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Cast iron spheroidization by plunging method and cored wire method

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Abstract

Changes in chemical composition and the degree of magnesium assimilation resulting from the performed treatment have been determined basing on data coming from 185 courses of cast iron treatment by plunging or cored wire methods. The investigations have dealt with nodular iron of EN-GJS-400-18-LT and EN-GJS-500-7 grades. In the case of plunging method cast iron has been treated with VL53M master alloy containing about 9% of magnesium; for cored wire method the magnesium content in the master alloy has been about 17%. It has been stated, among others, that the carbon content has been reduced due to spheroidizing treatment by 0.12÷0.30% as an average. Distinctly higher magnesium assimilation (at the level of 41÷44%) has been stated for plunging method, while for cored wire method it has been found to vary from 29% to 31% as an average.

Keywords: Cast iron, Spheroidization, Plunging method, Cored wire method

1. Introduction

One of the casting alloys which gains more and more interest in the world, also in recent years, is nodular iron. Its contribution to the total casting production in our country has reached 14% in the year 2005 [1], and the volume of production has been equal to 112,000 tons and over 129,000 tons in years 2005 and 2006, respectively [2].

Production of nodular cast iron consists of three basic stages:

- casting of basic cast iron with proper chemical composition, characterised by the high graphitization ability. This is provided by appropriate high content of carbon and silicon [3]. The cast iron cannot contain elements opposing the crystallization of nodular graphite (the so-called anti-spheroidizing elements) in amounts exceeding the determined limits [4];
- introducing the spheroidizing agent into the molten metal. Most often magnesium or its carriers in the form of various alloys are used for this purpose. Rare earth elements are applied more seldom e.g. in the form of cerium mixture containing mainly cerium (50% - 55%) and then lanthanum, neodymium, and praseodymium;
- subjecting of cast iron to graphitizing modification directly after the spheroidizing, e.g. with ferrosilicon or calcium silicon with small additions of other elements.

Spheroidization of cast iron with use of cerium mixture does not involve particular technological problems due to the low melting point (ca 850ºC) and high boiling point (ca 2600ºC) of this alloy [5].

The most difficult operation during the cast iron spheroidization with magnesium is introducing this metal or its alloys to the melt. This is caused by a large density difference between cast iron (about 7 g/cm^3) and magnesium (about 1.7 g/cm^3) what leads to floating of magnesium master alloy to the melt surface for many magnesium carriers. Also the relatively low melting and boiling points of magnesium, equal to 651ºC and 1107ºC, respectively, are very unfavourable as far as its contact with molten cast iron is concerned. A pyrotechnic effect occurs during the treatment, accompanied by melt boiling, metal flashes, and a large emission of smoke.

Many ways of introducing magnesium or magnesium-containing master alloys into cast iron have been developed [5-7]. Besides pouring the cast iron over the alloy master put at the bottom of the ladle, the most popular method in our domestic conditions has been introducing metal rods containing magnesium into a sealed ladle (the JPK method) and plunging method.

In the middle of nineties of XX century the cored wire method was first applied in Poland for introducing magnesium into cast iron. This method consists in introducing the spheroidizing master alloy into the molten cast iron in a special 'casing' - a thin-walled steel pipe. This pipe filled with master alloy containing magnesium is passed into the ladle by special feed rolls. The rate of feeding has to be selected in such a way that the dissolving of the pipe would occur near the ladle bottom and the release of spheroidizing master alloy would take place in that region.

2. Authors' investigations

The investigations have been aimed to compare the spheroidizing processes performed by plunging and cored wire methods in respect of magnesium assimilation. The schemes of both spheroidization methods are shown in Fig. 1.

a) b)

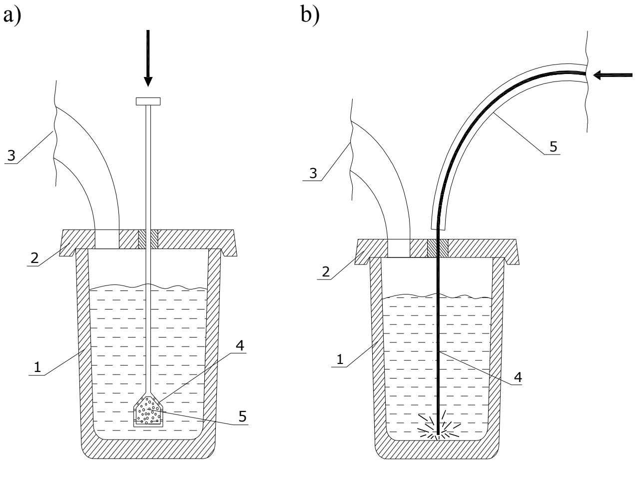

Fig. 1. Scheme of introducing magnesium into cast iron a) plunging method: 1 – ladle containing molten cast iron; 2 – cover; 3 – gas exhauster; 4 – plunger; 5 – magnesium master alloy; b) cored wire method: 1 – ladle containing molten cast iron; 2 – cover; 3 – gas exhauster; 4 – cored wire (introducing magnesium master alloy into the cast iron); 5 – feed rolls nozzle

The nodular cast iron of EN-GJS-400-18-LT and EN-GJS-500-7 grades (according to the [8] Standard), produced by one of Polish foundries, has been examined.

The first of mentioned cast iron grades is characterised by relatively high plastic properties. It should be mentioned that the impact resistance significantly depends from the place of sample taking, both for ferritic and ferritic-pearlitic cast iron [9, 10]. The tensile strength of EN-GJS-500-7 grade cast iron can reach 730 MPa [11], and the EN-GJS-400-18-LT grade – 460 Mpa [12].

The basic cast iron has been heated in medium-frequency induction crucible furnace of 2.5 Mg capacity with acid lining.

Spheroidizing by plunging method has been performed using the master alloy of VL53M trade name. It has contained basic elements in the following amounts: Si = 44%; Mg = 9%; Ca = 1,9%; Ce = 0,7%, Fe – the rest. In the case of cored wire method, the magnesium fraction in the spheroidizing master alloy has reached 17.10%, silicon content has been 27,89%, rare earth metals 0,53%, and the rest consisted of iron. The spheroidization process for this case has been volcanic, with numerous metal flashes and a large emission of smoke.

After spheroidizing treatment (no matter the method) cast iron has been subjected to graphitization by the in-stream method, using Inogen 75 or SMZ 25, as well as Inocullin 390 inoculants. The investigations extended over 185 processes of cast iron heating.

Table 1 presents contents of basic elements occurring both in the initial and in the spheroidized and graphitised alloy in respect to EN-GJS-400-18-LT cast iron, separately for the cast iron spheroidized by plunging method and by cored wire method.

Table 1. Data concerning production of EN-GJS-400-18-LT cast iron. Percentage of basic elements in the initial alloy and in the alloy spheroidized with plunging or cored wire method

Element	Content in cast iron, %			
	Initial cast iron		Cast iron after spheroidization and graphitization process	
	Range from - to	Average	Range from - to	Average
Plunging method				
Carbon	3.54 – 4.12	3.848	3.22 – 3.84	3.577
Silicon	0.96 – 1.55	1.142	2.00 – 2.67	2.279
Manganese	0.07 – 0.15	0.096	0.09 – 0.16	0.115
Phosphor	0.03 – 0.04	0.035	0.03 – 0.041	0.035
Sulphur	0.010 – 0.023	0.0169	0.008 – 0.016	0.0102
Cored wire method				
Carbon	3.48 – 4.08	3.779	3.36 – 3.98	3.660
Silicon	1.05 – 1.69	1.433	1.81 – 2.47	2.096
Manganese	0.07 – 0.18	0.116	0.08 – 0.19	0.126
Phosphor	0.025 – 0.052	0.035	0.026 – 0.048	0.035
Sulphur	0.012 – 0.034	0.0207	0.006 – 0.016	0.0097

Similar data, referring to EN-GJS-500-7 cast iron, are gathered in Table 2.

Comparing chemical compositions of cast iron before and after the spheroidization process presented in Tables 1-2 one can see distinct differences in contents of two basic elements occurring in cast iron, i.e. carbon and silicon.

Table 2. Data concerning production of EN-GJS-500-7 cast iron. Percentage of basic elements in the initial alloy and in the alloy spheroidized with plunging or cored wire method

Element	Content in cast iron, %			
	Initial cast iron		Cast iron after spheroidization and graphitization process	
	Range from - to	Average	Range from - to	Average
Plunging method				
Carbon	3.30 – 4.04	3.785	3.07 – 3.74	3.50
Silicon	1.50 – 1.66	1.584	2.51 – 2.88	2.70
Manganese	0.26 – 0.42	0.346	0.31 – 0.41	0.36
Phosphor	0.039 – 0.055	0.045	0.034 – 0.054	0.044
Sulphur	0.015 – 0.037	0.0257	0.008 – 0.017	0.0116
Cored wire method				
Carbon	3.45 – 4.23	3.80	3.06 – 3.82	3.50
Silicon	1.43 – 2.07	1.85	2.40 – 2.86	2.58
Manganese	0.23 – 0.42	0.33	0.25 – 0.41	0.35
Phosphor	0.035 – 0.057	0.046	0.032 – 0.057	0.045
Sulphur	0.015 – 0.034	0.0248	0.005 – 0.015	0.0112

Carbon. There is a distinct tendency of this element to decrease its content as a result of the performed treatment. The carbon content has been reduced as an average by 0.12% for the EN-GJS-400-18-LT grade cast iron spheroidized by cored wire method and by 0.27% - 0.30% in other cases.

Silicon. An increase of this element in cast iron after treatment (as compared with its content in initial cast iron) has resulted from introducing it to the alloy both by spheroidizing master alloy and by nodulizers. A more precise calculations concerning the balance of silicon content (this paper does not quotes the pertinent data) has shown that its content in the cast iron after treatment has been lower as an average by 0.08% (ranging from 0.03% to 0.19%) than the 'theoretical' content determined via calculations.

The spheroidization has been performed in the so-called slender ladle with acid lining; after these treatment cast iron has been transferred into pouring ladle of similar lining. Therefore a little increase of silicon content in cast iron could be expected. The analysis of chemical composition has revealed however that the relatively small melting loss has predominated.

Significantly less differences (or no difference at all) occur in content of other elements in cast iron before and after the treatment.

Manganese. A small increase in content of manganese in cast iron (up to 0.02%) has been probably caused by 'passing' of these element from the ladle lining into the melt. Ladles used for the examined production have been formerly used for the treatment of cast iron of higher manganese content.

Phosphor. The amount of this element stays practically at the same level of 0.03% - 0.05%, as it has been expected.

Sulphur. The drop in sulphur content is a result of performed treatment – mainly the desulphurizing influence of magnesium. The resulting sulphur content has been equal to 0.01%.

A very important factor for the assessment of spheroidization process is the degree of magnesium assimilation by the treated cast iron (called also the yield of magnesium). It is a proportion between the amount of magnesium remaining in the alloy and the total amount of magnesium introduced to the cast iron during its treatment. The direct data concerning the discussed parameter are presented in Table 3.

Table 3. Data concerning the degree of magnesium assimilation during cast iron spheroidization

Cast iron	Yield of magnesium, %			
	Plunging method		Cored wire method	
	Range from - to	Average	Range from - to	Average
EN-GJS-400-18-LT	35.8 – 55.5	43.81	22.2 – 45.6	30.94
EN-GJS-500-7	26.1 – 50.6	40.87	19.5 – 41.6	29.39

Figures 2 and 3 show the dependence between the degree of magnesium assimilation and the temperature of cast iron spheroidization for both discussed methods and for both EN-GJS-400-18-LT and EN-GJS-500-7 grades of cast iron, respectively.

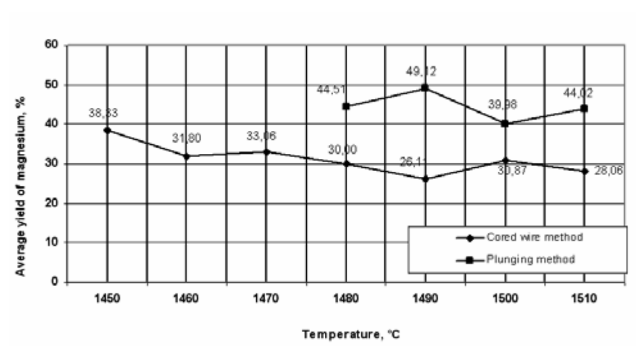

Fig. 2. Yield of magnesium versus spheroidization temperature of EN-GJS-400-18-LT cast iron grade by plunging method and by cored wire method

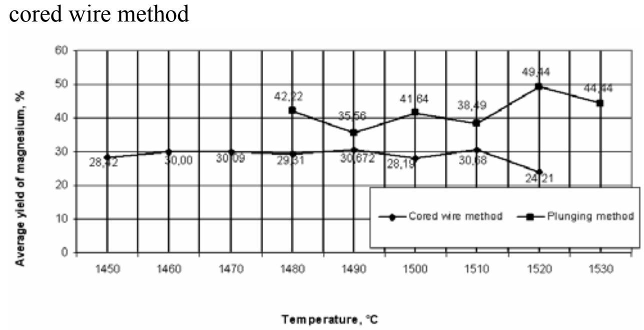

Fig. 3. Yield of magnesium versus spheroidization temperature of EN-GJS-500-7 cast iron grade by plunging method and by cored wire method

It is obvious from the data quoted in Table 3 and shown in Figs 2 and 3 that the higher magnesium assimilation (at the level of 41% - 44%) occurs for spheroidization by plunging method. Its values are very close to that stated in Ref. [13]. The yield of magnesium reached only 29%-31% as an average for the case of cored wire method. Large discrepancy between individual results can be stated for the degree of magnesium assimilation in both methods; the difference between maximum and minimum yield of magnesium usually have exceeded 20% (see data in Table 3). Perhaps the lower magnesium yield for the spheroidization performed by cored wire method has been connected with the higher magnesium content in the master alloy used for this process. It has been equal there to 17.10%, while the pertinent value for master alloy introduced by plunging method is lower nearly by half. No distinct relationship between the yield of magnesium and the temperature of spheroidization has been stated for the case of plunging method. However as far as cored wire method is concerned, a certain tendency towards the reduction of the yield of magnesium with the temperature rise can be distinguished (see Figs 2 and 3).

The slightly lower – for both methods - yields of magnesium during spheroidization process while producing EN-GJS-500-7 grade alloy as compared with EN-GJS-400-18-LT grade should have been probably attributed to the little higher sulphur content in the initial cast iron for the first case (compare data in Table 3 and in Tables 1-2).

3. Conclusion

A decrease in carbon content in the treated alloy (averagely in the range between 0.12% to 0.3%) takes place as a result of spheroidization for both methods. Rather little melting loss occurs for silicon. The content of other elements, except sulphur, practically stays unchanged.

The plunging method is characterised by distinctly higher yield of magnesium (at the level of 41% - 44%) as compared withcored wire method, for which the yield of magnesium has been equal to about 30%.

Significant divergences (even exceeding 20%) can be stated for both methods in relation to the degree of magnesium assimilation. It seems that the distinct decrease in the yield of magnesium with an increase in the temperature of spheroidization can be spoken about only for the case of cored wire method.

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