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# Properties of cast iron modifying with use of new inoculants

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**Materials**

## ABSTRACT

**Purpose:** Modification of various alloys is a well known process for improvement its properties by changing of microstructure character. In foundry technology it is connected mostly to cast iron production where many inoculants is used for obtaining some results like grain refinement, graphite inclusions proper distribution etc. Those changes caused that produced alloy have a much better properties especially mechanical ones.

**Design/methodology/approach:** In the paper were presented some results of the experiments made for checking quality of the two new on Polish foundry market complex inoculants. On of them is a "graphite" inoculant (about 50% C) and second is Ba-Ca combination based inoculant. The experiments contained metallographic and quantitative metallographic analysis and wedge test bars analysis.

**Findings:** These experiments proved a good quality of inoculants in the field of microstructure improvement (graphite size reduction) and a hard spot defects liquidation.

**Research limitations/implications:** The next experiments are planned for checking the mechanical properties of the produced alloys.

**Practical implications:** The inoculants being analysed are used in several Polish foundries now because of author's good results.

**Originality/value:** There were the first experiments with these materials although the methods of investigations are not novel or original. The results have a very big importance not only from scientific but from practical point of view too.

**Keywords:** Metallic alloys; Casting; Cast iron; Modifying

## 1. Introduction

The method of introduction of various reagents for microstructure (properties) of alloys modification is well known and important in foundry technology [1,2]. It is used in ferrous alloys and non-ferrous alloys production as well [3,4,5]. Production of high grades of gray or ductile cast iron require modification process after the magnesium (or mixture of others elements) treatment [6-10]. The inoculation cause significant mechanical properties increase because the microstructure of alloys is changed [11-13]. There are many various inoculants for ferrous and non-ferrous alloys and many various methods of its introducing into liquid metal bath. It is well known that some of the elements like: Ba, Ca, Sr and others are the most efficient for inoculation of both grey and ductile cast iron. But these elements are often very expensive so the problem is in optimisation of the chemical composition of the reagent and decreasing inoculant addition as big as possible [14,15]. Nowadays there are three most important ways to introduce inoculants into metal bath: into ladle, on liquid metal stream and in-mold technique, where the inoculant is introduced in casting mold in form of pieces or grains. The least quantities of inoculant can be introduced and a very good quality of cast iron can be obtain when we use an in-mold method. But this method is sometimes difficult and require a very high quality standards of metallurgical and casting process. So in many cases good enough are method of introduction into ladle or metal stream being pouring into mold or pouring out the furnace. But in every case the quality of inoculant may have decisive influence on produced alloy (castings) quality. There are two different ways to obtain the highest quality of inoculant and the best results of the inoculation process. The first is using of complex inoculant containing several reactive elements but such approach may sometimes be very expensive. The second is use of quite simple but carefully prepared inoculant with use of combination some selected elements, which have the most important influence on the inoculation results [11,12,14-16].

In the paper are presented the results of the experiments with two kinds of inoculants proposed for Polish foundry industry by one of the companies functioning on the metallurgical and foundry materials market. The experimental methods, results and its analysis is shortly presented as well as conclusions about quality and usefulness of materials being analysed.

## 2. Description of the own researches

The aim of the experiments was analysing of the properties of two kinds of reagents called “Feromod G8” and “Feromod B6” for grey cast iron inoculation process. The chemical analysis of them is presented below in Table 1.

Table 1.
Chemical analysis of used inoculants

| Inoc. | Si, % | Al, % | Ca, % | Others, % | Size, mm |
|---|---|---|---|---|---|
| G8 | 35-40 | 0,5-0,8 | max. 0,5 | $C_{gr}$ 45-50 | 1-8 |
| B6 | max. 70 | 1,0-1,5 | 1,0-2,5 | Ba 1,0-3,0 | 0,2-0,6/ 0,7-2,0/ 2,0-6,0 |

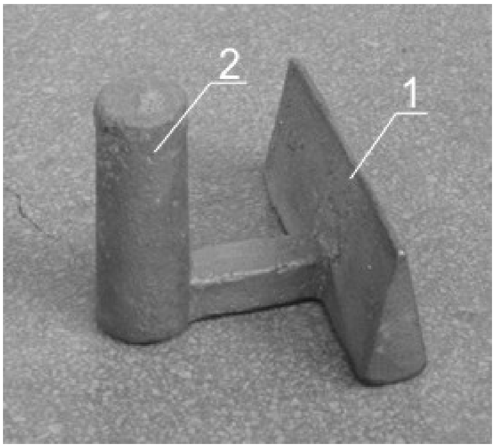



Fig. 1. Test casting, 1- chill test bar, 2- cylindrical test bar for metallographic analysis

The experiments were carried out with use of laboratory inductive crucible furnace with maximum capacity about 25 kg of molten cast iron. The inoculant was introduced onto liquid metal stream when the alloy was pouring from furnace into ladle. Next the test castings were made (see fig. 1) after some carefully measured time periods of 0 (immediately afterwards inoculation), 5, 10, 20 and 40 minutes. The time periods were set for checking what is the inoculation effect deterioration time.

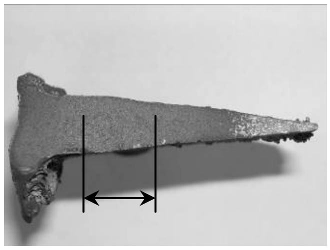
The alloy being modified was the grey cast iron with chemical analysis (before modification) shown in example in Table 2. The composition analysis after inoculation process was made too and did not indicate any important changes (apart from experiments with higher inoculant additions equal 0,6%). The table contains values for experiment with use of Feromod B6 inoculant which addition was 0,15% mass of charge (it is a addition rate proposed by producer of inoculant). But there were some problems to achieve the proper and repeatable values of particular elements content in molten iron, although the attested charging materials were used. It is connected to small capacity of the laboratory inductive furnace where every difference in charging materials chemical composition strongly influence on the heat results.

Table 2.
Chemical analysis of cast iron before inoculation

| Element | C | Si | Mn | P | S |
|---|---|---|---|---|---|
| Unit | % | % | % | % | % |
| Content | 2,96 | 1,89 | 0,20 | 0,029 | 0,015 |

Every single experiment required of pouring six test casts in sand mold with shape as seen on fig. 1. The analysis of chill area after breaking the bars was conducted and the examples are presented on fig. 2 for the same process parameter as was mentioned above.

a)



b)

c)

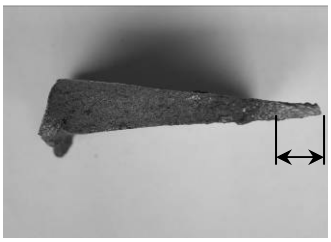


Fig. 2. Chill test bars after different time periods: a) without inoculation, b) immediately afterwards and c) 10 minutes after inoculation process, an arrow shows the chill area

It is clearly seen that the test piece made of cast iron without modification has a relatively big tendency to chilling, fig. 2a, but inoculant addition caused immediately the improvement of solidification condition and a hard spot is not visible at all, fig. 2b. But the effect of inoculation deterioration starts relatively quick because after 10 minutes time the chilling is appearing again, fig. 2c. So the time regime have to be kept on the highest level and the portion of inoculated alloy and a pouring time should be as small as possible. Ideally the inoculation should be made right before pouring into molds or with use of in-mold method. The second way is quite dangerous because not good carrying out the process may cause obtaining the proper microstructure only in some parts of the casting.

The next step was metallographic analysis of prepared specimens from produced alloys. The microsections were made and quantitative analysis with use of Multi Scan program as well. Fig. 3 presents some metallographic specimens for the same conditions as previously mentioned results.

a)

b)

c)

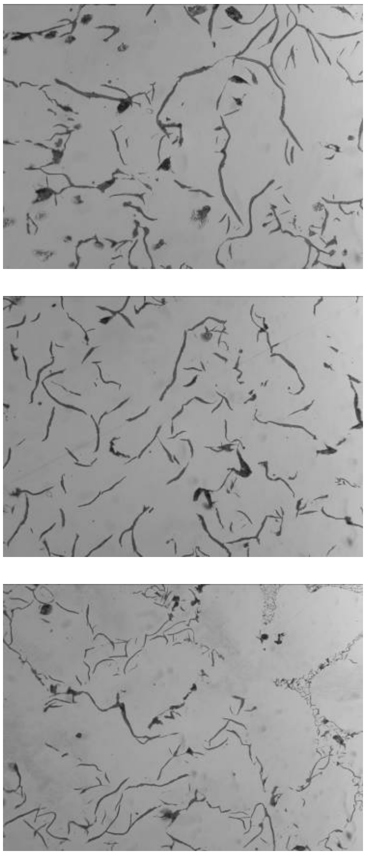


Fig. 3. Microsections of cast iron, without etching, magnification 100X, conditions the same as above, a) without inoculation, b) immediately afterwards and c) 10 minutes after inoculation process

The quantitative metallographic analysis made possible to prepare the histograms which show in various ways percentage of graphite size group as shown as an example on figure 4.

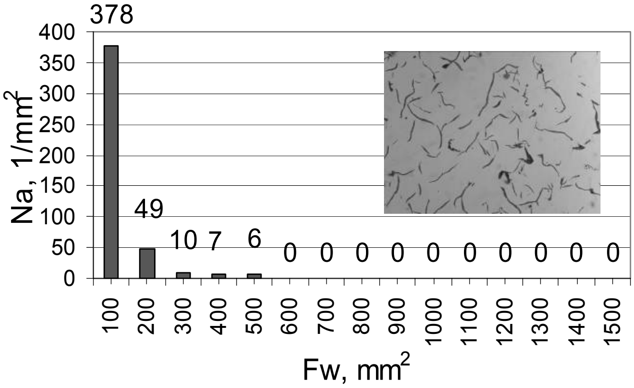



Fig. 4. Histogram of graphite inclusions distribution quantity Na in particular class of surface area Fw, connected to fig. 3b), experiment conditions the same as previously

It is seen that for presented example (fig. 4) the smallest graphite particles have the biggest part in all the graphite inclusions what is of course advantageous from alloy properties point of view. For every single experiment three different histograms were prepared and analyzed so 27 graphs were made all in all.

The same way of experiment was conducted for both inoculants and there were made totally 9 heats for both inoculants in various conditions: inoculant addition equal 0,15; 0,3 and 0,6% of charge mass. The temperature of inoculation was from 1420 to 1442 degrees Celsius and the temperature within the whole experiment period (up to 40 minutes after inoculation) was stabilized from 1325 to 1380 degrees Celsius. Such relatively big range of temperature changing is connected to small liquid metal mass but temperatures from this range are appropriate for cast iron production in industrial conditions.

## 3. Conclusions

In the paper were presented the results of researches with inoculation of cast iron with use of new on Polish market inoculants Feromod G8 and Feromod B6. The inoculants do not differ from others in foundry market in a sense of chemical composition. The results and its analysis allows to formulate the conclusions as follows:

1. The experiments proved the high efficiency of Feromod G8 and Feromod B6 as the inoculants for gray cast iron by into ladle addition method.
2. Both inoculants have advantage of strongly reduction of cast iron chilling and graphite modifying even for disadvantageous melting conditions (problems with temperature, chemical compositions of charging material etc.). Better in this circumstances is the Feromod B6 inoculant because of combination of Ba-Ca content.
3. The effect of inoculation deterioration appears after time period comparatively with others inoculants in Polish market, but Feromod B6 is better than Feromod G8. In order to keep this parameter on high level it is necessary to have production standards on the highest level too.

4. The addition of bigger inoculants amounts than these preferred by producer may cause not complete its dissolution and in effect – castings defects.

Because quality of higher grades of cast iron is not connected only to its microstructure but obviously to mechanical (or even mostly) properties, the presented results are not the ending of the researches in this field. The next stage of researches will be checking the mechanical properties of obtained cast iron and experiments in industrial conditions. The positive results of author's researches caused that several Polish foundries started to use these materials with good both technological and economical results.

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