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REFINING OF METAL MELTS BY FILTRATION METHOD

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The article describes the prerequisites of filtration refining of metal melts. When filtering the liquid metals the refining effect is caused by the deposition on the filter surface of suspended non-metallic particles in the melt, and by the release of the non-metallic phase directly from the melt. Along with this the mechanism of melt refining from a superequilibrium dissolved impurity is realized when filtering as a result of the reaction course of chemical binding of the impurity element.

Key words: filtration, steel, non-metallic inclusions, reducing agent, oxides, sulfides

INTRODUCTION

Recently the filtration method of after-treatment of metal melts has received the significant development in most developed countries of the world.

The high refining effect of this method is ensured by the fact that the entire volume of the metal is subjected to filtration consistently, and the process itself is carried out directly during melt pouring into a ladle, a mold, a casting shape or a crystallizer. Herewith the number of both primary and secondary inclusions is reduced, which is almost impossible to achieve in other ways. Besides, the superposition of the filtering process with casting eliminates the phenomenon of secondary oxidation providing the flow of refined melt directly into the mold cavity. The last one is especially important for metals containing highly reactive elements (rare earth metals, alkaline earth metals, etc.). The filtration method has a very high commercial and technological potential. Large capital investments are not required for its implementation, and this method easily fits into existing technological processes.

Herewith, it has not only a refining effect on the melt, but also it enhances the efficiency of its modification.

Therefore, the filtering method is used both independently of other methods not stove processing of liquid metals, and in combination with them.

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THEORETICAL ASPECTS OF FILTRATION REFINING

The versatility of influence of the filtering process on the properties of the melt is due to its deep refining impact. It manifests itself primarily in the purification of the filtered melt from non-metallic inclusions suspended in it - ready-made phase formations.

Herewith, they precipitate either at the entrance part of the filter (due to the grid effect), or on the walls of its channels (due to the adhesive effect) [1].

Along with this, the non-metallic phase can precipitate on the surface of the filter materials from the supersaturated melt, bypassing the stage of formation of the finished phase formations (adsorption-chemical effect) [2, 3]. The energy efficiency of the process is presented.

The necessary prerequisite for this is the thermodynamic possibility of the reaction process of chemical bonding of an element-impurity, for example, by the reaction:

$$X(R) + y(O) = (R_xO_y), \quad (1)$$

where R is an impurity element with high affinity for oxygen (O).

The equilibrium of the reaction (1) in the real conditions is not achieved for kinetic reasons. This means that although there are all thermodynamic conditions for isolating the reaction products R_xO_y in the independent phase in the melt, but this possibility does not get in time fully to realize due to the rapid temperature drop during metal casting, a temporary shortage, and also a shortage of germinal substrates for their crystallization. In other words, the supersaturation of the melt by the components forming the nonmetallic phase R_xO_y before the start of crystallization of the metal is not completely eliminated.

Filtration processes are described by Darcy law. The mechanism of filtration refining from over balance dissolved impurity is called the substrate, since the filter surface serves as a substrate for separating the non-metallic phase directly from the melt. For this, the atoms of deoxidizer (R) and oxygen (O) are delivered to the surface of the melt trickle and the stage of escape of the new non-metallic phase in the form of (R_xO_y) is realized on it upon contact with the filter surface. The reality of filtration refining of liquid metals from dissolved impurity by the substrate mechanism is proved by fixing of decrease in the activity of oxygen when the liquid metal is passing through the filter (Figure 1).

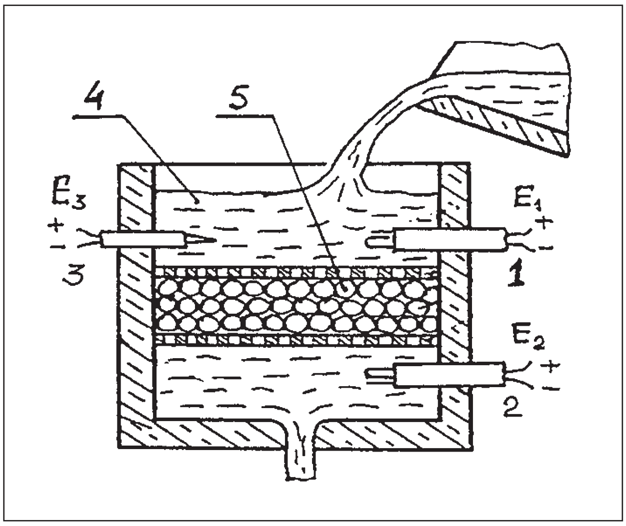

Figure 1 Scheme of activity measurement of oxygen in the liquid metal before filtering and after it: 1 - oxygen sensor above the filter; 2 - oxygen sensor under the filter; 3 - thermocouple; 4 - liquid metal; 5 - filter; E_1, E_2, E_3 - electric current

According to measurements, oxygen activity decreases for 20 – 40 % when filtering the liquid steel.

It is known that the heterogeneous crystallization of a new phase is preferable than homogeneous crystallization. Herewith any surfaces of the filtered melt division with a fire-resistant surface such as the walls of crucibles, lining of melting units and ladles including the surface of the filter can serve as a starter (or a substrate) for allocation of a new phase. When the molten metal flows through the granular filter, the surface of the contact between them is repeatedly increased at the expense of crushing the melt into many small streams, which at the same time undergo abrupt changes in the direction of flow. All this significantly intensifies and reduces the way of delivery of deoxidizer and oxygen to the surface of the filter elements, and, consequently, it contributes to the origin of the non-metallic phase on their surface by heterogeneous mechanism [4-6].

The expected dependences of the processes of refining metal melts were established after the detailed analysis of the articles [6]. We partially use the proposed method of research and processing of experimental data in our work. For processing experimental data, methods were used [7-9].

EXPERIMENTAL RESULTS

A quantitative assessment of the contamination of steel with inclusions was performed by the index of contamination and the point system [10]. It is established that filtering significantly reduces the content of non-metallic inclusions (NMI) in steel and changes their dimensional characteristics (Figure 2).

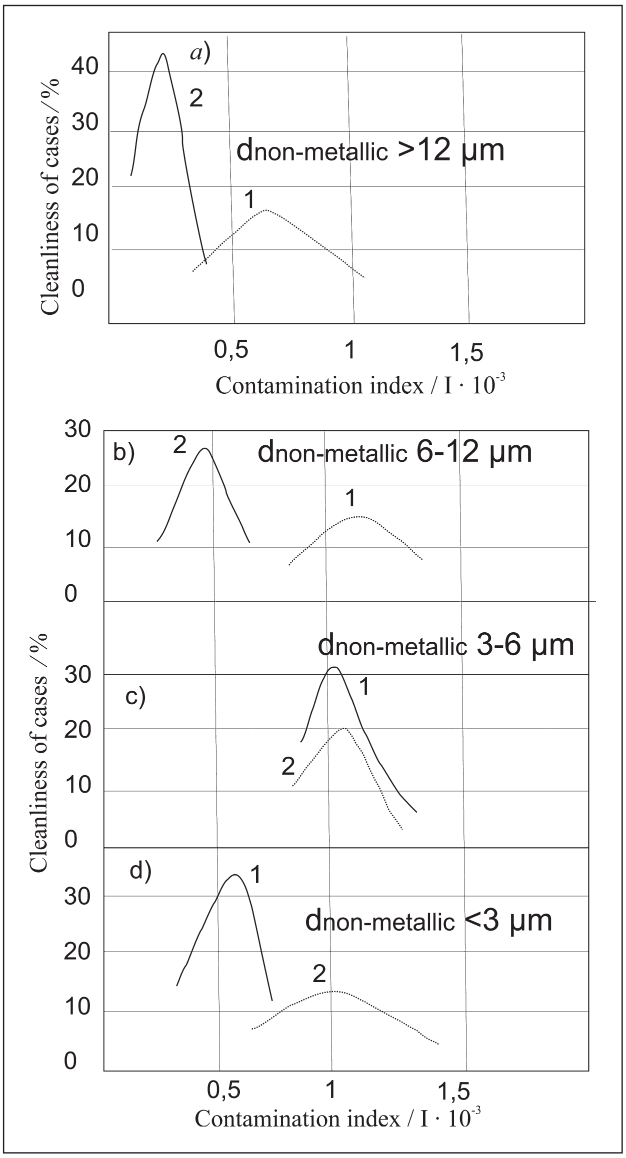

Figure 2 The effect of filtering on the contamination and the dimensional characteristic NMI in steel: 1 - unfiltered steel, 2 - filtered steel; *a*) dnon-metallic >12 μm; b) dnon-metallic 6-12 μm; c) dnon-metallic 3-6 μm; d) dnon-metallic <3 μm

Thus, the number of inclusions with the size of NMI of 6 – 12 μm and more decreases in 2,5 – 3 times during the filtration of steel, and the number of inclusions with the size of 3 – 6 μm practically does not change, and the number of NMI with the size of less the 3 μm increases. The point in NMI is reduced from 3,5 - 4 to 2,5 and

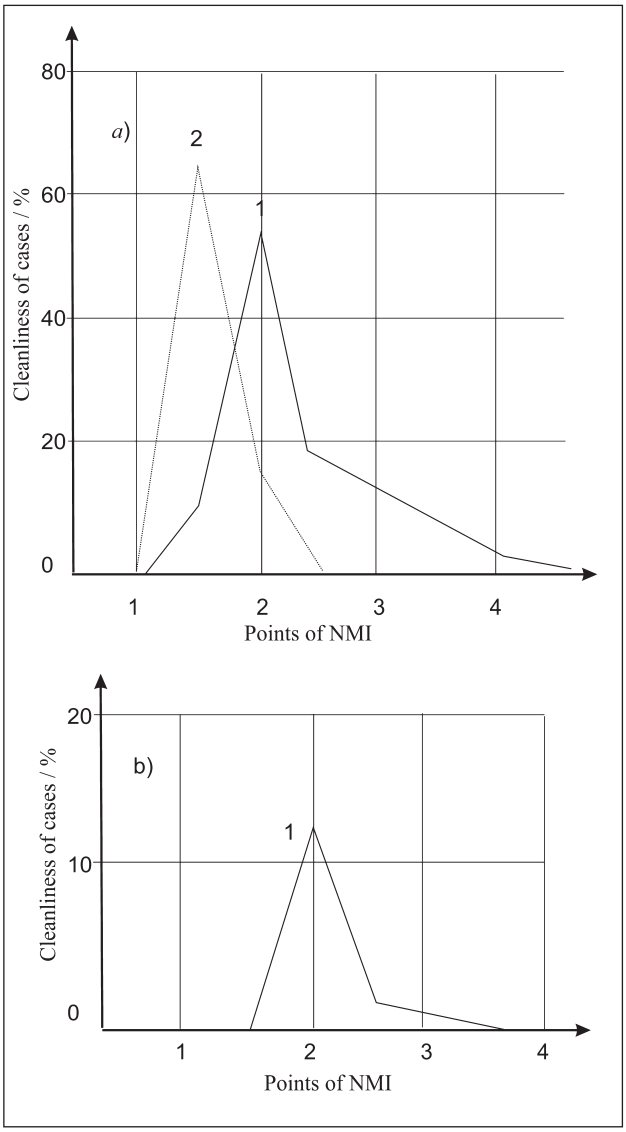

Figure 3 The effect of filtering of steel on contamination by its oxides (*a*) and by the inclusions of globular shape (b): 1 - unfiltered steel, 2 - filtered steel

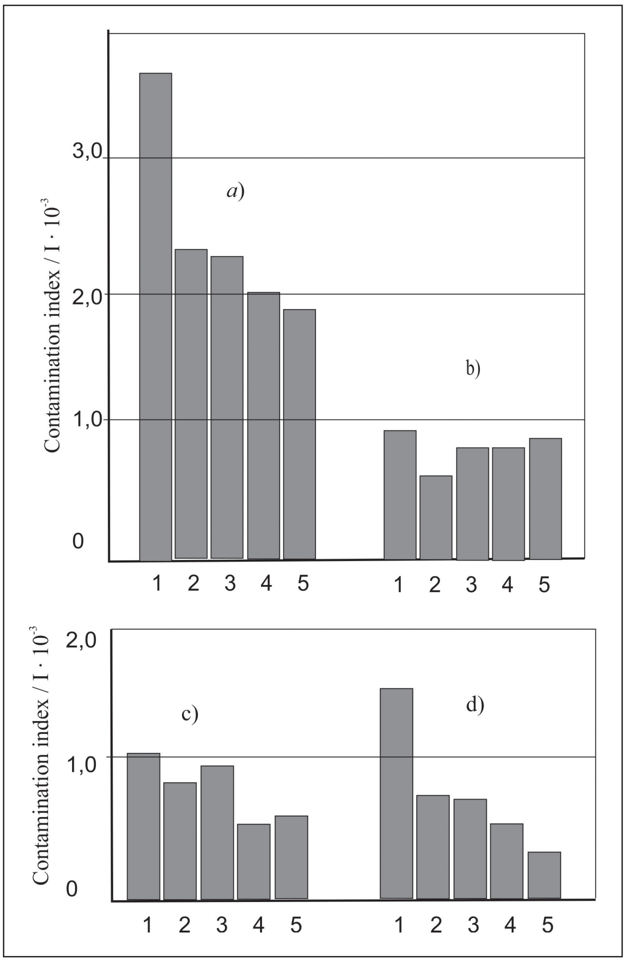

Figure 4 The effect of filtering of 20L steel processed with 0,1 % rare earth metals on the total contamination and according to the types of NMI: 1 - no filter, 2 - MgO, 3 - SiO_2, 4 - Y_2O_3, 5 - CeO_2. *a*) NMI; b) oxide; c) sulfides; d) oxysulfide

below than 10^{-3}. The influence of steel filtration on its contamination with the oxides and with the globular shape inclusions is shown in Figure 3.

When filtering casting carbon steels, the contamination of NMI reduces to 35 % mainly due to the removal of oxide inclusions

The refining effect of these steels processed rare earth metals provides a stable increase approximately twice in their frequency by NMI moreover both by oxide and sulfide (oxysulfide) inclusions (Figure 4).

CONCLUSIONS

The method of filtration of liquid metals is recognized as effective to ensure high quality castings, and this method allows to reduce the costs for their manufacture as well. This is due to the refining of metal from non-metallic inclusions and gases, as well as due to modification identified, in particular, when filtering iron and nickel alloys. Metals are more stable in terms of strength if they have been filtered. Their plastic properties increase. The use of filtering reduces such indicators as casting defects on slag and sand inclusions, and on accumulations of non-metallic inclusions in steels and irons treated with magnesium and rare earth metals. Herewith, the technological properties of the filtered metal such as the workability by pressure and cutting significantly improve.

This cleaning is carried out both in the melting furnace and in the transfer ladle, which allows achieving relatively positive results. However, a number of undesirable inclusions contributing to the reduction of the quality of the final casting appear in the process of transportation and casting of metal. These inclusions may have different origins: the particles of the lining of the ladle or sand from the valve oven; the inclusions from casting chamotte; the remains of adhesive used for bonding of gate systems; the secondary inclusions (they are metal reoxidation products), etc.

The most reliable method of metal cleaning is its filtration during casting. In this case, the filters should be installed as close as possible to the casting.

Thus, the obtained results show high efficiency of steel cleaning from non-metallic inclusions with lower costs. It is possible to use effectively the method we have considered for casting other alloys of non-ferrous and ferrous metals.

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Note: Translated from Russian into English by Tatiana B. Rumyantseva, a translator at the International Laboratory "Vision systems" of National Research Tomsk State University