°C, independently from used carburizer.

#### 4. Summary

On the basis of experiments, which were carried out, one can draw some conclusions:

- Carburizers, which were used in the researches, differed from each other in carbon content, surface and porosity, what is visible on the pictures of microstructures
- in every melts, regardless of the sort of carburizer, one obtained grey, hypoeutectic cast iron with flaky graphite
- distinct thermal effect appears on the crystallization curve of cast iron carburized by petroleum coke in temperature range from 1080 to 1130 °C. It is the result of heat emission just before the end of crystallization and it appears only in cast iron carburized by petroleum cokes
- the highest effectiveness was obtained during carburization by synthetic graphite (87,78%), and the lowest – for natural graphite (76,8%). The increment of initial carbon content Cp from 0,1 to 2,8% in liquid metal impairs carbon assimilation about 10%
- by analyzing distributions of percent part of graphite volume (size reduction in particular classes) one should notice, that the highest parameters are obtained for cast

iron carburized by synthetic graphite (GS), and the lowest for the one carburized by petroleum coke B (KNB). During the analysis of distributions of graphite' amounts in the structure one can claim that the highest parameters are typical for the melt with portion of petroleum coke A (KNA), and the lowest – for synthetic graphite (GS).

#### References

- R. Krzeszewski, Carburization of liquid iron by solid carburizer, Elaborations of Foundry Institute, Cracow, 1957, vol. 3-4, 175-195.
- [2] R. Krzeszewski, Kinetics of carbon dissolution in liquid iron, Elaborations of Foundry Institute, Cracow, 1963, vol. 1, 2-29.
- [3] S. Orsten, F. Oeters, Dissolution in carbon in liquid iron, Conf. Application of Mathematical and Physical in Iron a Steel Industry, 1988.
- [4] L. Król, J. Latusek, Kinetic model of carburization of liquid iron in production of synthetic pig iron, Archives of Metallurgy and Materials, 1983, vol. 1, p. 101-116.
- [5] A. Kosowski, The carburization kinetics of cast iron in the inductive furnace, Foundry Review, Nr 1-3, 1982 (in Polish).
- [6] S. Przeworski, Assessment of usability for particular carburizers in production of grey cast iron in arc furnaces, Elaborations of Foundry Institute, Cracow, 1986, vol. C-D, s. 219-234 (in Polish).
- [7] K. Janerka, D. Bartocha, J. Szajnar, M. Cholewa, The influence of different kind of carburizers and carburization on the effectiveness and iron structure, Archives of Metallurgy and Materials,52,2007,467-474.
- [8] K. Janerka, The rate and effectiveness of carburization to the sort of carburizer, Archives of Foundry Engineering, Vol. 7, No. 7 (2007) 95-100.
- [9] K. Janerka, D. Homa, S. Jura, J. Gawroński, J. Jezierski, Rates characterized the process of pneumatical carburization, Archives of Foundry, vol. 1, nr 1/2, 2001, s. 39-44 (in Polish).
- [10] K. Janerka: The factors effects on the pneumatic recarburization process parameters., Archives of Foundry, vol. 5, nr 15 (2005) 170-181.
- [11] K. Janerka, D. Bartocha, J. Gawroński, The technology of liquid iron alloys by the method of pneumatic injection, Archives of Foundry, vol. 4, No. 13,(2004) 115 – 120 (in Polish).
- [12] D. Bartocha, J. Gawroński, K. Janerka, Properties of cast iron depending on charge materials, Archives of Foundry, PAN – Katowice, nr 9, 2003 (in Polish).
- [13] D. Bartocha, K. Janerka, J. Suchoń, Charge materials and technology of melt and structure of grey cast iron, Journal of Materials Processing and Technology, 162-163 (2005) 465-470.