Analysis of quality and cost of FeSiMg treatment master alloy vs. cored wire in production of ductile cast iron

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Abstract

The results of studies on the use of FeSi5%Mg magnesium alloy in modern cored wire injection method for production of nodular and 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 (Mg recovery 47-70%) for the production of vermicular and nodular graphite cast irons at in at least 13 foundries. 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 results of numerous trials have shown that the magnesium cored wire process can produce high quality nodular and vermicular graphite irons under the specific industrial conditions of the above mentioned foundries. It has also been proved that in the manufacture of nodular graphite iron, the cost of the nodulariser in the form of elastic cored wire is lower than the cost of the FeSiMg5 master alloys.

Keywords: Ductile cast iron; Vericular cast iron; PE Method; Nodular graphite; Costs; Cored wire.

1. Introduction

An important stage in the productions of high-quality ductile iron and vermicular cast iron are treatment with different vermic- nodularisers, e.g. with magnesium or with the FeSiMg 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. 1), known also under the name of "Cored Wire Injection Method", was mastered [1,2]. As a result of joint efforts with active participation of the Ferro-Term Lódz, 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.

\[ M_{\text{g,d}} = \frac{M_{\text{g,kr}} + 0.75(S_1 - S_2)}{M_{\text{g,uzysk}}} \% \]  

where:
- \( S_1 - S_2 \) – the sulphur content in cast iron before and after treatment, respectively, wt.%;
- \( M_{\text{g,kr}} \) – the residual magnesium, 0.045 wt%;
- 0.75 - is the coefficient of sulfur and magnesium count., at %;
- \( M_{\text{g,uzysk}} \) - is magnesium addition, %.

- the following formula is used as a main tool for calculation of the wire length and magnesium recovery:

\[ L = \frac{(0.76 \cdot \Delta S + M_{\text{g,d}}) \cdot M_z}{\eta_{\text{mg}} \cdot M_{\text{g,p}}} \cdot m \]  

where:
- \( \Delta S = S_1 - S_2 \) is the difference between sulphur content before and after treatment, wt %;
- \( \eta_{\text{mg}} \) – is magnesium addition, %;
- \( M_z \) – is the cast iron volume, kg;
- \( M_{\text{g,p}} \) – is magnesium content in 1metre of the cored wire, kg/m,
- 0.76 – is the coefficient of sulphur and magnesium count, at%.

Another important aspect of this nodularising treatment is without any doubt the very encouraging cost of the nodulariser, and therefore the aim of this study has been an assessment of the cost of the FeSiMg5% as compared with the nodularisers used in the form of cored wire.

2. Cored Wire- production of cast iron

At the Foundrys of Drawski Młyn and “WSK–Rzeszów” Metallurgical Plant in Rzeszów, a special technique of the nodularising (or vermicularising) treatment was implemented. It was based on the use of cored wires, one cored with magnesium, and another with inoculant.

Compared with other techniques, the method of vermicularising or nodularising treatment by the technique of PE offers the following advantages:

a) it enables both nodularising as well as vermicularising of cast iron;
b) it ensures process stability expressed by target magnesium content in cast iron of 0.04-0.05% Mg for nodular graphite) and 0.015-0.02% for vermicular graphite (see in Fig. 2);
c) it ensures safe work conditions in foundry (no dust and metal “splashes” from the treatment ladle);
d) it enables production of ductile iron from the cupola-melted metal which, compared with the iron melted in electric furnaces, has high sulfur levels caused by the presence of coke;
e) it ensures process flexibility under variable initial parameters, like sulfur content in base iron, and temperature and weight of molten metal;
f) it enables collecting and storing the data in the computer of control device.
3. Cored Wire- comparison against traditional treatment methods of nodularisation

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. Practical application under industrial conditions of the “WSK- Rzeszów” Metallurgical Plant and Drawski Mlyn Fauntery of cored wires - one with magnesium.

Metallographic examinations of specimens taken from ductile iron castings made by the technique of FeSiMg5% master alloy and by the Cored Wire Injection Process have proved that the latter technique produces of the ductile iron grade EN-GJS-500-7; in the structure of castings higher count of graphite nodules of a regular shape and type “VI" according to EN-ISO 945 (Fig. 3).

It is worth noting that many domestic foundries have implemented within their own capacity the above mentioned PE technique for cast iron treatment, e.g. the well-known foundries of Srem and Kuznia Raciborska.

The cost of ductile iron production with:
1. FeSi5%Mg master alloy,
2. PE technique (a horizontal design of the PE wire spool- PE cored wire at the foundry)

The cost of ductile iron in the weight 800kg production with FeSi5%Mg master alloy:

- "light" type master alloy –FeSiMg5% (type VL 63M):
- price - 5.35 zl/1kg;
This technique has been used for both cupola- and electric vermicularising treatment of cast iron using special cored wire. The consumption rate of the cored wire was established allowing for the sulfur content in base iron. The said technique of the cored wire can be successfully used in many domestic foundries. It ensures the health and safety conditions during nodularising and vermicularising treatment of cast iron in accordance with the prescribed rules along with the required target content of magnesium. The technical and technological conditions of the treatment which should be satisfied have been highlighted.

**4. Summary**

The present study describes the method of nodularising or vermicularising treatment of cast iron using special cored wire. This technique has been used for both cupola- and electric furnace-melted iron in numerous domestic foundries, e.g. Ścinawka Średnia GZUT, Centrozap - DEFKA, EE Zawiercie, WSK- Rzeszów and PIOMA. The consumption rate of the cored wire was established allowing for the sulfur content in base iron and the weight of the cast iron batch to be treated. The said technique of the cored wire can be successfully used in many other domestic foundries. It ensures the health and safety conditions during nodularising and vermicularising treatment of cast iron in accordance with the prescribed rules along with the required target content of magnesium. The technical and technological conditions of the treatment which should be satisfied have been highlighted.

From observations of the nodularising treatment of cast iron carried out by the method of PE under the conditions of domestic foundries 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 nodular and/or vermicular graphite iron. Long-lasting experience gained during work in industry clearly indicates that the elegant and efficient techniques of PE is fully reliable and guarantee making castings from the nodular and vermicular graphite irons characterised by stable properties, consistent with and satisfying the most modern European standards. Both these techniques are equally suitable for the treatment of iron melted in electric furnaces and/or cupolas, an additional advantage in the latter case being the possibility of eliminating the additional process of desulphurising-often indispensable when other methods of the nodularising treatment are used.

It has been proved that the cored wire is very competitively priced, if compared with both types of the master alloys, specially with the imported "light" type of FeSi5%Mg master alloy. Compared to the cast iron treatment using master alloys, the operation of cast iron nodularising by PE technique is additionally very promising since it provides safe operating conditions, enables stabilisation of magnesium content during nodularising and ensures a regular shape of graphite nodules in the cast iron microstructure.

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 \( \eta_{Mg} \) expressed by equation (2), which depends on the technical conditions of the equipment designed and actually used by the foundry for this purpose. Due to the conducted investigations it has been possible to determine the level of magnesium recovery \( \eta_{Mg} \) in PE technique, which is in the range of 35-60% [3] and depends on the weight of molten metal batch to be treated and on the height of its column in foundry ladle.

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**References**

