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The Influence of the Shape of the Reaction Chamber on Spheroidisation of Cast Iron Produced in the Lost Foam Casting Process with Use of the Inmold Method

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Abstract

The article presents the results of the research on the influence of the shape of reaction chamber on spheroidisation of cast iron produced with use of the inmold method. The amounts of nodular graphite precipitates in castings produced with the use of different reaction chambers have been compared.

Keywords: Nodular Cast Iron, Inmold Method, LOST FOAM Casting, Innovative Casting Technologies, Reaction Chamber

1. Introduction

The method of production of nodular cast iron has been known since 1948, initially it consisted in introducing nickel and magnesium alloy to an open ladle. Later pure magnesium was added and currently special FeSiMg spheroidizers - master alloys are in use. Adding magnesium to molten cast iron is related with numerous problems resulting mainly from its properties. The most common and popular methods of cast iron spheroidisation are, among others:

- bell method,
- sandwich method,
- wire method,
- converter method,
- cored wire method,
- HTM,
- Inmold.

The “Inmold” method has been developed by International Mechanics Metal. The “Inmold” method consists in placing a portion of a spheroidising and modifying master alloy in a reaction chamber which is a part of the mould gating system. A stream of molten cast iron flows from the pouring gate to the reaction chamber where a reaction with the master alloy, i.e. cast iron spheroidisation, takes place. Cast iron is being modified simultaneously with spheroidisation, therefore the used master alloys must contain appropriate modifying elements [1]. Out of all commonly known methods of production of nodular cast iron, the Inmold method is one the most “elegant” and environmentally-friendly. Only a small amount of magnesium master alloy is consumed (0.7÷1.0%), while its reaction with molten cast iron is almost smokeless. The Inmold method guarantees the largest magnesium yield (70÷80%) out of all known cast iron spheroidisation methods [2].

The size of the casting is a certain limitation of the Inmold method. In practice, this method enables production of cast iron

castings up to 50 kg. The presence of the reaction chamber in the gating system and the mixing chamber in the mould neutral plane is related with limitations in terms of location and configuration of casting feeding. As a result, use of in-mold spheroidisation in the LOST FOAM casting process, where such limitations do not occur, seems reasonable, as this method lacks neutral area of the mould.

Large interest in the Lost Foam casting technology results from much lower production and investment costs, as compared to the traditional technology. In comparison to traditional casting in classic moulding sands, this method has a number of advantages, such as:

- reduction of the amount of equipment and process instrumentation,
- reduction of work consumption of final operations, due to lack of burrs, burns, etc.
- large size accuracy,
- use of moulding sands without binders,
- possibility of production of castings with complex shapes, especially in the inside, without the use of cores,
- reduction of the amount of casting dressing operations,
- possibility of thermal restoration of used moulding sand,
- much lower production costs [3-6].

2. Research methodology

Experiments verifying the possible influence of the shape of the reaction chamber used in the in-mold process of nodular cast iron production have been carried out at the laboratory of the Department of Materials Engineering and Production Systems, Łódź University of Technology.

Three pattern sets were prepared. Each of them contained a rectangular prism pouring gate, cuboidal runners, a rectangular spiral test mould (Fig. 1) and a reaction chamber. In each pattern the shape and dimensions of the gating system and the test mould were the same, only the shape of the reaction chamber varied. The volume of the three used chambers was the same. The effect of the chamber shape was analysed with a rectangular, a cylindrical and a spherical chamber. The layout of the gating systems with three different shapes of the reaction chamber and the test mould is presented in Figures 2, 3, 4.

In spiral bends, before the areas marked in the schemes as metallographic specimen collection locations, 8 electrodes have been installed. Additionally, one (basis) electrode has been installed in the runner feeding molten metal to the reaction chamber. The electrodes were used for checking the test mould cavity filling rate and checking the influence of the shape of the reaction chamber.

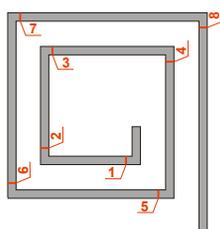


Fig. 1. Scheme of the test mould with marked locations of metallographic specimens collection

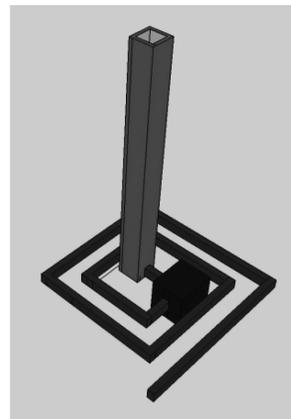


Fig. 2. Scheme of the gating system with test moulds: rectangular reaction chamber

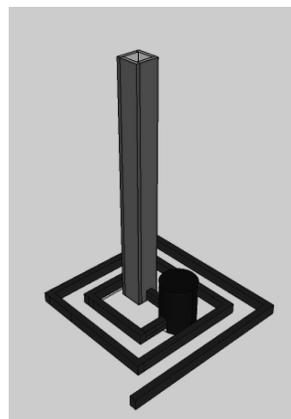


Fig. 3. Scheme of the gating system with test moulds: cylindrical reaction chamber

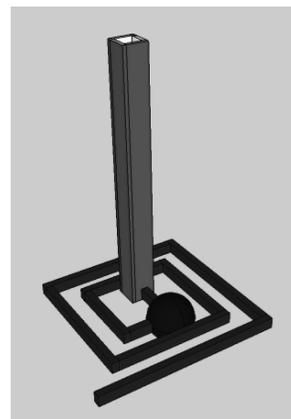


Fig. 4. Scheme of the gating system with test moulds: spherical reaction chamber

Cast iron was smelted in an induction furnace with charge capacity of 30kg PI -30. Norwegian OB pig iron was used for melting, its composition is specified in Table 1.

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

Silicon content was complemented by addition of FeSi75 ferrosilicon. LAMET 5504 1-4mm master alloy was used for cast iron spheroidisation in the mould, in the amount of 1.5% of the weight of the spheroidised cast iron. It is both the spheroidiser and the graphitiser [1]. Detailed chemical composition of the master alloy is presented in Table 2.

After melting of the charge, its temperature was checked with use of PtRh10-Pt immersion thermocouple. The mould was filled with cast iron with temperature of 1550°C.

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

3. Research results

The article presents the results of the tests of nodular cast iron castings produced with the use of the lost foam casting method with spheroidisation in the mould. The purpose of the tests was to determine whether the shape of the reaction chamber had influence on graphite morphology in the obtained nodular cast iron castings produced in the lost foam in mold process. A pattern with density of 24 kg/m³ was used in lost foam casting.

The test mould cavity filling rate checks as well as reaction chamber shape influence checks made with use of the electrodes have indicated that the difference of the shape of the reaction chamber had no effect on the mould cavity filling rate.

Specimens for microstructure analysis have been collected from the test castings according to Fig. 1.

The results of the metallographic analyses of the three representative castings produced in gating systems with reaction chambers with the shape of rectangular prism, cylinder and sphere are presented in Figures 5, 6, 7.

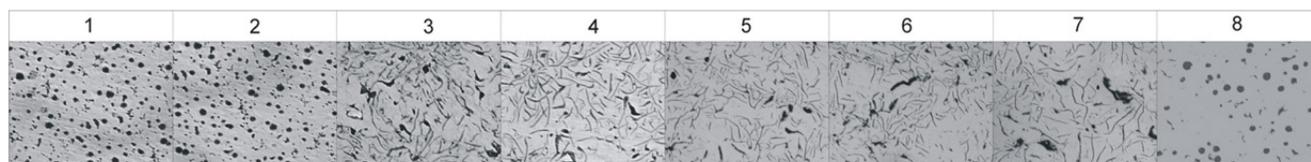


Fig. 5. Microstructure of nodular cast iron in the test casting - rectangular chamber

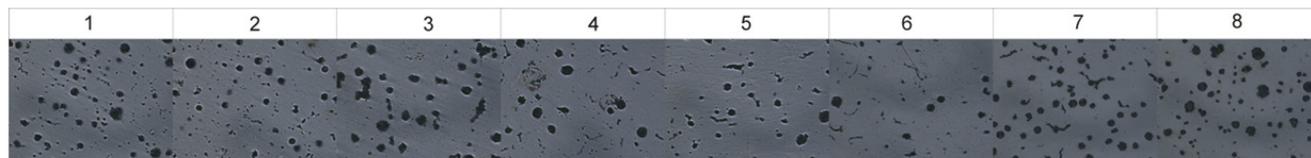


Fig. 6. Microstructure of nodular cast iron in the test casting - cylindrical chamber

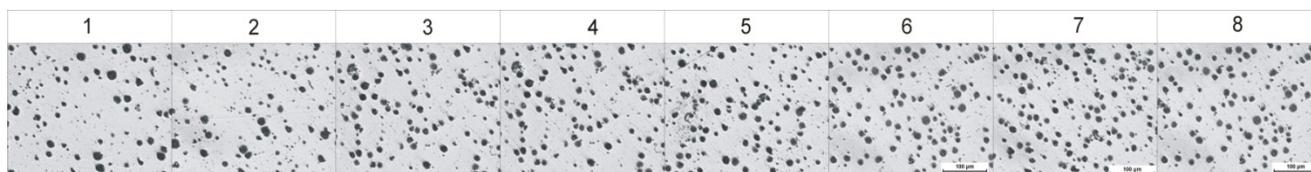


Fig. 7. Microstructure of nodular cast iron in the test casting - spherical chamber

NIKON microscope along with the software was used in graphite morphology evaluation.

The analyses have been carried out on two diagonals perpendicular to the surface of the metallographic specimen. The analysed area was 0.058413 mm².

The following coefficient has been used in describing the shape factor [8]:

$$c = \frac{O_{bk}}{O_{bw}} \quad (1)$$

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:

- dense nodular graphite:
 $0.80 < c < 1.00$
- vermicular graphite:
 $0.65 < c < 0.80$
- flake graphite:
 $0.20 < c < 0.65$

The carried out microscopic analyses facilitated determination of the percentage participation of nodular graphite precipitates in the obtained castings, Fig. 8.

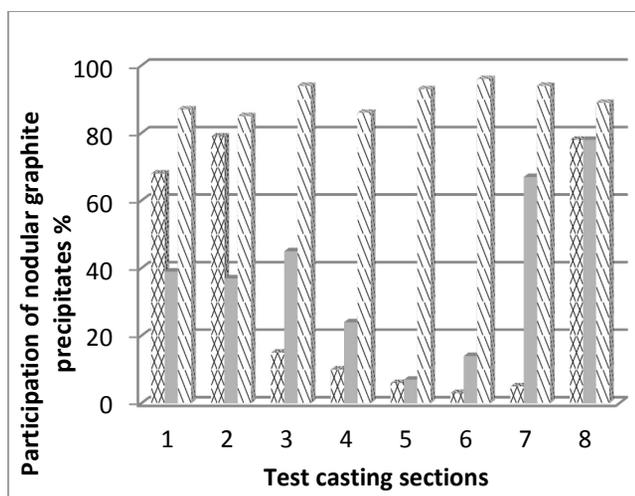


Fig. 8. Participation of nodular graphite precipitates in the obtained castings - chequered - rectangular chamber, plain - cylindrical chamber, lining - spherical chamber

When comparing the microstructures in Figures 5, 6, 7, we may conclude that the shape of the reaction chamber has a significant effect on the shape and amount of graphite precipitates, which is also confirmed in stereological evaluation. The smallest proportion of nodular graphite precipitates is observed with the rectangular reaction chamber. This shape also gives the smallest homogeneity of shape and size of graphite precipitates in the entire volume of the test casting. The largest nodular graphite yield and homogeneity in the casting was obtained in the system with the spherical chamber.

4. Summary and conclusions

The comparative analyses of castings produced with use of the in mold method of the lost foam casting process, presented in the article, indicate that similarly to the traditional moulding sand technology:

- the shape of the reaction chamber has a significant effect on the shape and amount of graphite precipitates,
- a spherical reaction chamber provides the largest nodular graphite precipitates yield,
- the smallest homogeneity of shape and size of precipitates is obtained with a rectangular reaction chamber.

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