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**DEVELOPMENT OF COMPOSITION OF WORKING MIXTURE OF GASES FOR UPGRADING OF CATHODES ON BASIS OF NICKEL FOR THE IONIC-PLASMA MELTING**

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**Abstract:** Modern power plants and aero-engines work at enhanceable temperatures, that on occasion can fold over 1700 °C. For providing of work at high temperatures apply heat-resistant coverages on the basis of nickel. The resource of shoulder-blades first of all depends on the quality indexes of the inflicted coverages (to evenness of absence of pores, including, chemical homogeneity). Quality of overcoating is determined by the modes of causing and quality of cathode. As a rule, cathodes are alloys that is inflicted with the special geometry. There are a few technologies of making of cathodes, each of that has the advantages and defects. One of methods is a layer alloy of cathodes in copper water-cooled mold with the use of the melted or inflexible electrode. **Purpose.** Improvement of the technological modes of smelting of cathodes that is nebulized, on the basis of nickel of the system Ni - Cr - Al - Y with the purpose of increase of their quality, namely is reduction of general amount of defects as pores, increase of homogeneity of structure and chemical composition and using as a protective atmosphere of rare gases most widespread from that are helium and argon. **Methodology.** An equipment, on that trial standards were got as "pucks" (by a diameter a 127 mm and in a 40 mm thick) that was used for research of microstructure and chemical composition, was improved. The modes of remelting are exhaust. Researches of chemical composition conducted with the use of SEM of PEM

106I, equipped by the system. **Scientific novelty.** Optimal correlation of protective gases was certain. At correlation 70/30% were got maximally quality cathodes on that conducted further researches. **Conclusions.** Based on the results of studies of the effect of the concentration of a gas mixture on the structure and composition of the cathodes, technological melting conditions were established, which made it possible to improve the quality indicators and economic indicators of the studied cathodes. This will positively affect the number of cathode defects, the health of parts that contain coatings and the resource of aircraft engines in general.

**Keywords:** cathode, nickeliferous alloy, melting, bar, structure, rare gas, protective atmosphere, argon, helium.

**Introduction:** Modern power plants and aircraft engines operate at elevated temperatures. While the first gas turbine engines (GTEs) had material operating temperatures ranged from 600 °C to 900 °C, later they increased significantly, reaching 1700 °C. To ensure operation at high temperatures, heat-resistant coatings, in particular, nickel-based coatings are used. Blade life primarily depends on the quality of the applied coatings (absence of pores, inclusions, chemical homogeneity). As shown in [2,3], the quality of coating is determined by the technological modes and the presence of defects in the cathode itself. As a rule, cathodes are machined alloy ingots with special geometry. There are several technologies for manufacturing cathodes (traditional coil casting, powder metallurgy, and electroslag welding). Each of them has its advantages and disadvantages. The main difficulties of these technologies are uneven distribution of chemical composition and structural defects. One of the most efficient methods of manufacturing cathodes is layer-by-layer cathode fusion in a water-cooled copper crystallizer using a consumable or non-consumable electrode. The latter method ensures reliable mixing of alloying and modifying elements through separate melting with repeated stirring of the cast billets, followed by their fusion into an ingot.

However, during layer-by-layer alloying of cast billets, non-consolidations may occur between the layers, which leads to cathode defects.

At the same time, the technology of layer-by-layer alloying has a number of features and requires the development of technological modes to ensure the quality of cathodes, the formation of the correct geometry, alloy layers, and the absence of defects such as pores and non-melts [4]. The solution to these problems is possible by changing the linear energy. The simplest and most affordable way to solve this problem in arc welding is to increase the electrode melting rate by increasing the welding current. However, this approach has limitations in terms of equipment capabilities, non-consumable electrode diameter, and the use of power sources.

Consequently, this trend has significant limitations in welding current and application [5]. The most appropriate method of changing the geometry of metal penetration without fundamental changes in the design of the equipment is to use a mixture of inert gases (argon, helium) instead of single-component environments. However, this requires additional research. Thus, it is possible to produce high-quality ingots for cathodes by optimizing the technological parameters of melting, in particular by adding a mixture of argon-helium gases and determining their optimal ratios.

According to studies [3...5], the addition of helium to argon changes the thermophysical properties of shielding gases, which affect the technological properties of the arc and the shape of the welds. For example, compared to argon, helium has a higher ionization potential and greater thermal conductivity at plasma temperatures.

**The aim of the work:** to improve the quality of nickel-based cathodes (Ni - Cr - Al - Y) by improving the technological modes of ingot smelting. The objective is to reduce the total number of defects in ingots in the form of discontinuities, pores, and non-melts, and to increase the homogeneity of the structure and chemical composition.

**Methods:** A vacuum arc furnace VD-1 was used to melt the samples, which was improved by adding a ramp and a helium cylinder. The unit is a cylindrical body installed on a frame. In the lower part there is a copper crystallizer, in the upper part of the body there is electrode holder in the lid, and on the left there is a manipulator. A viewing window is used to observe and control the smelting process. The body,

crystallizer, and electrode holders are cooled by water. On the right, the body is connected to the high and low vacuum system through a vacuum shutoff. When working with the unit, samples are loaded into the furnace, the vacuum is pumped out by a pump and argon and helium are supplied from cylinders through a ramp to the working chamber. After these operations, the melting process is carried out. The power source of the unit is a welding rectifier VDU1200.

The technological modes of operation of the ingot smelting equipment included: operation of a 2NVBM-160 steam-oil vacuum booster pump and an AVZ-20 vacuum pump, which operated for 3 hours per smelting; the operation of the pumps was controlled by a VIT 2-P vacuum meter. The range of modes is as follows:  $I = 450 - 1800$  A,  $U = 30 - 45$  V,  $\tau = 25 - 35$  min, preliminary vacuum creation of  $1 \times 10^{-4}$  mbar, working environment - a mixture of Ag + He gases, pressure 0.5 bar, melt temperature before pouring from  $1400^{\circ}\text{C} - 1700^{\circ}\text{C}$ .

Each ingot with a diameter of 50-70 mm and a height of 5-7 mm is melted 3-5 times under certain parameters. After that, all ingots were loaded into the furnace and melted layer by layer (depending on the required dimensions) under the same parameters. In this process, the required geometry of the ingot used to make the cathode is formed in layers. Ingots were tested at different percentages of argon and helium (Table 1). At a ratio of 70/30%, the highest quality ingots were obtained, which were used for further research.

To practice the smelting process, test samples in the form of "washers" (127 mm in diameter and 40 mm thick) were obtained and used to study the microstructure and chemical composition.

The chemical composition was studied using a multipurpose scanning electron microscope REM 106I equipped with a microanalysis system.

Metallographic studies of the obtained ingot structure were performed using optical and electron microscopes. Samples for metallographic studies were made by successive grinding and polishing. Etching of the grinds was carried out in the following reagent composition: HF - 10 ml, HNO<sub>3</sub> - 25 ml, glycerin - 65 ml. Microstructural analysis was performed using an inverted microscope "Neophot-32".

The energy dispersive analysis was performed using a JSM-6360LA multi-purpose scanning electron microscope with an integrated microanalysis system. It allows to study the chemical composition of local areas of the alloy microstructure.

**Research results:** to determine the optimal modes (gas mixtures) that provide the best cathode quality indicators, layer-by-layer alloying of ingots was performed at different concentrations of gases (argon and helium) in their mixture (see Table 1).

**Table 1**

**Results of quality tests**

Mixture of protective gases	The ratio in %	The result of remelting
Ar+ He	90+10	surges
Ar+ He	80+20	distinct alloying boundaries
Ar+ He	70+30	no overlaps, the boundaries of the alloying layers are blurred

The study was carried out in two zones of the sample fragment for a comprehensive assessment of the chemical composition. In order to make a final conclusion on the compliance of the experimental alloy with the requirements, a control melting was performed taking into account the rational modes and transition coefficients determined experimentally.

The results of the chemical composition study allow us to conclude that the chemicals of the experimental nickel alloy are evenly distributed. Thus, we obtained ingots that meet the requirements of the task in terms of chemical element concentration.

The macro- and microstructure of the cathode billet was analyzed on samples cut from the ingot. The macrostructure (MITOM-21 microscope) showed even and high-quality fusion of the cathode layers, which confirms the correct selection of the ratio of inert gases. The macro-grind of the ingot shows that it was completely melted, with no pores, inclusions or discontinuities. The microstructure analysis showed even distribution of structural components and no obvious liquation. The analysis of metallographic studies shows a finely dispersed structure, high homogeneity of ingots and the absence of defects. Analysis of the results of metallographic studies reveals that the structure of the obtained alloy is finely dispersed. No structural inhomogeneities were found.

It was found that the addition of helium to the argon shielding gas environment would provide a more concentrated arc. This makes it possible to precisely adjust the height of the deposited layers. This can be explained by the penetrating properties of the arc when helium is added as a shielding gas.

A visual inspection of ingots melted in a mixture of 70 % Ar + 30 % He showed that there were no overlaps on the side surface of the ingots, the alloying limits of the metal layers were blurred, and the structure of the side surface of the ingots was close to the cast one, which led to the conclusion that the gas mixture of 70 % Ar + 30 % He is optimal for arc remelting of an alloy of a given chemical composition in terms of producing ingots without technological defects (layers overlapping, non-fusion of metal layers).

The obtained samples are characterized by a finely dispersed, homogeneous structure with sufficient evenness of phase distribution throughout the ingot volume.

Thus, the implementation of the new development has improved the quality of the ingots for cathodes under study. This makes it possible to reduce the number of defects, which makes it possible to predict an increase in the quality of cathodes and, in turn, strengthening of protective coatings. This will have a positive impact on the service life and performance of products and important parts for aviation applications.

**Conclusions:** 1. Based on the analysis of the technology for the production of nickel-based cathodes for ion-plasma coatings, ways to improve the quality of cathodes by reducing the number of pores and defects and improving the structure of ingots of cathode blanks were identified. 2. The possibility of cathode smelting using a mixture of gases (argon + helium) was implemented by improving the design of the vacuum arc melting unit by adding a ramp and a helium cylinder. 3. The influence of the composition of the argon-helium mixture on the structure and chemical composition of ingots for cathodes, optimal technological modes and quality of cathodes was studied. It was found that the addition of helium to the argon shielding gas environment will provide a more concentrated arc, which will allow you to adjust the height of the layers more precisely. It was found that a gas concentration of 70%+30% ensures the

production of an alloy of a given chemical composition in terms of ingots without technological defects (layers overlapping each other, non-fusion of metal layers).

Improving the quality of cathodes allows us to conclude that the quality of coatings has improved and the service life of the blades has increased.

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