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 \textit{KO}mpleksowy \textit{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 FeSi\textsubscript{75} ferrosilicon and form potent heterogeneous nucleation sites for graphite. The structure of the KOMO inoculant was proved to comprise silicon and an FeSi\textsubscript{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.

\textit{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
(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 Kompleksowy Modyfikator - 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.

<table>
<thead>
<tr>
<th>No.</th>
<th>Trade name of inoculant</th>
<th>Chemical composition, wt %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Si</td>
</tr>
<tr>
<td>1</td>
<td>Superseed 75</td>
<td>73-78</td>
</tr>
<tr>
<td>2</td>
<td>Foundrysil</td>
<td>73-78</td>
</tr>
<tr>
<td>3</td>
<td>Zirconoc</td>
<td>73-78</td>
</tr>
<tr>
<td>4</td>
<td>Si 75A</td>
<td>73-78</td>
</tr>
<tr>
<td>5</td>
<td>SB5</td>
<td>64-70</td>
</tr>
<tr>
<td>6</td>
<td>SMW 605</td>
<td>60-64</td>
</tr>
<tr>
<td>7</td>
<td>SRF 75</td>
<td>73-76</td>
</tr>
<tr>
<td>8</td>
<td>ZL 80</td>
<td>74-76</td>
</tr>
<tr>
<td>9</td>
<td>Superseed 50</td>
<td>45-50</td>
</tr>
<tr>
<td>10</td>
<td>Barinoc</td>
<td>73-78</td>
</tr>
<tr>
<td>11</td>
<td>Inobar</td>
<td>64</td>
</tr>
<tr>
<td>12</td>
<td>LMC</td>
<td>66</td>
</tr>
<tr>
<td>13</td>
<td>SZR504</td>
<td>45-50</td>
</tr>
<tr>
<td>14</td>
<td>SiCa</td>
<td>60-65</td>
</tr>
</tbody>
</table>
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
Fig. 2. The distribution and chemical composition of phases occur in a KOMO inoculant. 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.

\[
\begin{array}{cccc}
1 & \text{Ba - Al - Sr - Si} \\
2 & \text{Fe Si$_2$} \\
3 & \text{Sr - Ca - 6a - Si} \\
4 & \text{Si} \\
\end{array}
\]

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KOMO - Poland
Huta Łaziska S.A.

SB- 5 or Foundrysil
SKW Trostberg - Germany

FeSi75
ELKEM - Norway

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.
Mikonstrukcja wybranych modyfikatorów przeznaczonych dla żelwa

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, FeSi₂ 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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