THE APPLICATION OF ADDITIVE TECHNOLOGIES TO CONTROL THE PROCESS OF SEGREGATION IN THE PRODACTION OF INGOTS AND CASTING

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Introduction

In connection with the increase in the size of products for traditional and nuclear energy, heavy and petrochemical engineering, as well as the military-industrial complex, the demand for large and extra-large high-quality ingots and forging blanks is growing. The mass of ingots can reach several tens and hundreds of tons [1]. The quality of the ingots is determined by the number of shrinkage and segregation defects associated with a specific production method. With an increase in the size of ingots, the degree of alloying significantly deteriorates their quality. The axial porosity and volume of the shrinkage cavity shell increase. This significantly affects the homogeneity and uniform distribution of properties over the cross section of the ingot [2-3]. To ensure the corresponding properties and especially homogeneity structure over the entire cross section of the ingot, only part of the ingot is used, which reduces the yield. Therefore, increasing the chemical and physical homogeneity of ingots and castings is of priority importance.

The main reasons that must be overcome to improve the quality of cast metal are two: metal contamination by non-metallic inclusions and crystallization processes. The first reason metallurgists managed to overcome through the use of after-furnace treatment. They are still trying to overcome another reason related to crystallization phenomena. To do this, apply: vibration; ultrasound; electromagnetic effect, regulation of the temperature of the liquid metal, regulation of the thermal field on the surface of the bath, the introduction of refrigerators and the like. But significant achievements, especially in field the crystallization of large ingots, are not yet available. The main reason is the uncontrolled crystallization rate.

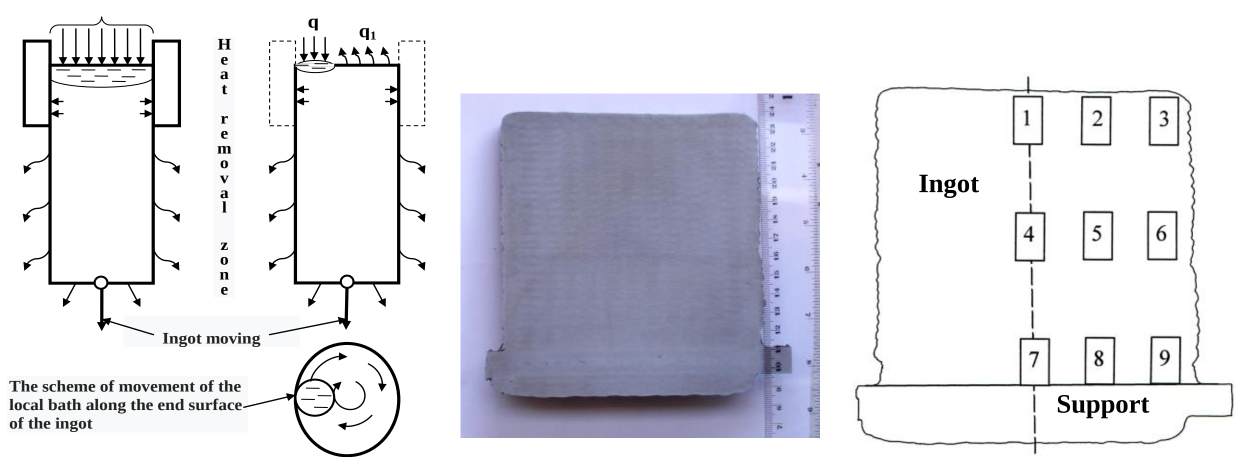
During crystalization of metals, a first-order phase transition occurs. It is inherent in such a phenomenon as segregation. segregation during crystallization of metals and alloys is associated with different solubilities of elements in solid and liquid phases [4]. The ratio of element concentrations in phases is determined by the distribution coefficient in the equilibrium stage [4]. Deviation from equilibrium leads to a change in the coefficient. In real conditions, it is necessary to talk about the effective coefficient of the distribution of elements in the solidification of metal [5], which can be calculated by the formula:

$$K = \frac{K_0}{K_0 + (1 - K_0)e^{-f\delta/D}},$$

where: f - is the crystallization rate, cm / s; δ - is the thickness of the diffusion layer adjacent to the crystallization front and enriched with impurities, cm; D - is the diffusion coefficient of the impurity, cm^2 / s.

Purpose of the study

Development of a method for suppressing segregation, regardless of the size of ingots and cast products. To achieve the goal, we proposed to change the way the ingot is formed, replacing a large metal bath with a local one that moves at high speed. In this case, an additional outflow of heat from the end surface not covered by the bath appears, Fig. 1a. It becomes possible to set the crystallization rate, respectively suppress segregation and control the structure of the ingot.



a *b* *c*

Fig. 1. Heat distribution when production ingots by different technologies (a), macro section of the ingot (b) and sampling scheme (c).

Experiment Conditions

An ingot was smelted to verify the proposed approach under laboratory conditions. A local bath was formed using an arc heating source and moved at a speed of 3 mm/s. The arc current was 150 A, and the arc voltage was 19.4 V. Welding wire with a diameter of 1.2 mm 09G2S was used as a consumable.

The discussion of the results

A macro section of the vertical section of the ingot and a metal selection map for research are presented in Fig. 1b, c. As follows from the figure, the macrostructure of the ingot is homogeneous and fine-grained. Further investigation of the microstructure of the samples taken at points 1–9 showed that grains in size correspond to 8–9 numbers, Fig. 2. The above results show that the creation of stable conditions for the formation of the ingot eliminates the scale factor and extends the results to almost any size ingots. The obtained large ingots can be used without removing the head and bottom parts. At the same time, the weight of especially large ingots can be reduced with the same loads on the products that will be made from these ingots, due to the equality to the unit coefficient, which takes into account the scale factor, and an increase in strength due to both the absence of zonal segregation and a decrease in the level of dendritic segregation. Other products, such as a bowl, were produced using a local bath. The main problem that was solved when forming the bowl was the formation of thin-walled products.

Measurements were made of the mechanical characteristics of the products. As measurements showed strength, toughness and other mechanical characteristics increased by 10-50% compared with the characteristics of the same grade of metal obtained by traditional technology, table 1.

This is especially important for products from highly alloyed alloys operating in extreme conditions. The proposed approach is a way to obtain large ingots with properties and structure that cannot be obtained using traditional technology. Further testing of products from such ingots in real conditions will confirm or refute the appropriateness of the proposed approach.

Table 1

Alloy 092S	Tensile strength, MPa	Yield strength, MPa	Relative extension, %	Impact strength, J / cm^2
Source metal	441,5	304,1	21	-
Ingot	497,7	359,5	37,5	227,9

Fig. 2. . Photos of microsections. Magnification 200. The arrangement of photographs corresponds to the scheme in Fig. 1c.

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