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The Structure and Mechanical Properties of Pearlitic-Ferritic Vermicular Cast Iron

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Abstract

The results of studies on the use of magnesium alloy in modern Tundish + Cored Wire injection method for production of vermicular graphite cast irons were described. The injection of Mg Cored Wire length is a treatment method which can be used to process iron melted in an electric induction furnace. This paper describes the results of using a high-magnesium ferrosilicon alloy in cored wire for the production of vermicular graphite cast irons at the; Tundish + Cored Wire to be injected methods (PE) for pearlitic-ferritic matrix GJV with about 25 % ferrite content. The results of calculations and experiments have indicated the length of the Cored Wire to be injected basing on the initial sulfur content and weight of the treated melt. The paper presents a microstructure matrix and vermicular graphite in standard sample and different walled castings. The results of numerous trials have shown that the magnesium Tundish + PE Method process can produce high quality vermicular graphite irons under the specific industrial conditions of the above mentioned foundries.

Keywords: Vermicular cast iron, Pearlitic-ferritic matrix, Tundish + Cored Wire method

1. Introduction

The compacted/vermicular graphite as a new engineering materials has already been widely used. Vermicular cast irons are used where increased 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]. 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”. 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 A₅ 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*).

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 | 300-375 | 220-295 | 1,5 | 140- |
| 16112/JV/300/S | * | min. 210 | 2,0 | 210 * |
| GJV- 350 | 350-425 | 260-335 | 1,5 | 160- |
| 16112/JV/350/S | * | min. 245 | * | 220 * |
| GJV- 400 | 400-475 | 300-375 | 1,0 | 180- |
| 16112/JV/400/S | * | min. 280 | * | 240 * |
| GJV- 450 | 450-525 | 340-415 | 1,0 | 200- |
| 16112/JV/450/S | * | min. 315 | * | 250 * |
| GJV- 500 | 500-575 | 380-455 | 0,5 | 220- |
| 16112/JV/500/S | * | min. 350 | * | 260 * |

* ut. sup.

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

Tensile strength UTS - *FG*, *VG*, *NG*;

Elongation (plastic properties) A - *FG*, *VG*, *NG*;

Yield strength YTS - *FG*, *VG*, *NG*;

Fatigue strength Z - *FG*, *VG*, *NG*;

Modulus of elasticity E - *FG*, *VG*, *NG*;

Brinell hardness HB- comparable within the same metallic matrix;

Damping capacity - *NG*, *VG*, *FG*;

Coefficient of thermal expansion - *comparable*;

Thermal conductivity K - *NG*, *VG*, *FG*;

Resistance to oxidation at elevated temperatures - *FG*, *VG*, *NG*;

Thermal fatigue resistance (shock resistance) - *NG*, *VG*, *FG*.

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.

Compared with different techniques, the method of vermicularising treatment by the technique of Tundish + Cored Wire (PE) offers the following advantages: it ensures process stability expressed by target magnesium content in cast iron of and 0.017-0.02% Mg range for vermicular graphite.

The aim of the present study has been determination of changes in microstructure and mechanical properties of the cast iron with vermicular graphite (pearlitic and ferritic matrix) in the

castings with different wall walled castings and „YII” keel block standard (production by metod: Tundish + Cored Wire PE).

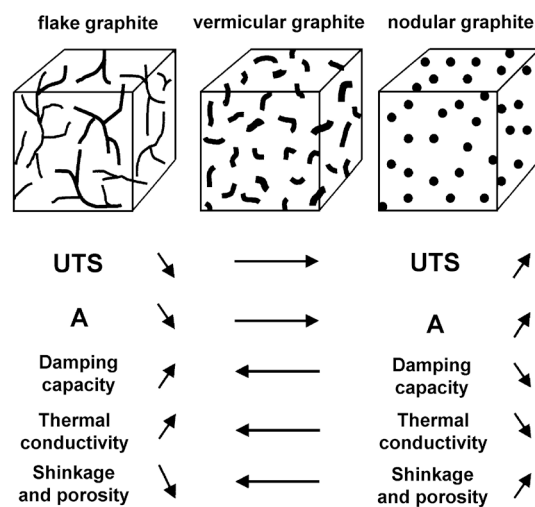


Fig. 1. The scheme of properties inoculant cast iron (with flake graphite) and nodular cast iron as well as vermicular cast iron

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 1460-1470°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) and flexible Cored Wire – Fig. 2 (technique is described in literature as a PE method [3-7]). In this particular case, the treatment was carried out by means of a flexible wire with magnesium core 120g Si/m, 65g Mg/m and to 1.5% RE. 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 inoculant SB5 (FeSiCaAlBa). The figure having prepared liquid metal, a casting mould has been poured in, which made of bentonite substance.

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 (10, 16 and 25 mm) – Fig. 3 and standard “YII” keel blocks on the formation of microstructure and vermicular graphite precipitates in function of the cooling rate.

The examinations were made under the quantitative analyzer Leica MEF-4M QWin. The vermicular cast iron used in this study have a chemical composition in a range of the following of (wt. %): 3.7%C, 2.47%Si, 0.28%Mn, 0.6%Cu, 0.02% P, 0.015% S and 0.018% Mg (see Fig. 5).

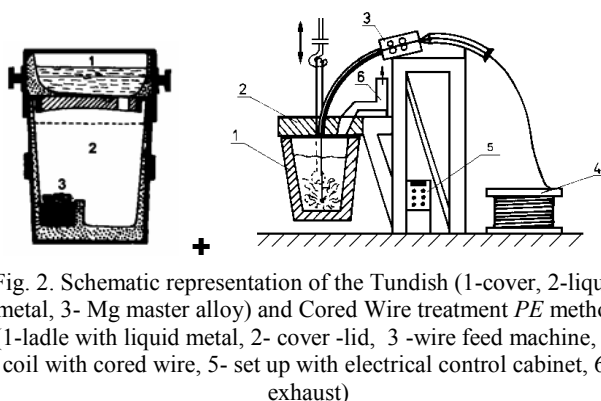


Fig. 2. Schematic representation of the Tundish (1-cover, 2-liquid metal, 3- Mg master alloy) and Cored Wire treatment PE method (1-ladle with liquid metal, 2- cover -lid, 3 -wire feed machine, 4- coil with cored wire, 5- set up with electrical control cabinet, 6- exhaust)

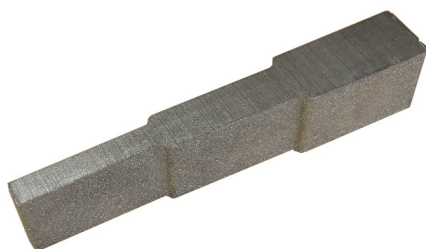


Fig. 3. The stepped test plate casting 10, 16 and 25mm

3. Results and analysis

From analysis of this "chessboard" it follows that the range of parameters of both of the above mentioned operations guarantees the structure of cast iron with either vermicular or nodular graphite. Comparing the results of microstructure of the tests obtained „YII” keel blocks and stepped test plate by wall castings 10, 16 and 25mm. Table 2 present the quantitative metallography determinations to “YII” keel block and stepped plate castings. Based on the microstructural observations, it was found that the reinforcing graphite distribution of both the nodular V and VI and vermicular III graphites (for wall 10-16mm- up 72 % and for – 25mm up 70%) in the pearlitic-ferritic matrix. In Figures 4 there are shown examples of wall casting microstructure for 10 and 25mm. Examples of printout of report (from Foundry) with a microstructure and mechanical properties vermicular cast iron (GJV-400 Grade) results in the „YII” keel block shown in Fig. 5. Mechanical tests conducted on a sample taken from the “YII” keel block gave the following results: UTS=403 MPa, YTS= 312 MPa, A₅=1.9% and hardness HB=195-198 units.

As it turned out vermicular cast iron with 0.6% Cu and 0.28% Mn fulfill requirements concerning tensile strength UTS and elongation a destined for vermicular cast iron of 16112/JV/400/S (GJV-400) Grade. Metallographic examinations of specimens taken from GJV castings made by the technique of FeSiMg master alloy and by the Cored Wire (PE method) have proved that the latter technique produces of the vermicular cast iron.

Table 2.

Results of microstructure of vermicular cast iron in wall stepped test plate, 10, 16 and 25 mm and “YII” block standard

| “YII” keel block standard | Stepped test plate, wall casting 10 -16mm | Stepped test plate, wall casting 25mm |
|--|---|---------------------------------------|
| pearlite = 73.83%, ferrite = 26,17% | pearlite ~ 80%, ferrite ~ 20% | pearlite ~ 80 %, ferrite ~ 20% |
| graphite III~78%. | graphite III~ 72%. | graphite III~ 79%. |
| graphite V,VI~22% | graphite V,VI~28% | graphite V,VI~21% |

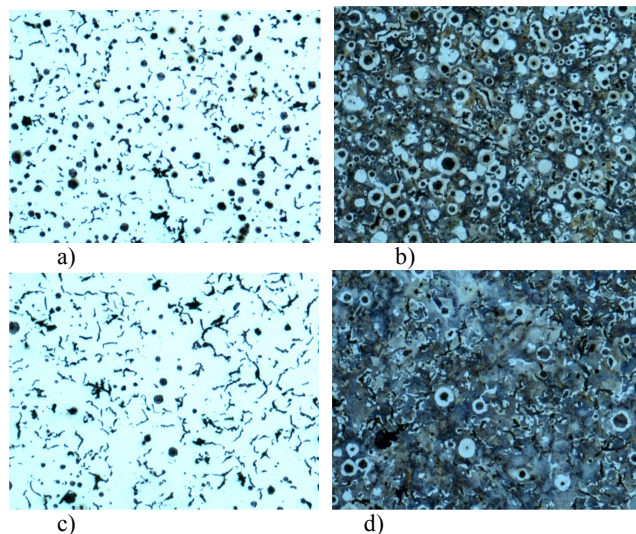


Fig. 4. Typical microstructure vermicular cast iron (GJV) of 10 mm (a, b) and 25 mm (c, d) plate wall castings

4. Conclusions

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

1. From observations of the vermicularising treatment of cast iron carried out by the Tundish + PE method 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 cylinder blocks in engine castings from quality GJV cast iron.
2. Applying the “duplex method” e.g. Mg master alloy and Cored Wire treatments for vermicular cast iron with 0.6%Cu and 0.28% Mn 0.018% as well as Mg enable to obtain material, which from of: UTS, YTS, A₅ and hardness HB can be classified as a cast iron of 16112/JV/400/S Grade.

Acknowledgements

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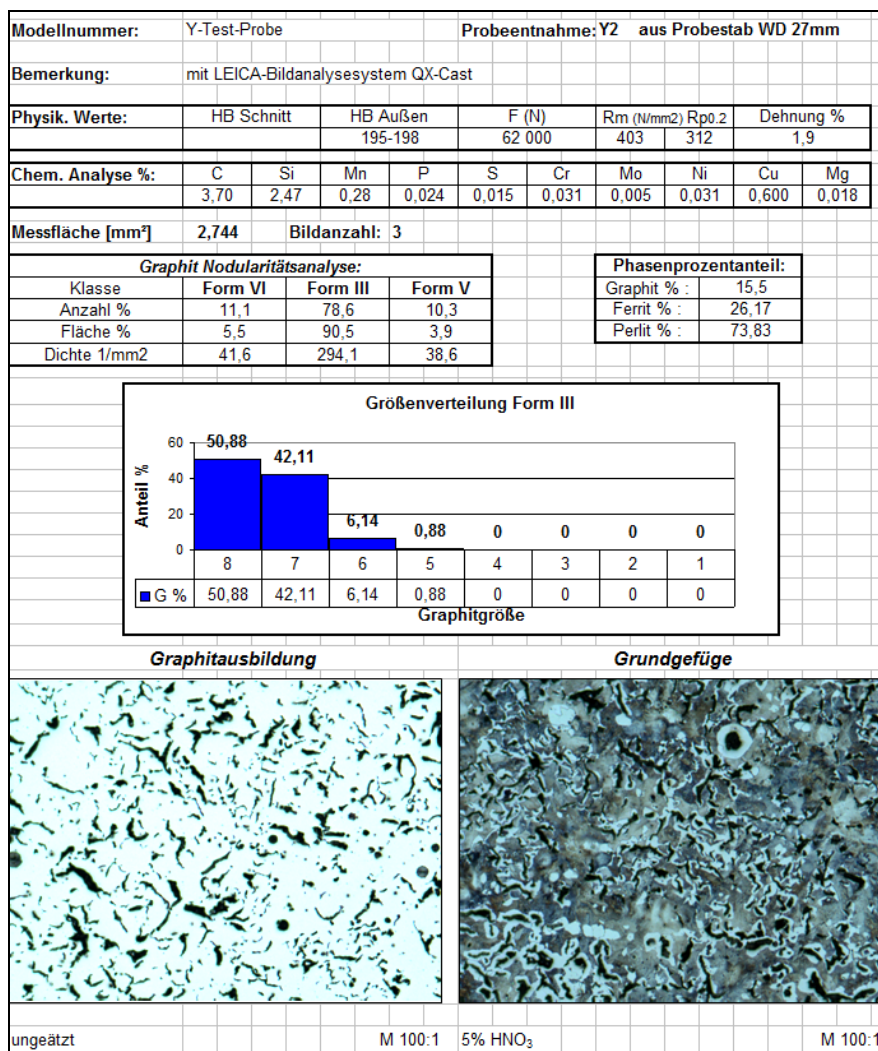


Fig. 5. Printout of report (Giesserei H. GmbH) with a microstructure and properties 16112/JV/400/S (GJV- 400) Grade cast iron results

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