Application of cored wire injection method to the producing of vermicular cast iron

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Abstract

The results of studies on the use of magnesium alloy in modern cored wire injection method for production of vermicular graphite cast iron 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 (Mg recovery 45\%) for the production of vermicular graphite cast irons at Giesserei Heunisch GmbH Foundry. 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 cored wire process can produce high quality vermicular graphite irons under the specific industrial conditions of the above mentioned foundries.

Keywords: vermicular cast iron, PE method, cored wire, air conditioner box

1. Introduction

Although vermicular graphite iron (VGI) has existed for more than 20 years, its applications have been limited to simple, low-volume components with wide microstructural tolerances, pump housings, brackets, box, car engine blocks, etc. Cast iron with vermicular graphite is not included into any national standards, but there is an American standard ASTM A842-85 from 1985, revised and updated in 1991, which quotes 5 grades of this cast iron characterised by minimum values of UTS equal to: 250, 300, 350, 400 and 450 MPa, and minimum values of elongation $A_{3}$ equal to: 3; 1.5; 1.1 and 1%, respectively. According to the guidelines elaborated by the German Foundrymen Association (Verein Deutscher Giessereifachleute), five grades of this cast iron are distinguished and designated by appropriate symbols: EN-GJV- 300, 350, 400, 450 and 500, characterised by minimum values of UTS amounting to: 300, 350, 400, 450 and 500, respectively, and by elongation of 1.5-0.5\% \cite{1}. 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 ferrite 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 below (for the sake of clarity the following designations have been used: FG, NG and VG for inoculated, ductile and vermicular cast irons, respectively) \cite{1}:

- Tensile strength UTS – FG, VG, NG;
- Elongation (plastic properties) A – FG, VG, NG;
- Proof stress 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.

Notwithstanding its undeniable advantages, the cast iron with vermicular graphite (also called „compacted” graphite in American literature) 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. A comparison between the cast iron with vermicular graphite and that with nodular graphite gives just opposite results.

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

Another important aspect of this vermicularisation treatment and applications of vermicular cast iron for air conditioner box.

2. Cored Wire- production of vermicular cast iron and method of investigation

An important stage in the production of high-quality vermicular cast iron is its treatment with different method, e.g. with magnesium COMPACTMAG, FeSiMgTi master alloys. Full success has already been achieved in this respect as regards the implementation into industrial practice of various techniques of introducing the reagents into molten iron, either in bells made from different materials, or by pouring the reagents placed on the bottom of a ladle (Sandwich or Tundish process) or directly in mould (Inmold process). In Poland, in 1995, for the first time a most modern and fully mechanised technique of the nodularising or vermicularising treatment of cast iron by means an elastic cored wire (PE – Fig. 2), known also under the name of “Cored Wire Injection Method”, was mastered [1]. As a result of joint efforts with active participation of the Ferro-Term Łódż, this technique has been implemented in several domestic foundries. From practical experience it follows that both the PE and 2PE techniques (using two elastic wires – one cored with magnesium, and another with inoculant) ensure low manufacturing costs and stabilization of magnesium content at a level of about 0,04%, necessary to obtain nodular graphite, and at a level of 0,015-0,02% Mg, necessary to obtain vermicular graphite. Changing of magnesium level in cast iron is very easy; it is just enough to change the time of feeding the wire on a roller conveyor (at a constant feeding rate). This solution effectively eliminates the time- and labour-consuming operation of repeated weighing of the individual batches of the nodulariser and inoculant, typical of other techniques of the nodularisation and inoculation.

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

![Fig. 2. Schematic representation of the cored wire treatment (PE method): 1 – ladle with liquid metal, 2 – cover (lid), 3 – wire feed machine, 4 – coil (basket) with cored wire, 5 – set up with electrical control cabinet, 6 – exhaust](image)

Over the past 13 years, the PE technique of the cast iron treatment has roused vivid interest of the Polish foundry industry and has been implemented, among others, in several domestic foundries, the Department of Alloys and Composites Casts Engineering at the (AGH) University of Science and Technology being responsible for implementation of this process in at least 13 foundries [1].

The following formula is used as a main tool for calculation of the wire length injected to metal and magnesium recovery:

\[
L = \frac{(0.76 \cdot \Delta S + M_{GP}) \cdot m}{\eta_{Mz} \cdot M_{GP}}
\]

where:

\[
\Delta S = S_1 - S_2 \text{ is the difference between sulfur content before and after treatment, wt%};
\]

\[
\eta_{Mz} - \text{is magnesium addition for VGI: 0.015-0.02, wt%};
\]

\[
M_z - \text{is the cast iron volume, kg};
\]

\[
M_{GP} - \text{is magnesium content in 1 metre of the cored wire, kg/m, 0.76 - is the coefficient of sulfur and magnesium count, at%}.\]

Melts of the cast iron with vermicular graphite were conducted at the Giesserei Heinisch GmbH, Bad Windsheim-Germany 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 1450-1470°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 VL(Ce) master alloy and flexible wire (technique is described in literature as a PE method). In this particular case, the treatment was carried out by means of a flexible wire with magnesium core SKW Trostberg; 120g Si/m, 64g Mg/m and to 2%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 inoculants FeSi75(Ca,Al) and SRF75 (FeSiCaAlSr). 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 casting (11-32mm), standard “Y2” keel blocks on the formation of microstructure and vermicular graphite precipitates in function of the cooling rate. The examinations were made under the Leica MEF-4M optical microscope and under the Scanning Electron Microscope Joel.

3. Results and analysis

The cast iron with vermicular graphite is a material suitable for cylinder heads operating in high-capacity diesel engines, and at present it is used, among others, for the above mentioned cast parts of engines operating in motor cars. Until now, at the Giesserei Hennisch GmbH-Bad Windsheim, Germany the for air conditioner box castings (Fig. 3) have been made from the vermicular cast iron, grade GJV-300.

Comparing the results of mechanical tests obtained „Y2” keel blocks, in wall casting 11-35mm in cast box obtained properties and some similarities that prevail in both cases, one can observe that the obtained properties are grouped in certain ranges of values reflected in the utilization properties of casting. This is shown on a schematic diagram below giving the ranges of values obtained on the castings (Table 1).

Table 1. Results of tensile properties of (VGI) cast iron

<table>
<thead>
<tr>
<th>Y2” keel block standard</th>
<th>Wall casting 11 – 25mm</th>
<th>Wall casting 32mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>JTS=370-390MPa</td>
<td>JTS=315-323 MPa</td>
<td>UTS=325-330 MPa</td>
</tr>
<tr>
<td>UTS=245-295 MPa</td>
<td>YTS=237-245 MPa</td>
<td>YTS=240-248MPa</td>
</tr>
<tr>
<td>A5 = 4.0 – 4.4 %</td>
<td>A5 = 4.0 – 5.2 %</td>
<td>A5 = 3.9 – 5.7 %</td>
</tr>
<tr>
<td>HB = 162 -170</td>
<td>HB = 155 -166</td>
<td>HB = 150 -155</td>
</tr>
</tbody>
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Compared with other techniques, the method of vermicularising treatment by the technique of PE offers the following advantages: it ensures process stability expressed by target magnesium content in cast iron of and 0.015-0.02% Mg range for vermicular graphite (Fig. 4).

The metallic matrix of the air conditioner box in as cast condition is about 90% ferrite + 10% pearlite. The size vermicular and nodular (up to 20% volume content permitted) graphite precipitates in structure as illustrated in Figure 5.

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 method of PE 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 air conditioner box castings from quality vermicular cast iron.
2. An important technological parameter of the PE technique, determining essentially the length of the cored wire injected to molten metal and the cost of the treatment, is the level of magnesium recovery used expressed by equation (1), which depends on the technical conditions of the equipment designed and actually used by the foundry for this purpose.

References


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Fig. 4. The change of magnesium content in cast iron in the case of vermicularising treatment carried out with cored wire

a)

b)

c)

d)

Fig. 5. Microstructure of cast iron with precipitates of vermicular graphite and traces of nodular graphite (a-c), b and c – etching. A JOEL-SEM photograph; specimen after deep etching (d)