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Optimization of Master Alloy Amount and Gating System Design for Ductile Cast Iron Obtain in Lost Foam Process

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Abstract

The paper presents the optimization of master alloy amount for the high nodular graphite yield (80-90%) in cast iron obtain in lost foam process. The influence of the gating system configuration and the shape of the reaction chamber, the degree of spheroidisation cast iron was examined. Research has shown that the, optimal of master alloy amount of 1.5% by mass on casting iron. The degree of spheroidisation is also influenced by the gating system configuration. The best spheroidisation effect was obtained for liquid cast iron was fed into the reaction chamber from the bottom and discharged from the top.

Keywords: Innovative casting technologies, Ductile iron, Inmold method, Lost foam casting

1. Introduction

This paper presents a technology of ductile cast iron obtain by lost foam process with use of inmold method.

Inmold method developed in Great Britain in 1970 [1, 2, 3]. She possess many advantages:

- the high magnesium yield upper to 90%;
- the lack of smoke and shine;
- easy of automation;
- easy control of liquid cast iron quality (TDA) [4].

Some limit of this method is the cast size. This method can be apply up to 50kg mass casts of ductile cast iron. Location in gating system reaction chamber and mixing chamber in parting plane of mould decrease of number of casts.

Use of inmold spheroidisation in the LOST FOAM casting process, where such limitations do not occur, seems reasonable, as this method lacks neutral area of the mould. [5]. In this connection, no need to place the ingate and outgate of the reaction chamber along a single plane, as in the classical method [6], and the gating system can be almost freely configured.

2. Research methodology

Experiments concerning the production process of the casts from ductile cast iron by the lost foam method with the spheroidisation in the mould have been carried out at the laboratory of the Department of Materials Engineering and Production Systems, Łódź University of Technology.

Pattern set consisting of the pattern of two cylindrical test cast: high 150 mm, diameter 30 mm, ingate, reaction chamber, rectangular sprue: high 350 mm, width and thickness 35 mm, was made from foamed polystyrene of the density $\rho = 20$ kg/m^3

The spherical reaction chamber with a diameter 70 mm was used to determine the optimal amount of master alloy (Fig. 1).

Two rectangular chambers of different heights, but of the same volumes as a spherical chamber was used to research of the gating system configuration.

The experimental casting sets shown in Fig. 2.

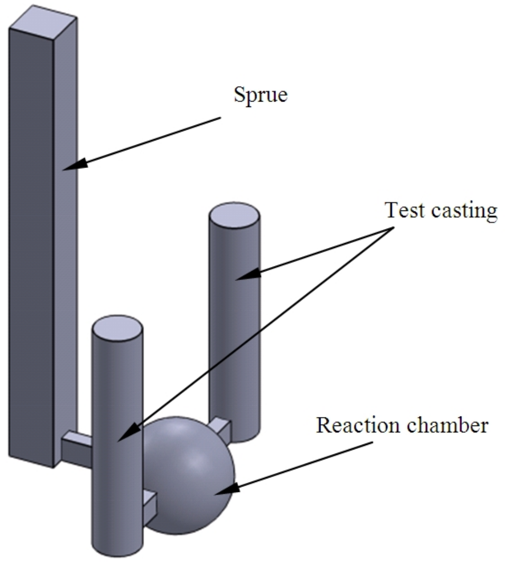

Fig. 1. The experimental casting set used for optimization of master alloy amount

The experimental casting sets was covered with a coating of Ashland. And then, after drying, dry sand without binder was filled up and compacted by pneumatic vibrator. Norwegian OB pig iron was used for melting, its composition is specified in Table 1. Silicon content was complemented by addition of FeSi75 ferrosilicon. LAMET 5504 1-4mm master alloy was used for cast iron spheroidisation in the mould. Detailed chemical composition of the master alloy is presented in Table 2. The mould was filled with cast iron with temperature of 1450°C.

Range of added amounts of master alloy was determined based on literature [7] and own preliminary research.

After a preliminary examination, it was found that: percentage participation of nodular graphite was less than 20% if the addition of FeSiMg in amounts was less than 0.8%.

The minimum of master alloy amount was set at 0.8% by mass on the casting iron. The maximum amount of master alloy set on 2%.

Table 1.
Chemical composition of Norwegian OB pig iron

Chemical composition, %				
C	Si	Mn	P	S
3.94	1.09	0.015	0.023	0.004

Table 2.
Chemical composition of the spheroidising and modifying master alloy

Chemical composition, %				
Si	Mg	Ca	MZR*	Al
40.0-49.0	3.0-6.5	0.3-1.0	0.4-1.4	0.5-1.2

*rare-earth elements

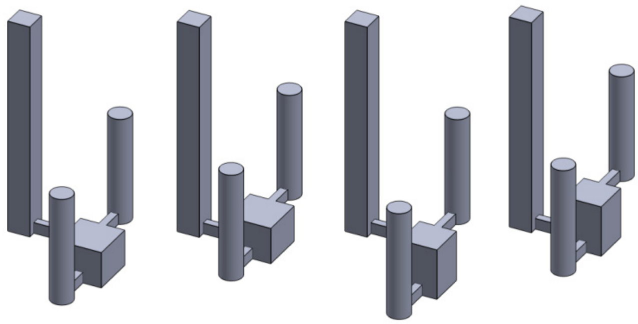

Fig. 2. Schema of the gating system configuration low reaction chamber N, fed into the top (a) fed into the bottom (b) and high reaction chamber W fed into the top (c) fed into the bottom (d)

Three Specimens for microstructure analysis and ductile iron quality have been collected from each of the test castings. The degree of spheroidisation of graphite was determined by the shape ratio (1) [8]

$$c = \frac{O_{bk}}{O_{bw}} \tag{1}$$

where:

O_{bk} is the circumference of a perfect circle with the area of the graphite precipitate,

O_{bw} is the circumference of the graphite precipitate.

For typical shapes of graphite occurring in cast iron, the shape factor is:

- $0.8 < c < 1.0$ dense nodular graphite,
- $0.65 < c < 0.8$ vermicular graphite,
- $0.2 < c < 0.65$ flake graphite.

The percentage of graphite shape ratios was determined for each of the amounts of master alloy and for the various of the gating system configurations using the formula (1).

Then, particular participation ratios in the range of 0.8-1.0 corresponding to dense, nodular graphite has been compiled.

The percentage share of nodule graphite in the resulting casting was determined from the calculations.

3. Results

Effect of the amount of master alloy the participation of graphite in ductile cast iron is shown on Figure 3.

As shown on figure, optimal amount of master alloy for obtained casting is 1.5% by spheroidizing mass.

Master alloy allows to obtain the 94% tested casting graphite ratio c = 0.8-1.0%.

Application of the master alloy in an amount of 2% causes a decrease in participation of nodular graphite in the structure, which may indicate that beyond a certain value of magnesium ceases to be spheroidizing element and becomes a despheroidizing.

It is believed that after binding of the oxygen present in the iron, the excess residual magnesium iron reduces the surface tension which results in the reduction in the aspect ratio of the graphite.

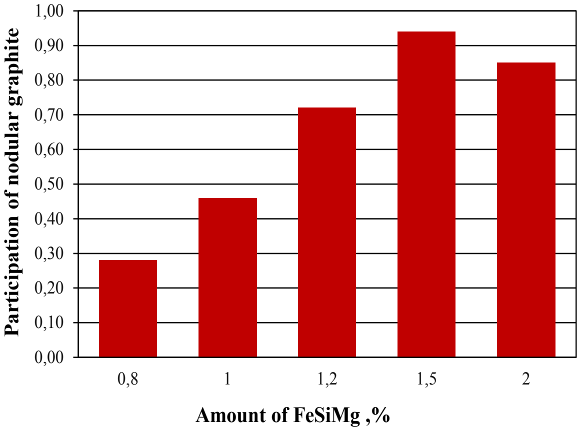

Fig. 3. Participation of nodular graphite in the test casting for different amount of master alloy

In Figure 4 are presented microstructure in the casting obtained which confirm that the higher the amount of master alloy reduces the number of graphite flake, and an increasing number of graphite nodule with an aspect ratio of 0.8-1.0.

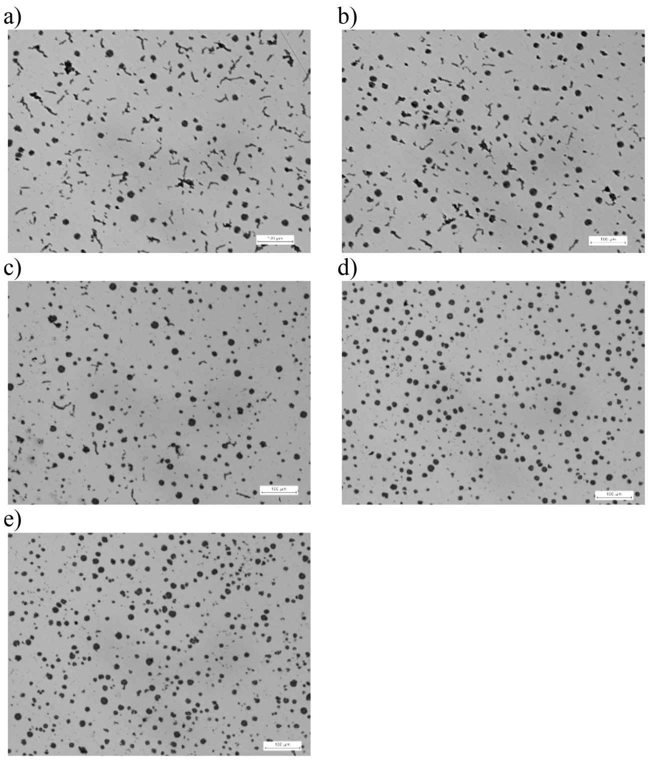

Fig. 4. Microstructure in the test casting: a) 0,8%, b) 1,0%, c) 1,2%, d) 1,5%, e) 2% master alloy in an amount by mass on casting iron

The influence of the gating system configuration and the shape of the reaction chamber, the degree of spheroidization cast iron is shown on Fig. 5.

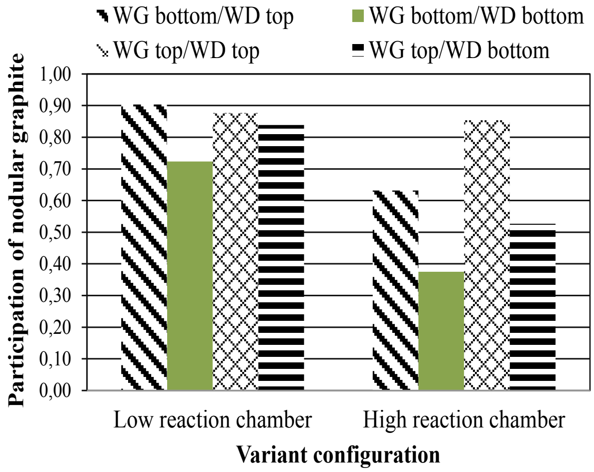

Fig. 5. Participation of nodular graphite for different gating system configuration

As shown on Figure 5, largest participation of nodular graphite obtained by using a low reaction chamber when the liquid iron flows into the reaction chamber at the bottom and flows out of the top part of.

The worst degree of spheroidization was obtained when the reaction chamber is above ingate, i.e. ingate and outgate of iron from the reaction chamber takes place from the bottom.

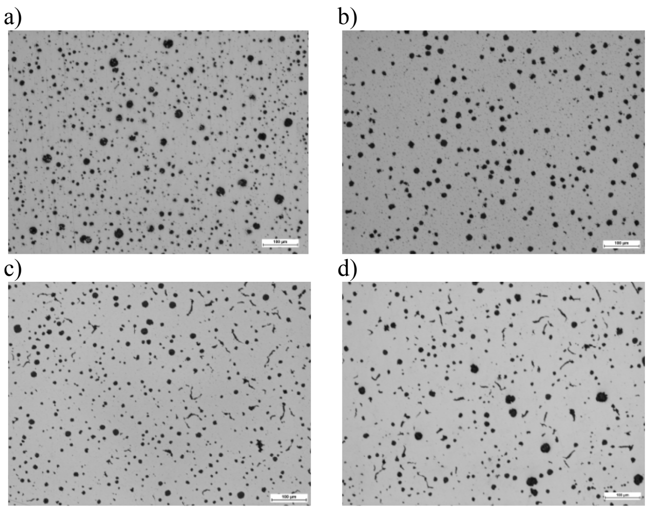

Fig. 4. Microstructure in the test casting configuration: a) WG bottom/WD top– reaction chamber low, b) WG bottom/WD bottom– reaction chamber low, c) WG bottom/WD top – reaction chamber high, d) WG bottom/WD bottom – reaction chamber high

Comparing the microstructure obtained castings due to the height of reaction chamber, a smaller participation of nodular graphite precipitates in the microstructure can be observed in the case of test castings, which uses a high reaction chamber (Fig. 6 c, d). In this case spheroidisation is incomplete. Liquid cast iron has a shortest contact with the master alloy because flow of liquid iron through the reaction chamber its more laminar.

4. Conclusions

Research has shown strong influence of the reaction chamber on spheroidizing process in the inmold method.

Using a supply and discharge of iron from the reaction chamber in the same plane as is the case in traditional technology in order to ensure correct spheroidization process, the reaction chamber must have a spherical shape [9].

The research shows that the optimum amount of master alloy is 1.5% by spheroidizing mass iron to produce ductile iron in lost foam technology which have high participation of nodule graphite.

Since in lost foam technology is not necessary to take into account the parting plane of a preferred procedure to increase the degree of spheroidization is to change the liquid iron flow direction through the reaction chamber iron.

Offset cast relative to the feed direction of casting iron into the reaction chamber and supply to the iron from the bottom of the reaction chamber and discharging from the top allows for the high share of nodular graphite in the structure of cast iron.

This is possible despite the use of the reaction chamber of rectangular shape which, as stated in the conventional technology (the use of iron supply and discharge of the reaction chamber in a single plane) and the smallest share of nodule graphite [7, 9].

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