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THE MICROSTRUCTURE OF THE SELECTED INOCULANTS FOR USE CAST IRONS

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SUMMARY

The type and composition of the phases present in *KOMO* (from ***KO***mpleksowy ***MO***dyfikator - eng. Complex Inoculant) - a Polish inoculant and in foreign inoculants (Foundrysil, SB-5, Ferrosilicon 75) have been investigated. The purpose of those reactive elements is to combine with Ca, Al, Ba and Sr in the FeSi75 ferrosilicon and form potent heterogeneous nucleation sites for graphite. The structure of the *KOMO* inoculant was proved to comprise silicon and an $FeSi_2$ phase, as well as two other phases containing Ba-Al-Sr-Si (with Ba prevailing) and Sr-Ca-Ba-Si (with Ca and Sr prevailings). The combined effect of Ca, Al, Ba and Sr elements also give better chill control than Ca +Al. The new *KOMO* inoculant is most effective in increasing the nodule count in ductile cast iron, in grey cast iron with flake graphite, and in vermicular cast iron. Finally conclusions are drawn, as related to the practical application of the results obtained.

Key words: inoculation KOMO, cast iron, ductile iron, complex inoculant

1. INTRODUCTION

Graphitising inoculation is a very important and necessary step in the process of making high-quality cast iron. Various types of inoculants are available at present, and also in the domestic market numerous graphitising inoculants for molten cast iron are offered by foreign, e.g. ELKEM (Norway), PECHINEY (France) SKW TROSTBERG

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(Germany), as well as domestic companies, e.g. Huta ŁAZISKA S.A. (Poland). The trade names and chemical compositions of those inoculants are given in [1]; in Polish foundries the inoculants compiled in Table 1 are in most frequent use. The inoculants based on Fe-Si-Ca-Al alloy, containing also additions of barium and strontium, have not been offered as yet. On the other hand, quite well known are the inoculants for cast iron which, physically, constitute a mixture of ferrosilicon plus additives, like e.g. Fe-Si-Ca-Al plus Ba (up to 20%) and Sr (2÷10%); they are protected by a Polish patent PL 130621 granted in 1986 [2]. Within the scope of the conducted research works aiming at optimising the performance of inoculants for cast iron, and specially at reducing the inoculant consumption rate and making its effect last longer, a batch of the Fe-Si-Ca-Al-Ba-Sr inoculant containing 76 % Si; 0,49 % Ca; 1,1 % Al; 0,44 % Ba and 0,45 % Sr was produced. The inoculant was melted at HUTA ŁAZISKA S.A. and was given a trade name *KOMO* (from ***KO***mpleksowy ***MO***dyfikator - eng. Complex Inoculant). Melting of the inoculant was described in [3]. The inoculant was subjected to tests

Table 1. Chemical composition of different inoculants for cast iron.
Tabela 1. Skład chemiczny różnych modyfikatorów dla żeliwa

No.	Trade name of inoculant	Chemical composition, wt %				
		Si	Ca	Al	Ba	other
1	Superseed 75	73 – 78	0,1 max	0,5 max	-	0,6–1,0 Sr
2	Foundrysil	73 – 78	0,75–1,25	0,75	0,75-1,25	-
3	Zircinoc	73 – 78	2–2,5	1–1,5	-	1,3-1,8 Zr
4	Si 75A	73 – 78	2–5	1–1,5	-	-
5	SB5	64 – 70	1	1,5	2	-
6	SMW 605	60 – 64	1,8 – 2,4	0,8 max	-	1 RE, 1 Bi
7	SRF 75	73 – 76	0,1 max	0,5 max	-	0,6–0,9 Sr
8	ZL 80	74 – 76	2,5	1,4	-	1,5 Zr
9	Superssed 50	45-50	0,1max	0,5max	-	0,6-1,0Sr
10	Barinoc	73-78	1-2	0,8-1,5	2-3	-
11	Inobar	64	1	1,3	9	-
12	LMC	66	1,7	0,8	0,8	-
13	SZR504	45-50	2,5-3,5	1	-	Zr
14	SiCa	60-65	30-33	1,5max	-	-

conducted under both laboratory and industrial conditions to examine its effectiveness in the process of manufacturing high-quality cast iron.

The aim of the present study was to determine the type of microstructure and the composition of phases present in inoculants of the *KOMO* type and in some selected imported inoculants containing calcium, aluminium, or - additionally - barium, affecting the number of graphite nuclei formed in cast iron.

2. RESULTS AND THEIR ANALYSIS

The results of the examinations of the number of eutectic grains falling to a unit surface and of testing some selected mechanical properties, i.e. tensile strength UTS, elongation A and hardness HB, obtained in inoculated, ductile and vermicular cast irons using *KOMO* inoculant were described in [3,4]. The industrial trials confirmed the high effectiveness and versatile effect of this inoculant when applied to the three mentioned above cast irons, this additionally matched with its high profitability.

The high useful value of the *KOMO*-type inoculants, well proved in cast iron in comparison with e.g. an FeSiCaAl (Si75A) inoculant and an inoculant additionally containing barium (SB-5 and Foundrysil - see Table 1), is without any doubt caused by a different morphology and chemical composition of phases present in their structure.

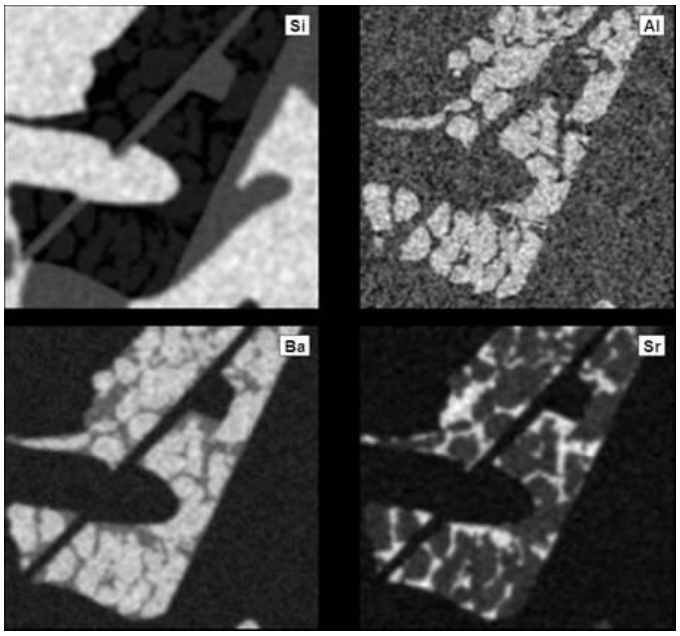
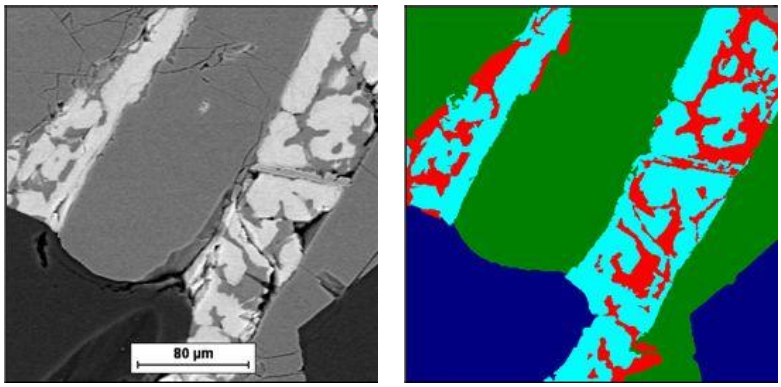


Fig. 1. The distribution of the Si, Al, Sr and Ba elements in a *KOMO*- a Polish type inoculant.
Rys. 1. Rozkład Si, Al, Sr i Ba w polskim modyfikatorze *KOMO*



Point 1		
Element	at. %	wt %
Si	69,69	45,48
Ca	1,36	1,27
Ba	12,65	40,38
Sr	1,88	3,83
Al.	14,42	9,04
Phase: **Ba - Al - Sr - Si**		

Point 2		
element	at.%	wt %
Si	58,25	43,18
Ca	32,26	34,13
Ba	0,58	2,10
Sr	8,90	20,59
Phase: **Sr - Ca - Ba - Si**		

Point 3		
Element	at. %	wt %
Si	68,17	52,39
Fe	30,07	45,96
Al.	1,30	0,97
Mn	0,46	0,69
Phase**: Fe Si_2**		

Point 4		
element	at.%	wt %
Si	100	100
Phase: **Si**		

Fig. 2. The distribution and chemical composition of phases occur in a *KOMO* inoculant.
Rys. 2. Rozkład i skład chemiczny faz występujących w polskim modyfikatorze *KOMO*

The examinations revealing these differences were conducted on a Hitachi S-4200 scanning microscope equipped with an X-ray detector. Due to the use of the detector it was possible to enlarge the scope of application of this device and perform qualitative as well as quantitative analysis of the chemical composition in microregions. The results of these examinations, supported by a mapping technique [5], enabled revealing the specimen regions of a typical phase constitution. Examples of the images of microstructures and the distribution of the elements Si, Al, Sr, Ba presents in *KOMO*, inoculant are shown in Figures 1 and 2.

The binary images of the regions with determined mass fraction of the selected elements were obtained by means of multiple binarisation [5]. Using these images, the

distribution maps of the most important phases present in the examined inoculants were drawn. The structure of the *KOMO* inoculant was proved to comprise silicon and an $FeSi_2$ phase, as well as two other phases containing Ba-Al-Sr-Si (with Ba prevailing) and Sr-Ca-Ba-Si (with Ca and Sr prevailings). Without any doubt these two phases present in the structure of the inoculant while it is added to cast iron are responsible for the formation of a large number of the nucleation sites for nodular or flake graphite in high-quality cast iron, ultimately expressed by a large number of the eutectic grains.

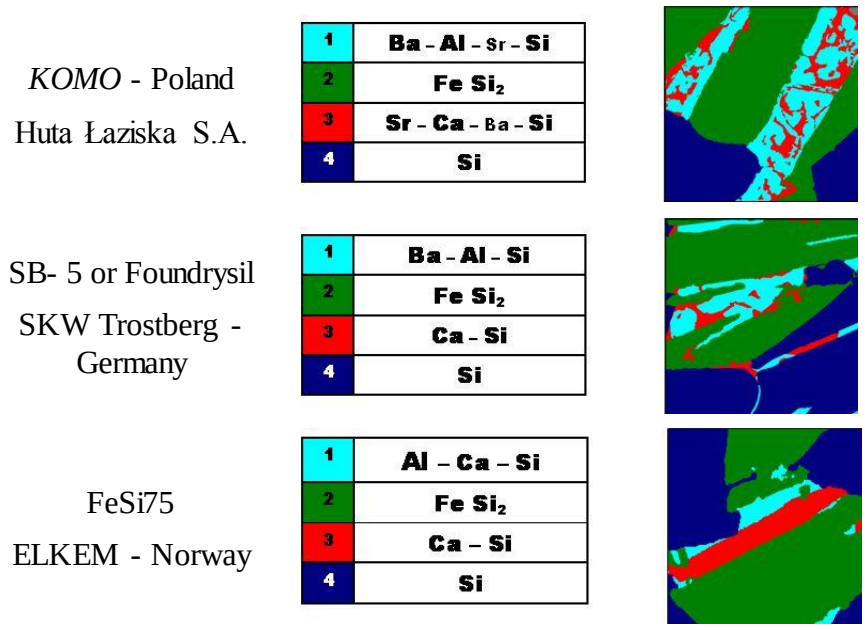


Fig. 3. The distribution of the main phases present in inoculants: *KOMO* - (FeSi+Ca+Al+Ba+Sr), and SB-5 or Foundrysil - (FeSi+Ca+Al+Ba) as well as in Ferrosilicon – (FeSi+Ca+A)l.
Rys. 3. Rozkład głównych faz występujących w modyfikatorze *KOMO* – (FeSi+Ca+Al+Ba+Sr), i SB-5 lub Foundrysil – (FeSi+Ca+Al+Ba) a także w Ferrosilicon – (FeSi+Ca+A)l.

This can explain the high inoculation power of this agent, compared with the ferrosilicon-type inoculants, which contain Ca and Al only, possibly also barium (Figure 3). In an FeSi+Ca+Al inoculant (the trade name according to Polish Standard – Si75A), besides the precipitates of Si and $FeSi_2$ phase, two other phases containing Al-Ca-Si and Ca-Si were detected, while in a barium-containing inoculant the first phase was additionally enriched with barium. The phases of this inoculant act as sites for graphite nucleation in cast iron, but they are much less effective than the phases composed of Ba-Al-Sr-Si and Sr-Ca-Ba-Si present in new domestic inoculant of the *KOMO*-a Polish type.

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MIKROSTRUKTURA WYBRANYCH MODYFIKATORÓW PRZEZNACZONYCH DLA ŻELIWA

STRESZCZENIE

W opracowaniu przedstawiono mikrostrukturę krajowego modyfikatora typu *KOMO* oraz modyfikatorów importowanych typu: żelazokrzemu FeSi (zawierającego Al i Ca), Foundrysil oraz SB-5 (zawierających Al, Ca i Ba) przeznaczonych dla żeliwa wysokojakościowego: modyfikowanego, sferoidalnego i żeliwa z grafitem wermikularnym. Wskazano na istotną różnicę w budowie faz występujących w tych modyfikatorach; w strukturze modyfikatora *KOMO* występują następujące fazy Ba-Al-Sr-Si, Sr-Ca-Ba-Si, $FeSi_2$ oraz krzem, natomiast w modyfikatorach importowanych dwie pierwsze fazy pozbawione są takich kombinacji ilościowych pierwiastków jak Ba i Sr. Wyjaśniono, dlaczego walory modyfikujące krajowego modyfikatora typu *KOMO* produkcji Huty ŁAZISKA S.A. są lepsze od modyfikatorów importowanych.

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