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Original scientific paper

IMPROVEMENT IN THE TECHNOLOGY OF POURING COPPER PLATES FOR THEIR FURTHER USE IN ELECTROLYSIS PRODUCTION

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Abstract

The existing technology of pouring of copper into ingot molds to produce anode plates for further use in the electrolysis production is considered. An assessment of the quality of the plates obtained by the existing technology of pouring is given. A new technical solution is proposed in which the copper melt after pouring it into an ingot mold is subjected to the pulsed magnetic field (PMF). Thermal-force action of the PMF on the melt improves the quality of the free surface of the plates, structure, and properties of the metal throughout the volume after crystallization. An evaluation of the factors of the pulsed-magnetic action is given. The mechanism of such action is described. The advanced considerations are confirmed by experiments. Proposals for cooperation to realize the new technical solution are stated.

Keywords: *copper anode plates, pulsed magnetic field, electrolysis, crystallization, eddy currents*

1. INTRODUCTION

High-quality copper is obtained using copper anodes by the electrolysis method [1]. The copper anodes are produced by pouring crude copper into ingot molds. The quality of the anodes is largely determined by the experience and qualification of the operator performing the pouring. Casting defects – nonuniformity of properties of the metal after crystallization, presence of micro and macro irregularities on the surface – depended on the skill of the operator. During further electrolysis, inadequate quality of the anodes leads to nonuniformity of thermal and current load, to the increased consumption of electrical energy. The process of pouring is performed on rotary machines with a large number of ingot molds (Figure. 1) and lasts a few hours. In this case, fatigue of the operator leads to a departure of the plates from given geometry, weight, and properties of the metal. That is why the task of improving the quality of anode copper plates is very urgent.

Figure. 1. Rotary machine furnace for pouring crude copper into ingot molds.

2. EXPERIMENTAL

The essence of the proposed technical solution, leading to an improvement in the quality of cast anode plates, is the action upon the free surface of the melt in the ingot mold by the pulsed magnetic field (PMF) (Figure. 2).

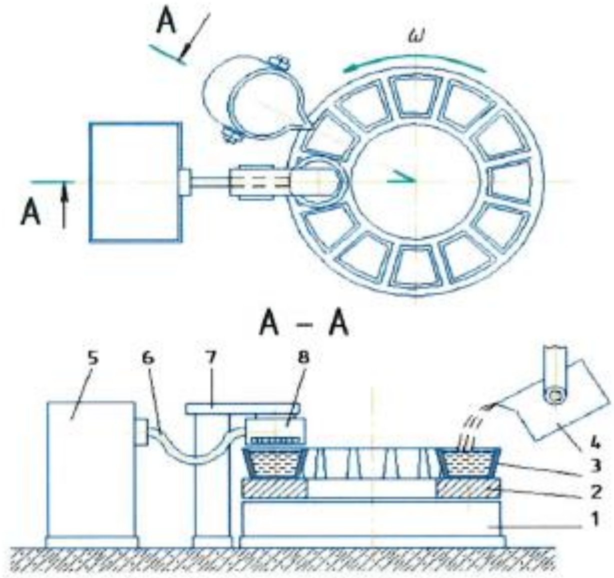

Figure. 2. Scheme of PMF action on copper melt: 1 – Base with actuator for table rotation:2 – Rotary table, 3 – Ingot mold, 4 – Ladle, 5 – PMI, 6 – Cable adapter, 7 – Inductor holder, 8 – Inductor.

The inductor (a multi-turn flat coil) is fitted on the rack above the ingot mold. The inductor is connected with the pulse-magnetic installation (PMI) [2]. At the time of discharge of the PMI's capacitor bank into the inductor, the pulsed magnetic field (PMF) is formed around turns of the inductor. Under action of the PMF, eddy currents of tens to hundreds of kilo-amperes are induced in the melt. Between the current in the inductor and that in the melt, electrodynamic repulsive forces arise. In this case, the time of action on the melt is $10^{-3} \div 10^{-4}$s. During the passage of the ingot mold with the melt under the inductor, the repeated force action of the PMF is performed in the whole time interval of the crystallization curve (Figure. 3).

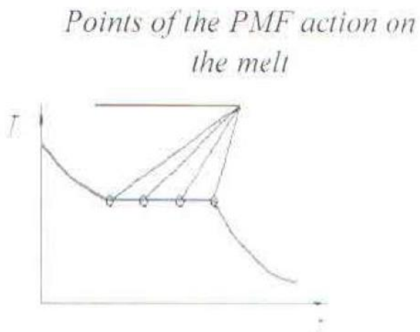

Figure. 3. Scheme of the repeated action of the PMF on the melt in the process of its crystallization.

As the carousel rotates, new ingot molds with the just-poured melt are brought under the inductor consecutively. The rack with the inductor is placed above the ingot mold immediately behind the pouring ladle. Movement of the inductor with the ingot mold for one step of carousel advance (rotation) is possible.

3. RESULTS AND DISCUSSION

Factors and the mechanism of the pulse-magnetic action on the copper melt [3].

The intensity of the pulse-magnetic action on the melt is determined by the value of electrical energy stored in the PMI's capacitor bank (W=CU2/2), whereas the shape of the originated force action is defined by the shape of the current curve of the discharge circuit (installation – inductor – melt)

The eddy currents, induced in the melt, are distributed with depth unevenly: they are maximum at the surface and decrease with the melt depth according to the exponential law (skin effect). The depth of the skin layer is $= \sqrt{\frac{2}{\omega\gamma\mu}}$. Consequently, the force action on the melt is three-dimensional.

Heat action. The eddy currents are additional internal heat sources changing temperature conditions of crystallization. The amount of heat released in the skin layer leads to the temperature increase $\Delta T = \int_0^T \frac{R*I_{max}^2}{2*Y*C_y}$

Force action. Three-dimensional electrodynamic forces, arising in the melt, lead to initiation of stress waves, metal-flows, and propagation of them over the mold volume, resulting in changing the structure and properties of the metal, their homogeneity, as well as assisting in degassing and eliminating of micro and macro defects on the surface. Control over the thermo-force action is possible by choosing the energy W, by varying the parameters of the discharge circuits of the installation and inductor [4], their orientation relative to the melt surface, the number of loading pulses, and time intervals between them.

Evaluation experiment [5].

The conducted experiments on the action of the PMF on the aluminum melt (Silumin) have shown the feasibility and effectiveness of such action from the viewpoint of improvement in both the structure and properties of the metal (Figure. 4).

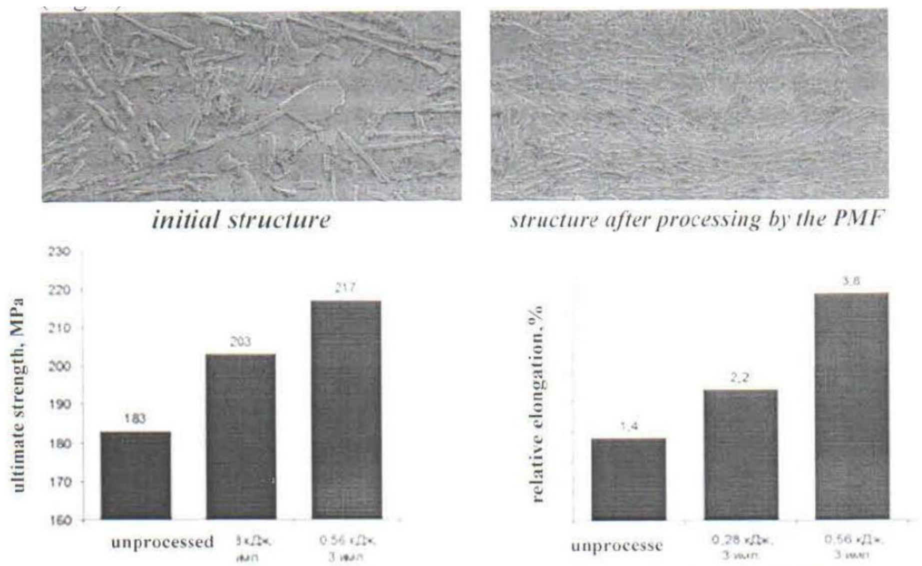

Figure. 4. Changes in structure and properties of the metal after the PMF action

As the PMF acts on a weld seam during arc-argon welding [6], effects of smoothing off the surface of strengthening of the weld seam as a whole were observed.

4. CONCLUSION

1. A new technical solution aimed at upgrading the quality of anode copper plates under the action of the pulsed magnetic field was proposed. A scheme of modernization of the rotary machine, needed for realization of the proposed technical solution, was developed.
2. Factors of the pulse-magnetic action on the copper melt – energy, frequency, the number of pulses, etc. – were determined, and the mechanism of such thermo-force action was stated: additional internal heat sources, stress waves, metal-flows.
3. The feasibility of the proposed technical solution was confirmed by experimental investigations performed with the aluminum melt.

To put the proposed technology into practice, the following needs to be done: 1) Creation of a procedure for calculation of parameters of the action and a procedure for simulation of processes occurring in the melt; 2) Performance of experimental investigations and assessment of quality of the plates; 3) Execution of design works and pilot-industrial mastering of the process. This amount of work can be performed with the joint efforts of universities and industrial enterprises interested in the results of the work.

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