S. BOCKUS, G. ZALDARYS

ISSN 0543-5846
METABK 48(1) 19-22 (2009)
UDC – UDK 621.74:669.13.7 = 111

INFLUENCE OF THE SECTION SIZE AND HOLDING TIME ON THE GRAPHITE PARAMETERS OF DUCTILE IRON PRODUCTION

Received – Prispjelo: 2008-01-10
Accepted – Prihvaćeno: 2008-07-20
Original Scientific Paper – Izvorni znanstveni rad

This work was conducted to establish the conditions required to produce a desirable structure of the castings of various section sizes.This investigation was focused on the study of the influence of cooling rate or section size and holding time on graphite parameters of the ductile iron. Plates having thickness between 3 and 50 mm were cast in sand molds using the same melt. The present investigation has shown that the section size of ductile iron castings and holding time had strong effect on the graphite parameters of the castings.

Key words: ductile iron, section size, microstructure, mechanical properties

Utjecaj debljine stjenke i vremena zadržavanja na grafitne parametre pri proizvodnji žilavog lijeva. Rad je proveden da se ustanove potrebni uvjeti za proizvodnju željene strukture odljevaka različite debljine stjenki. Istraživanje je usmjereno na proučavanje utjecaja brzine hlađenja ili debljine stijenki na vrijeme zadržavanja s obzirom na grafitne parametre žilavog lijeva.
Ploče debljine 3 i 50 mm lijevane su u pješčane kalupe upotrebom jednake taljevine. Ova istraživanje je pokazalo da debljina stjenki odljevaka žilavog lijeva i vrijeme zadržavanja imaju veliki utjecaj na grafitne parametre odljevaka.

Ključne riječi: žilavi (nodularni) lijev; debljina stjenke; mikrostruktura; mehanička svojstva

INTRODUCTION

The goal of the metallurgist is to design a process that will produce a structure that will yield the expected mechanical properties. The quality of the final product depends on the mechanisms of defect formation and microstructure evolution [1]. The structure determines many of the properties inherently available from the cast metal. This structure is largely determined during crystallization from the melt. Crystallization from metal melt involves the successive stages of nucleation and growth. The relative possibilities for nucleation and growth depend upon foreign particles or solutes present in the liquid, whether as trace impurities or as deliberate additions [2]. The control of processing parameters requires knowledge of the structure-properties correlation for the ductile iron under consideration as well as of the factors affecting the structure [3]. When discussing the metallurgy of ductile iron, the main factors of influence on the structure that one needs to address are: chemical composition, cooling rate, liquid treatment and heat treatment [4 - 7]. When changing the cooling rate, effects similar to those discussed for gray iron also occur in ductile iron, but the section sensitivity of ductile iron is lower. This is because spheroidal graphite is less affected by cooling rate than flake graphite. But pouring very thin sections in ductile iron presents danger of massive carbides as-cast [8]. The liquid treatment of ductile iron is more complex than of gray iron. The two stages for liquid treatment of ductile iron are: modification, which consists of magnesium or magnesium alloy treatment of the melt, with the purpose of changing graphite shape from flake to spheroidal, and inoculation to increase the nodule count or to suppress carbide formation. Increasing the nodule count is an important goal, because a higher nodule count is associated with less chilling tendency and higher as-cast ferrite/pearlite ratio [9]. Normally, spheroidizing is followed by inoculation. It may take place at different process in combination or separately [10].

This investigation was conducted to establish the conditions required to produce a desirable structure of the castings of various section sizes.

EXPERIMENTAL

Casting procedure

A high-frequency induction furnace was utilized to prepare 120 kg experimental spheroidal graphite cast

S. Bockus, G. Zaldarys, Faculty of Mechanics and Mechatronics, Kaunas University of Technology, Kaunas, Lithuania

iron melts. The charge material consisted of pig-iron, mild steel, return scrap and carburizing agent.

The analysis of the influence of sections size on the diameter and shape of the graphite spheroids and respectively the influence of graphite distribution on the mechanical properties was been carried out with the similar matrix microstructure in all samples. Therefore, the base irons were of eutectic composition; the concentration of Si was 2,4-2,8 wt%. But the silicon content increases up to 3,5-3,8 wt% after spheroidizing and late inoculating treatments. It had ensured a fully ferritic matrix in all samples because silicon reduces the carbon diffusion path during the eutectoid transformation, prevents formation of carbides and increases the amount of ferrite in the structure [10, 11].

The spheroidizing process was carried out by applying the sandwich method, and using *Lamet* noduliser (6% Mg, 0,4-0,6% La). Treatment temperature was 1450-1470 °C. The temperature of molten iron was measured by thermocouple using Pt-Rh thermocouple. After the nodularising treatment reaction subsided the melt was inoculated with 0,3 wt% of ferro-75 wt% silicon based inoculant *Alinoc* containing 70-75% Si, 3,5-4,5% Al, 0,5-1,5% Ca. The agent was added into the stream when reladling from treatment to pouring ladle. The pouring temperature range for the first and the last molds were 1300-1310 °C and 1270-1280 °C, respectively.

Mold design

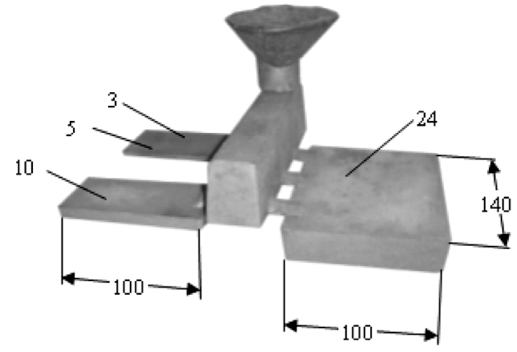
The treated irons were poured into greensand molds. The test castings were step plates consisting of joined strips different wide (from 25 mm to 140 mm) by 100 mm long. The thicknesses of the strips were nominally 3, 5, 10, and 24 mm. Two different molds were used to obtain test plates of vertical and horizontal configuration (Figure 1). The 50 mm thickness plate was cast separately. Pouring time was approximately 4 seconds. Shakeout time was approximately 120 minutes.

Testing procedure

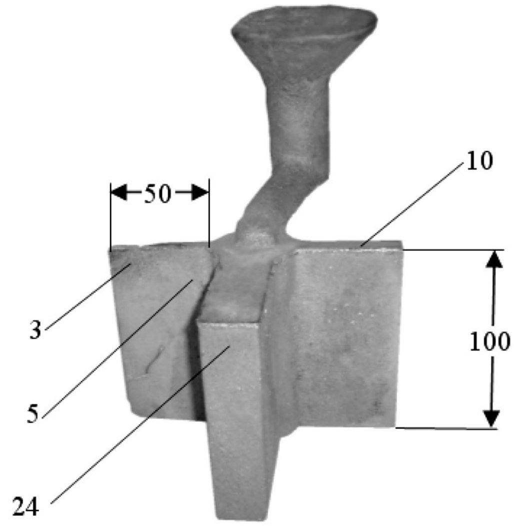
Microstructure was observed with an optical microscope. Tensile strength, elongation and Brinell hardness were measured using the 30 mm diameter specimens cast separately in sand molds. The chilled samples were also obtained for final chemical analysis. Chemical composition of the cast iron has been determined by spectrometer SPEKTROLAB.

EXPERIMENTAL RESULTS AND DISCUSSIONS

The effect of the sections size of the vertical and horizontal specimens on the diameter of the graphite spheroids was evaluated. The results for samples taken from the vertical moulds are shown in Figures 2 and 3. As the section size increases, the average spheroids diameter increases too. This effect is seen on the horizontal plates too (Figure 4) and can be explained by different cooling rate of plates [12]. As in the case of vertical molds, there is no noticeable difference between the average size of graphite nodules in the samples taken from top and bottom of plates (Figure 2).



a)



b)

Figure 1. Horizontal (a) and vertical (b) test castings (dimensions in millimetres)

The effect of the time after spheroidizing treatment on the size of the graphite spheroids was been cared out on the 10 mm thick plates. It was established that the graphite size had not varied after 5, 10 and 15 minutes but after 20 and 25 minutes it was appeared strong non-homogeneous size of graphite spheroids (from 20 to 55 μm) (Figure 5). Additionally after 25 minutes it was appeared irregularly shaped graphite spheroids. Respectively, such microstructure changes are of major importance in mechanical ductile iron properties (Table 1).

It is well known to the foundry people that all inoculants effects fade with time after addition. Usually 20 minutes is the maximum time to insure any residual effect of spheroidizing [13, 14]. According Table 1 date,

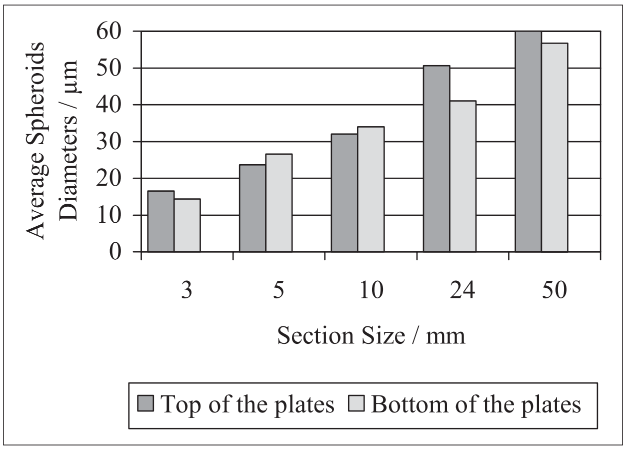


Figure 2. Effect of the sections size of the vertical specimens on the diameter of the graphite spheroids

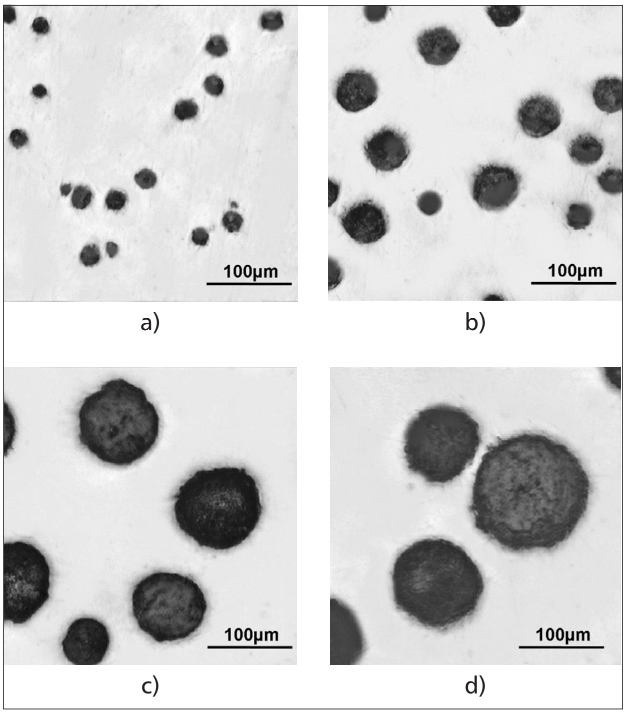


Figure 3. Optical microstructure of castings of different section size: *a* – 3 mm, *b* – 5 mm, *c* – 24 mm, *d* – 50 mm

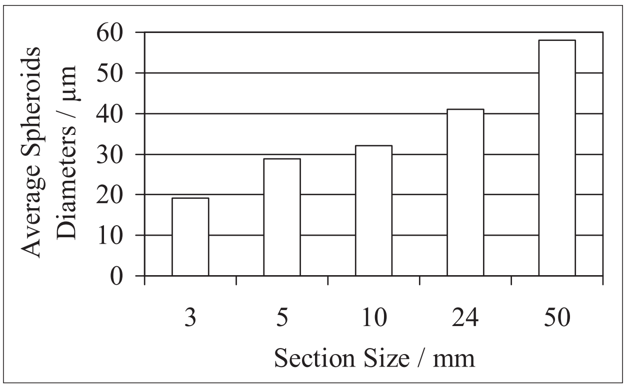


Figure 4. Effect of the sections size of the horizontal specimens on the diameter of the graphite spheroids

15 minutes is the maximum time to insure ductility of ductile iron castings. It is advisable therefore to pour the

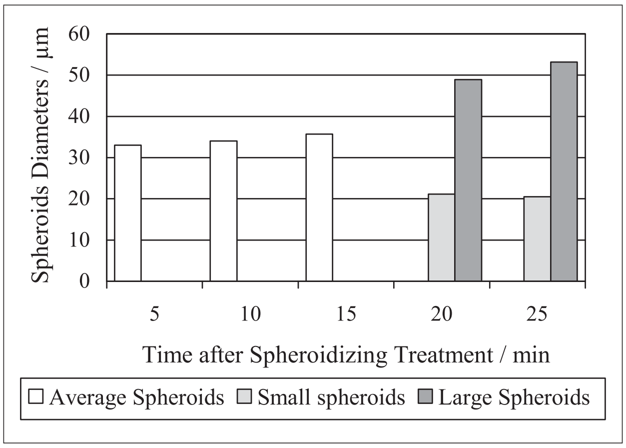


Figure 5. Size of the graphite spheroids diameters in 10 mm thick plates as a function of the time after

Table 1. **Effect of time after spheroidizing treatment on the mechanical properties of ductile iron**

Parameter	Time after spheroidization / min				
	5	10	15	20	25
Tensile strenght / MPa	572	562	582	585	588
Elongation / %	12,8	12,8	11,4	8,6	5,7
Hardness / HB	192	187	199	197	192

molds as quickly as possible. However, the practical controlling factor of strength and hardness is temperature rather than the effect of inoculants fading, thus this conclusion give more latitude to the time between spheroidizing and pouring. These observations were attributed to the fully ferritic ductile iron only. The approach used in this investigation can be further extended to applications in more general cases for optimization of design of ductile iron casting technological process.

CONCLUSIONS

Melts of eutectic composition were used to cast plates of thickness ranging from 3 to 50 mm. The results show that the wall thickness of spheroidal graphite cast iron castings had very strong effect on the graphite size and shape of the castings.

The time after spheroidal treatment has significant effect on the elongation, but insignificant effect on the tensile strength and hardness of castings. The graphite shape is under the sway of the holding time too.

Any effect of plates position in the molds was not observed.

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Note: The responsible for Englisch Language is the Author S. Bockus.