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Preparation Vermicular Graphite in Thin and Thick Wall Iron Castings

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Abstract

The results of studies on the use of magnesium alloy in modern Tundish for production of vermicular graphite cast irons were described. This paper describes the results of using a low-magnesium ferrosilicon alloy for the production of vermicular graphite cast irons. The paper presents a vermicular (and nodular) graphite in different walled castings. The results of trials have shown that the magnesium Tundish process can produce high quality vermicular graphite irons under the specific industrial conditions of Foundries - Odlewnie Polskie S.A. in Starachowice. In this work describes too preliminary studies on the oxygen state in cast iron and their effect on graphite crystallization.

Keywords: Vermicular Cast Iron, Ductile Cast Iron, Tundish Method, Oxygen in Cast Iron

1. Introduction

Ductile iron continues being one of the most modern cast materials,. Due to its excellent technological properties it has found a way to general technical applications and right now is the material of choice more and more willingly used by designers. In Europe, the largest use of ductile iron is in the automotive industry (36%), in the production of industrial valves (32%), in the construction industry (16%) and for parts of machines (4%).

Globally, since 2000, a systematic growth in production volume of ductile iron to about 30% of the overall production of cast iron has been reported. In Poland, since 2011, a significant increase in the production of ductile iron has been observed, and right now it covers over 25% of the total domestic production of cast iron (according to Modern Casting, Dec. 2011 - the produced volume of cast iron with flake graphite was 445,1 thousand tons; ductile iron – 152,3 thousand tons). In the past few years, i.e. since 2000, the production volume of ductile iron in Poland increased by over 50% and continuation of this upward trend is to be expected.

In contrast, vermicular cast irons are used where increased and ductility, yield, machinability, thermal conductivity over nodular graphite cast irons are required. Although vermicular graphite iron (GJV) has existed for more than 25 years, its applications have been limited to simple, low-volume components with wide microstructural tolerances, pump housings, brackets, box, car engine blocks, etc. [1-6]. International Organization ISO and German Foundryman Association (Verein Deutscher Giessereifachleute VDG) have developed and published standards for GJV with Grades in terms of the tensile strength and structure, expressed as percent nodularity. The currently available standards are summarized in Table 1; GJV cast iron has been known by the names “Compacted Graphite Iron” and “Vermicular Graphite Cast Iron”, with the Compacted terminology primarily being used in English speaking countries and Vermicular- predominating in most other languages. Cast iron with vermicular graphite is included in ISO 16112 international standard from 2006 was published using the combined name: „Compacted (Vermicular) Graphite Cast Iron”.

An important role in shaping of the structure and hence the performance properties has the crystallisation of graphite eutectic and primary dendrites of austenite, as shown in [7-9].

Table 1.
Summary of Vermicular Cast Iron Standards ISO and suggestion of German Foundryman Association (VDG)

Vermicular cast iron (Grade)	UTS MPa, min.	YTS MPa, min	Elongation A %, min.	Brinell hardness HB
GJV-300 16112/JV/300/S	300-375 *	220-295 min. 210	1,5 2,0	140-210 *
GJV- 350 16112/JV/350/S	350-425 *	260-335 min. 245	1,5 *	160-220 *
GJV- 400 16112/JV/400/S	400-475 *	300-375 min. 280	1,0 *	180-240 *
GJV- 450 16112/JV/450/S	450-525 *	340-415 min. 315	1,0 *	200-250 *
GJV- 500 16112/JV/500/S	500-575 *	380-455 min. 350	0,5 *	220-260 *

* ut. sup.

The ISO 16112 standard designation for CGI has been abbreviated as „GJV" and five Grades have been specified in separately cast test pieces, including: minimum values of UTS - MPa GJV-300 (ferritic) GJV- 350, GJV-400, GJV- 450 (pearlitic) and GJV-500 (alloyed). Minimum values of elongation A_5 equal from 3 to 1%. Whereas the customer specifications referred to above can demand up to 50% of nodules present, the new and as-yet unpublished ISO standard requires a general limit of 25 %. The narrow band showing less than 25% of nodules defines the small window of opportunity to meet this demand. From this, it can be deduced that GJV requires far greater control than ductile iron.

Examining closely the properties of vermicular graphite cast iron it is easy to see some of its specific advantages, specially when a comparison is made with the high-performance inoculated cast iron (with flake graphite FG) and ferritic ductile iron (with nodular graphite - NG).

As regards the most important mechanical, physical and utilization properties, they can be arranged in an increasing order shown in Table 2 (for the sake of clarity the following designations have been used: FG, NG and VG for inoculated, ductile and vermicular cast irons, respectively) [2]:

Table 2.
Important mechanical, physical properties of cast iron with flake graphite, vermicular graphite and nodular graphite

Properties	Type of graphite
Tensile strength UTS	FG VG NG
Elongation (plastic properties)	
Yield strength YTS	
Fatigue strength Z	
Modulus of elasticity E	
Resistance to oxidation at elevated temperatures	
Damping capacity	NG VG FG
Thermal conductivity	
Thermal fatigue resistance (shock resistance)	
Brinell hardness HB	comparable
Coefficient of thermal expansion	

As shown in Fig. 1 the cast iron with vermicular graphite is an good engineering material, taking an intermediate position between the high-performance inoculated cast iron with flake graphite and ductile iron with nodular graphite.

Notwithstanding its undeniable advantages, the cast iron with vermicular graphite GJV has not been in wide use so far, specially compared to ductile iron. From the comparison made above it follows that the cast iron with vermicular graphite surpasses the inoculated grey cast iron in mechanical properties (specially plastic properties) and in most of the engineering and utilization properties, while being inferior in the damping capacity and thermal fatigue resistance.
The aim of the present study has been determination of changes in microstructure in the castings with different wall walled castings (production by method: Tundish).

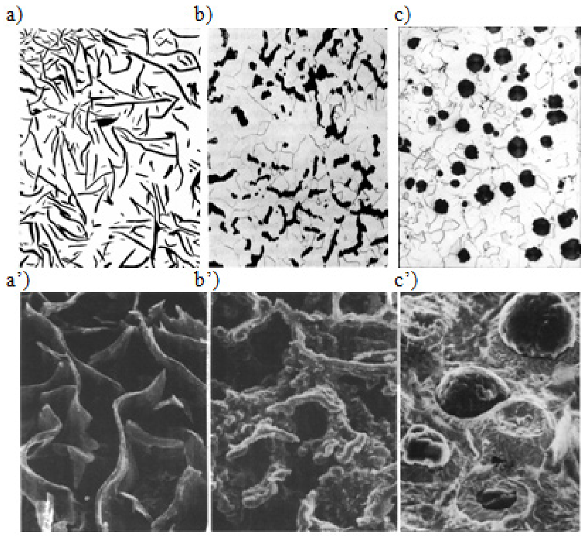


Fig. 1. Typical microstructure of cast iron from: flake graphite (a,a'), vermicular graphite (b, b') and nodular graphite (c,c') [10]

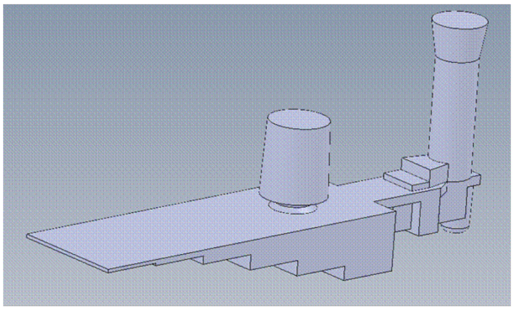
2. Experimental procedure

Melts of the cast iron with vermicular graphite were conducted at the foundry where the operations of vermicularising treatment and inoculation have been well mastered during the process of making high-performance cast iron. The metal after melting in a furnace is preheated to a temperature of 1510°C and held at that temperature for about 5 minutes. Then, at a temperature of about 1460°C -1470°C, the metal is tapped to a slender ladle. The ladle (capacity 1.0 Mg) is next handled to the vermicularising treatment post where the treatment is carried out using a part of the Mg master alloy (Tundish method). After treatment the metal is transferred to a pouring ladle and inoculated in the ladle. After vermicularising, metal is poured into a distribution ladle where it is modified with inoculants type SB5.

After treatment of the metal bath, i.e. after vermicularising and inoculation, and transfer to a pouring ladle, the mould was poured together with a measuring system installed there in order to examine the effect of cooling rate in individual walled castings

(3, 5, 12, 25, 38 and 50) – Fig. 2 on the formation of microstructure and vermicular graphite precipitates in function of the cooling rate. The vermicular cast iron used in this study have a chemical composition in a range of the following of (mass %): 3.77%C, 2.488%Si, 0.157%Mn. 0.048% P, 0.012% S and 0.025% Mg (melt No. 1) and 0.035% Mg (melt No. 2).

a)



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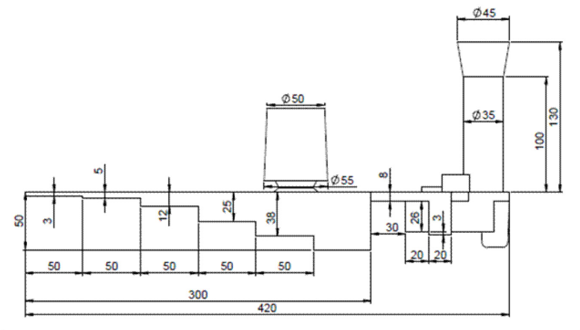

Fig. 2. The stepped test plate casting – (a) and dimensions of the test plate casting – (b)

3. Results and analysis

3.1. Structure of cast iron

From analysis of microstructure it follows that one can determine the critical thickness of the casting.

Comparing the results of microstructure of the tests obtained and stepped test plate by wall castings 3, 5, 12, 25, 38 and 50 mm. Table 3 present the microstructure stepped plate castings. Based on the microstructural observations, it was found that the reinforcing graphite distribution of both the nodular and vermicular graphite.

The study showed that in castings with a thickness of above than 12 mm formed vermicular cast iron - to the 0.025 mass % Mg (Fig. 3). In this structure consists of: 20% of nodular graphite and 80% of vermicular graphite. When the concentration of magnesium is 0.035mass % formed ductile cast iron (Fig. 4) in thick walls castings.

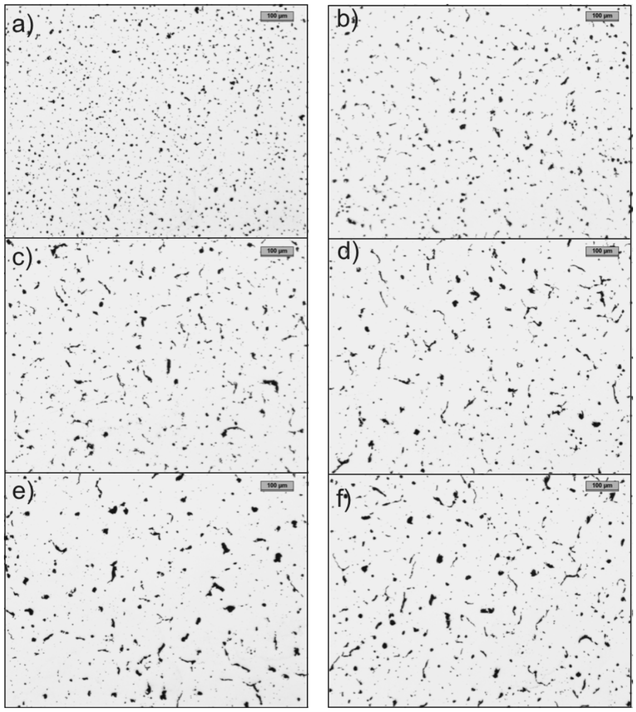

Fig. 3. Typical microstructure test cast iron with the addition of 0.025mass % magnesium of 3 mm - (a), 5 mm - (b), 12 mm - (c), 25 mm – (d), 38 mm – (e) and 50 mm (f) plate wall castings

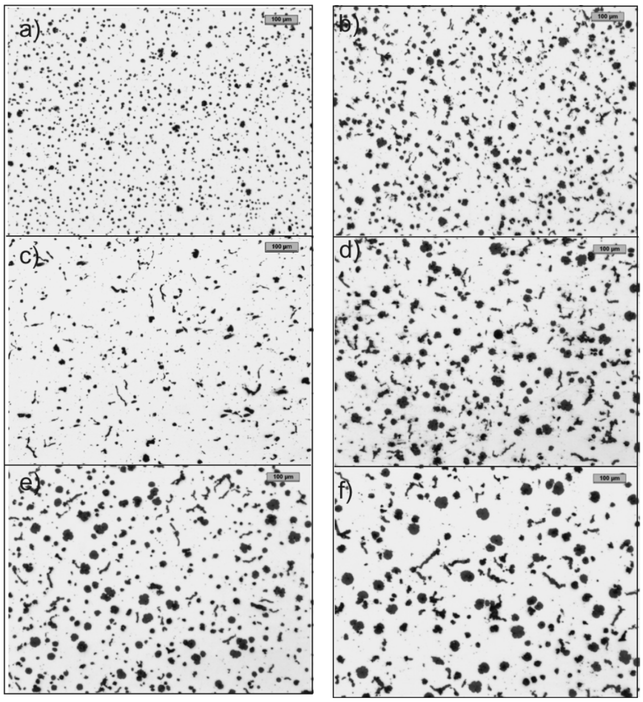

Fig. 4. Typical microstructure test cast iron with the addition of 0.035 mass % magnesium of 3 mm - (a), 5 mm - (b), 12 mm - (c), 25 mm – (d), 38 mm – (e) and 50 mm (f) plate wall castings

3.2. Effect oxygen in cast iron on graphite crystallization

Oxygen in graphitic cast irons substantially influences crystallization in that actively participates in nuclei formation [11]. The experimental works were aimed at evaluation of oxygen influence during manufacture of cast irons on structure. With the increase of magnesium in cast iron, the oxygen activity decreases. Oxygen activity in vermicularyzation and spheroidyzation cast iron is reduced to the range 61 - 81 ppb (Fig. 5 and Fig. 6a). Over time, the value of active oxygen increases to a critical level equal to approximately 140 ppb and formed vermicular graphite (Fig. 5 and Fig. 6a).

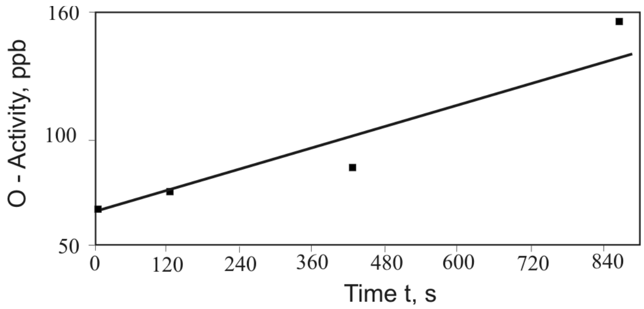

Fig. 5. The oxygen activity changing in the technology time t

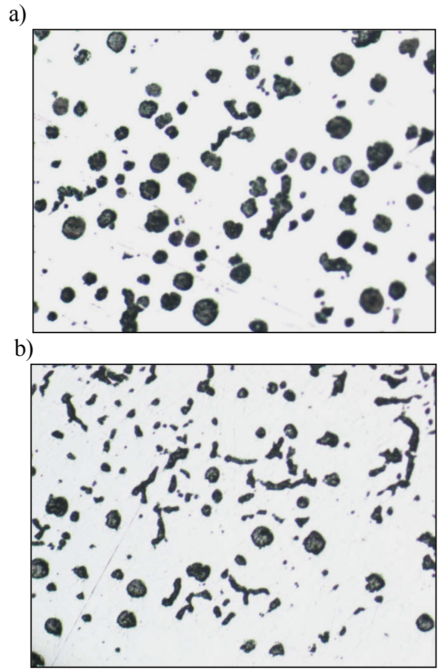

Fig. 6. Microstructure of experimental cast iron with different contents of activity oxygen in the melt No. 2: 73 ppb for the time t = 120 s – (a) and 155 ppb for time t = 865 s - (b)

4. Conclusions

Based on conducted studies of nodular and vermicular cast iron following conclusions have been formulated:

1. From observations of the spheroidising or vermicularising treatment of cast iron carried out by the Tundis under the conditions of foundry it follows that this technique has gained full approval of the foundry industry. Therefore it is used more and more often at home and abroad in manufacture of castings from ductile and vermicular cast iron.
2. Relationship with the critical thickness of the casting and magnesium content in cast iron and oxygen activity in liquid alloy allows control of the crystallization of graphite.

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