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EFFECT OF INOCULANT INTRODUCING ON IMPROVING INGOT STRUCTURE

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The paper deals with the inoculant–freigrator effect on some parameters of the structure: grain size and contamination index. The "beads" extracted from steelmaking slags were used as the inoculant. The effect of the fractional composition and the number of introduced "beads" were investigated. The "beads" were preliminarily crushed to the fraction of 100 – 1 500 µm and were introduced into the melt in the amount of 0,5 – 1,5 % by mass. It was established that the introduction of the "beads" of the fraction of 500 – 600 microns in the amount of 1 – 1,5 % as the inoculant contributed to the grinding of grain, reduced the tendency to segregation and dendre formation.

Key words: steel ingot, melt, structure, grain size, inoculant

INTRODUCTION

Inoculants are substances that are introduced into the melt to change the structure or adjust the composition. Various substances are used as inoculants: powders of metals and alloys, cast shot of a complex composition, waste of metallurgical production (chips, metal-containing part of slags, etc.). Depending on the purpose of the inoculant, its content in the mass of the ingot can vary in a wide range: from fractions of a percent (microalloying, modifying, micro-coolers, etc.) to 50 – 75 % if the inoculant is introduced as a reinforcing material.

The use of inoculants to improve the structure of the ingot is considered in sufficient detail in works [1-4].

The greatest effect on the process of structure formation is exerted by inoculants- modifiers for grinding grain and inoculants-freigrators for improving and intensifying heat exchange processes in the liquid melt. The input quantity ranges from 0,01 to 0,5 % and 0,5 to 10 %, respectively [3-6].

In a number of works [2, 7–11] it is noted that introducing the metal-containing part after slag processing improves heat exchange, removes overheating, increases the number of primary crystallization centers, reduces segregation, thereby contributing to the formation of a more homogeneous structure.

EXPERIMENTAL STUDIES

Equipment and tools

In this work the metal-containing part of the foundry slag was used after smelting medium-carbon steels in the arc steel furnace (ASF)-400. The slag sample was crushed, then grinded in a ball mill to the 500 µm fraction content at least 40 %. After grinding the slag sample was exposed to the magnetic field to extract the metal-containing part.

The chemical composition of the slag and the resulting fraction was determined using the DFS-71 spectrometer. The results are presented in Table 1.

Table 1 **Chemical composition of the slag metal-containing part / mass. %**

C	Cr	Mn	Si	Fe
0,27 – 0,29	1,12 – 1,3	0,94 – 1,3	1,1 – 1,33	rem.

Them the metallic fraction was subjected to the fractional analysis using the AS 200 analytical screening machine. The results are presented in Figure 1.

The first stage of the study was studying the effect of the fractional composition of the inoculant introduced on the parameters of the ingot structure after crystalliza-

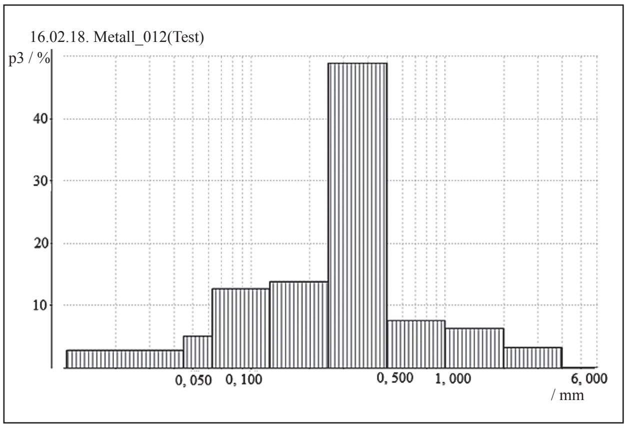

Figure 1 The results of the slag metal-containing part fractional analysis

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tion. The experiment was carried out as follows. The 30HGSNMA steel melt was poured into the СЬС crucible with the 3 liters capacity, the inoculant was introduced into the melt using a special device that allows introducing the inoculant into the depth of the melt under pressure. The metal-containing part of the slag of different fractional composition was used as the inoculant. The amount of the inoculant was 0,5 % by weight of the ingot. After complete crystallization and cooling metallographic thin sections were made from the ingot, on which the microstructure was studied. The results are presented in Table 2, and eg. (1)

Table 2 **The inoculant fractional composition effect on the ingot structure parameters**

Number of the vibration mode	Fraction / µm	Grain average diameter / mm	Contamination index
0	-	0,075	1,89
11	1 500	0,069	3,21
12	1 000	0,065	3,09
13	800	0,053	1,86
14	500	0,040	1,37
15	200	0,039	1,48
16	100	0,041	2,73

$$I = \frac{b\sum a_i \cdot m_i}{l}, \ldots \qquad (1)$$

l is the length of counting in µm where b is the ocular scale division value at the given magnification in µm;

a_i is the average size of inclusions in the ocular scale divisions;

m_i is the number of inclusions of the given group;

The contamination index was determined not only for non-metallic inclusions, but mainly for the presence of undissolved inoculants in the melt during the crystallization process. Presumably, large-sized inoculants may not have time to dissolve in the melt during the crystallization process therefore, when introduced into the melt, their fraction must be reduced. The analysis of metallographic thin sections confirmed the correctness of this assumption. Figure 2 shows the inclusion: an undissolved “bead” in the structure; it is obvious that the contamination index increases as a result.

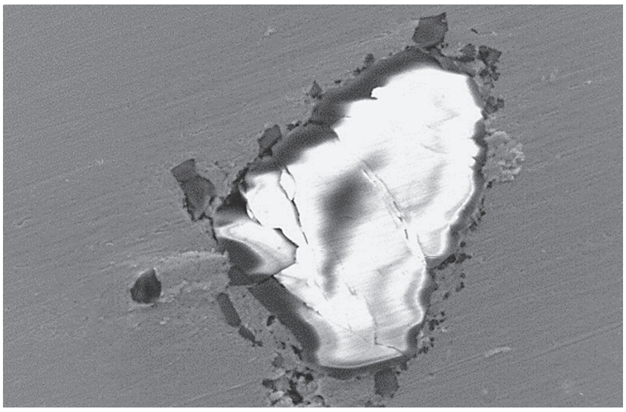

Figure 2 Presence of the undissolved inoculant in the structure × 1 500

It can be seen from the data of Table 2 that introducing the inoculant increases dramatically the contamination index. However, it seems that this process is connected not with the formation of new non-metallic inclusions but with the presence of undissolved particles of the inoculant in the structure. By reducing the size of the inoculum to 800 µm the contamination index becomes comparable to the standard, with further decreasing the inoculant dispersion to 500 µm the contamination index decreases by almost 30 %. Decreasing the pollution index with introducing the inoculant fraction of 500 – 800 µm can be explained by the positive effect of the inoculant on the crystallization process as a whole. Introducing the inoculant reduces the temperature of the melt, removes overheating, improves heat transfer. The latter circumstance in turn reduces the tendency to segregation and leads to the redistribution of non-metallic inclusions.

However, decreasing the inoculant dispersion to 100 µm leads again to increasing the contamination index (Figure 3). This is apparently explained by the fact that with a high dispersion, the inoculant tends to stick together and form aggregates, the size of which considerably exceeds the expected particle size. As a result, the inoculant does not completely dissolve, the contamination index rises.

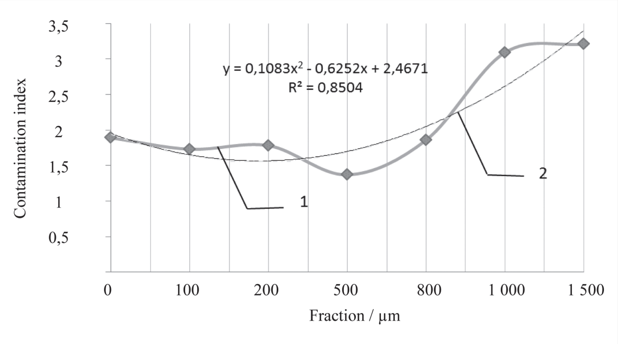

Figure 3 Inoculant dispersion effect on the contamination index. 1 – theoretics; 2 – experimental.

The analysis of the data in Table 2 shows that introducing the inoculant helps to reduce the grain size, regardless of the fraction of the inoculant. With introducing a large fraction (1 500 µm), the average grain size remains almost unchanged and remains at the level of the standard. However, with reducing the fraction to 800 µm, the average grain size decreases by more than 30%. This trend continues with further decreasing the particle size of the inoculant. However, by reducing the particle size to 100 microns, the average grain size increases slightly. This is apparently explained by the same phenomenon as increasing the contamination index, i.e. the formation of inoculant aggregates due to adhesion (Figure 4).

Thus, reducing the inoculant particle size to smaller than 200 microns seems impractical, leading to the formation of insoluble aggregates of the inoculant that in-

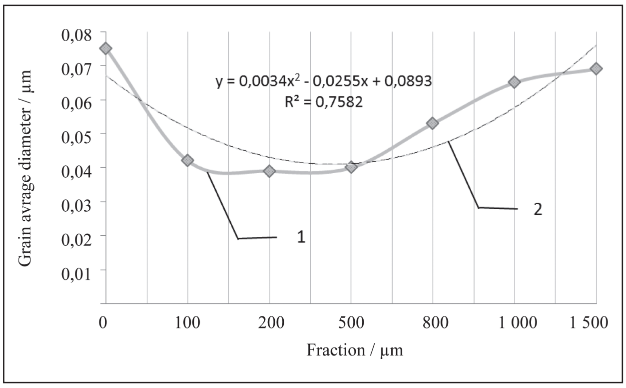

Figure 4 Inoculant dispersion effect on the grain average size. 1 – theoretics; 2 – experimental.

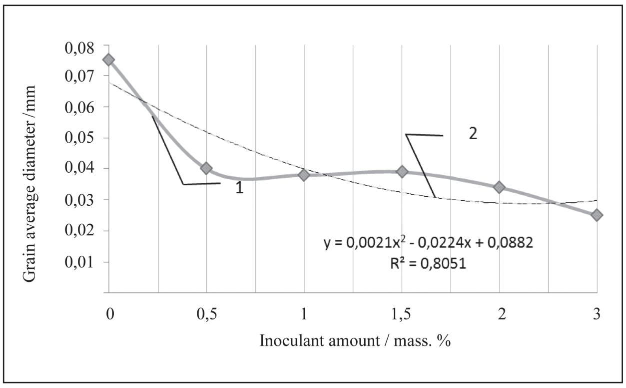

Figure 5 Inoculant amount effect on the grain average size. 1 – theoretics; 2 – experimental.

crease the contamination index and act as additional stress concentrators, which leads to decreasing strength properties. Thus, the optimal particle size of the inoculant to be injected should be considered in the range of 800 - 500 microns. These data are somewhat at variance with the data of [4] and [5]. In one case the optimal size of the inoculant is considered to be 1 – 60 mm, in the other case the inoculant is introduced in the form of nanopowders with the fraction size smaller than 50 µm. In the first case low carbon steels were used as inoculants, in the second case high-temperature oxides of ZrO_2 type, etc. This discrepancy is one more confirmation of the fact that there is no the universal recommendation for dispersion and the inoculant amount, in each individual case these parameters are to be determined individually depending on the melt and the nature of the inoculant.

The second stage of the study was studying the effect of the inoculant amount on the crystallization process and structure parameters. There was used the same inoculant of the 500 microns fraction to be introduced. The number of inoculant varied in the range from 0,5 to 3 % by weight of the ingot. In addition to the parameters of the structure, the temperature of the melt was also controlled. The temperature control was carried out using the GM1650 pyrometer with the measurement accuracy 1,50. The results of the experiment are presented in Table 3.

Table 3 **The effect of the inoculant amount on the structure parameters and temperature of the melt**

Mode number	Inoculant amount, mass / %	Grain average diameter / mm	Melt temperature / ⁰C
0	-	0,075	1 567
17	0,5	0,040	1 546
18	1	0,038	1 532
19	1,5	0,039	1 512
20	2	0,034	1 501
21	3	0,025	1 486

It can be seen from the data of Table 3 that introducing the inoculant in an amount of 0,5 – 3 % by weight reduces the grain size in the entire investigated range, which should have a positive effect on increasing surface hardness (Figure 5).

However, increasing the inoculant amount leads at the same time to decreasing the temperature of the melt. According to [6], the liquidus temperature of the 30HGSNMA steel is about 1 389 °C. Considering that the casting temperature should be 100 - 130 °C higher than the liquidus temperature, the amount of inoculant 3 % is critical in this case, since it leads to decreasing the temperature of the melt to the critical value. Further decreasing the temperature of the melt can cause decreasing the fluidity of the melt, which in turn will lead to worse mold filling in the course of manufacturing shaped castings (Figure 6).

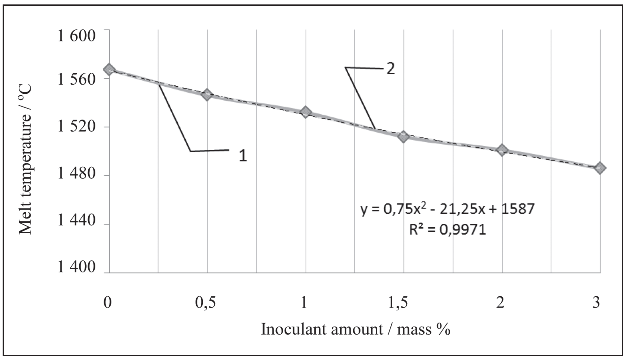

Figure 6 Inoculant amount effect on the melt temperature. 1 – theoretics; 2 – experimental.

In addition, further increasing the inoculant amount may change the chemical and phase composition of the melt, since the chemical composition of the inoculant differs from the composition of the matrix melt.

Taking into account the obtained data, it is recommended to introduce the inoculant in the amount from 0,5 to 1 %.

CONCLUSION

Thus, the studies carried out have shown the possibility of using the metal-containing part of the final steelmaking slag as inoculant modifiers-freigrators, and the optimal fraction for introducing is in the range of

500 - 800 microns, the optimal amount of 0,5 – 1 %. The use of this additive allows homogenizing the structure from the standpoint of obtaining a more fine-grained equiaxial structure with the reduced tendency to dendrite genesis by reducing overheating and increasing the centers of primary crystallization.

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Note: The responsible for England language is Nataliya Drag, Karaganda Kazakhstan