

PAPER • OPEN ACCESS

## Characteristics and problems of exploitation of plated electrode carriers in arc steel furnaces

To cite this article: R A Bikeev *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **194** 052004

View the [article online](#) for updates and enhancements.

### You may also like

- [Application of seismic sensors on measurement while drilling for real-time rock property detection](#)  
M Khanal, B Shen, Y Duan *et al.*
- [Numerical investigation on signal transmission characteristic of electromagnetic measurement-while-drilling in underground coal mine](#)  
Zhiwei Chu, Quanxin Li, Jun Fang *et al.*
- [Design and Application of Downhole Drilling Mud Pulse Signal Transmission System](#)  
Lei Zhang, Gang Chen, Changkun Li *et al.*



**ECS**  
The  
Electrochemical  
Society  
Advancing solid state &  
electrochemical science & technology

**DISCOVER**  
how sustainability  
intersects with  
electrochemistry & solid  
state science research

# Characteristics and problems of exploitation of plated electrode carriers in arc steel furnaces

**R A Bikeev, V S Cherednichenko, V A Serikov**

Novosibirsk State Technical University, 20, Karla Marksa Av., Novosibirsk, 630073, Russia

E-mail: [bikeev@ngs.ru](mailto:bikeev@ngs.ru)

**Abstract.** In this article, the processes of destruction of current-carrying arms made of plated copper-steel materials, leading to substantial reduction of their endurance, are discussed. Measures which may be recommended for ruling out the said negative processes are proposed.

## 1. Introduction

Russian metallurgical plants employ electric arc furnaces (EAF) from 30 to 180 tons in capacity with specific power of 0.6 to 1 MVA/t. Such equipment is used for melting steel in GUP "Founding and Rolling Plant" (Yartsevo), West-Siberian Metal Plant (Novokuznetsk), CJSC "Chelyabinsk Metal Plant", CJSC "Magnitigorsk Metal Plant", PC "Taganrog Metal Plant", PC "Asha Metal Plant", CJSC "NMLK-Ural", Nizhnesergievsky Metal Plant (Revda), CJSC "Kama-Steel" (Perm), CJSC "Seversky Pipe Plant" (Polevskoy), CJSC "Ural Steel" (Novotroitsk), LLC "NLMK-Sort" (Kaluga), CJSC "Rostov Electrometallurgical Plant", CJSC "Severstel", CJSC "Pervouralsky Pipe Plant", CJSC "Serov Metal Plant", CJSC "Novorossmetal" (Novorossiysk), CJSC "Abinsk Electrometallurgical Plant", LLC "UGMK-Steel" (Tyumen). The majority of these plants are equipped not only with EAFs of various capacities, but also with ladle furnaces. Apart from the mentioned plants, electric arc furnaces are employed in many machine-building factories, answering the needs of small-scale metallurgy.

Electric arc furnaces and ladle furnaces of various constructions are equipped with bimetallic electrode carriers. Rated endurance of plated electrode-carriers (steel-copper) determines the guaranteed service life of at least 8 years. This parameter was determined for conditions of functioning of electrode carriers (including the clamping rings) under conditions of secure functioning of electrode-roof gaskets, lowered pressure of the steam, dust and gas mixture in the working space of the furnace and minimal heating of electrodes in the clamping rings. These conditions minimize the interaction between surfaces of electrode carriers and the gases released from the furnace.

If these conditions are followed, actual service life of electrode carriers exceeds the rated and the guaranteed ones. However, for some furnaces (for instance, EAF-180, CJSC "MMK", firm VAI-FUCHS; EAF-150, PC "Tagmet", firm SMS DEMAG; EAF-80, PC "NMZ", firm DANIELI ControMET) their life service turns out to be reduced to 2.5-4 years.

This article is dedicated to analysis of the causes of substantial reduction of service life of electrode carriers under review.

## 2. Analysis of the causes for the decrease in the life of the electrode carriers



Metal constructions of EAF work under conditions of cyclical strains and permanent and periodical heating, which also affect the electrode carriers during the realization of the technological process.

Due to constant pursuit of production outputs, the intensity of exploitation of the equipment rises as well. At the same time, the furnace constructions are constantly modified in order to diminish the exploitation expenses.

Graphitized electrode is held in vertical position in the clamping ring by means of pressing the pad onto the surface of the electrode. Figure 1 shows an arc steel electrical furnace with current-carrying arms and plated electrode carriers for graphitized electrodes of 45 mm in diameter. Contact resistance between the pad and the electrode can only be determined approximately due to the fact that the radius of copper water-cooled pad and the diameter of each electrode section may not match, since the electrodes have large tolerance in geometric size.

That results in diminished contact area in the pressing of the pad onto the electrode, increased current density in the contact and release of energy on that resistance. Even though the pad is necessarily cooled, the electrode can become heated to 700-800°C in this area. In order to diminish the graphitized electrode consumption, spraying of water is added under the electrode clamp.

During the whole melting cycle, streams of CO and CO<sub>2</sub>, coming into interaction with the surfaces of graphitized electrodes, oxygen in the air and surfaces of electrode carriers, come out from the working space through the gaps between electrodes and roof gaskets. That leads to escaping of a large amount of energy from the furnace, which raises the temperature of the electrode and the electrode carrier while entering into interaction with them. The part of electrode that stands out over the roof heats up to the temperature of more than 500°C and becomes intensely oxidized.

There is a vast variety of technical variations of gaskets of the roof electrode holes: ceramic, gas-dynamic, mechanical, cotton, etc [1]. However, to this day no definitely reliable options have been designed. Overall flaws of common economizers are: complexity of construction, high cost, big weight, short service life, and insufficient effectiveness. Figure 2 shows the areas of thermochemical interaction of the graphitized electrode with the cooling water with and without gaskets.

As a result, even with gaskets present, the gas mixture comes out through the gaps out of the working space of the furnace. In case when the construction for spray cooling of the electrodes is present, over-heated water steam blends in with the exiting gases. As a result, the following reactions occur on the surfaces of the roof and the electrode carriers:



The speed of reaction (2) with isolation of hydrogen exceeds by far the speed of reaction (1) due to kinetic, diffusional and adsorption-chemical factors. That is facilitated by the difference in chemical bond energies of C = O in CO<sub>2</sub> molecule (707,79 kJ/mol) and the strength of the O = H bond in molecule H<sub>2</sub>O (467,60 kJ/mol) [2].

Quick regeneration of hydrogen is additionally helped by the reaction of water gas (3), which is a heterogeneous-catalytic one and occurs on high speed in the temperature range of the gases over the furnace roof. The intensity of reaction is facilitated by the high concentrations of CO around the electrode carrier, in addition to the heating due to electric current flowing through it.

As a result, in the space above the roof, where the electrode carriers are situated, a hot gas mixture made up of CO, CO<sub>2</sub>, H<sub>2</sub>, H<sub>2</sub>O and air becomes formed. The composition of this mixture varies as the electrode carriers are lowered during the melting process.

Without discussing the questions of heat exchange of the gas mixture with the electrode holders, we should point out the kinetic characteristics of the interaction of the gases with copper water-cooled



a



b

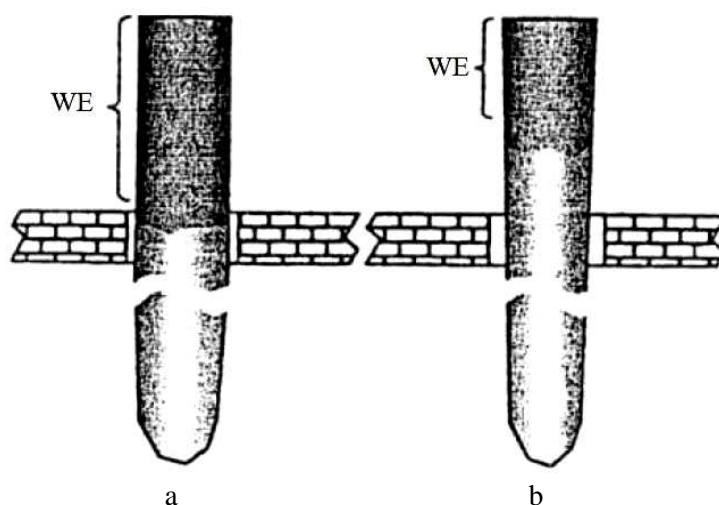
**Figure 1.** Electrical furnace with current-carrying arms (a) and plated electrode carriers (b).

units of the electrode carriers. Ideally, the gas mixture rises vertically above the furnace and is removed through the hood. If the units of the electrode holders are streamed around, not all components of the gas mixture interact equally with the surfaces of the furnace units. The coefficients of free diffusion in the gas mixture differ and for the system of hydrogen and water steam they exceed the diffusion coefficient of hydrogen monoxide mixture 3-8 times, depending on the temperature conditions of the interaction with the surfaces of metal constructions [3].

Energetic and chemical advantages of the  $H_2$ - $H_2O$  mixture in the interaction with copper surfaces persist in case of mass transfer through fine pores, affected by the laws of Knudsen molecular flow, in which the geometric sizes are commensurable with the mean free path of molecules. In this case, each gas diffuses independently from all others with a diffusion coefficient inversely proportional to



the square root of the molecular mass of the gas. Therefore, the most active gas of the mixture in the



**Figure 2.** Areas of watering of the electrodes (OE) with the gaskets present (a) and without them (b).

interaction with the electrode carriers turns out to be hydrogen. At the same time, diffusional processes are intensified by acoustic and vibrational fields in which electrical furnaces function [4].

Copper-steel plated material is most often produced by employing either the explosion welding technology or the knurling method. The approximate range of porosity for sheet material is 0.5-1%, and the size of pores ranges from 10 to 30  $\mu\text{m}$ . Apart from that, the gaps between the layers of copper and steel may reach up to 5% of the overall area. In the exploitation process these pores and gaps become filled with hydrogen and reduce copper oxide:  $\text{Cu}_2\text{O} + \text{H}_2 = 2\text{Cu} + \text{H}_2\text{O}$ . Water steams create high pressure, which leads to swelling of the copper layer, ruptures and cracks. The most actively destroyed welds are those with higher porosity. This effect is known as hydrogen corrosion of copper.

### 3. Summary

The discussed processes of destruction of current-carrying arms made of copper-steel plated materials reduce the service life of electrode carriers. Considering that to this day no reliable quantitative information is available on the reduction of graphitized electrode consumption with the employment of spray water cooling of the electrodes in EAF, this method requires additional economical verification.

The following measures may be recommended:

1. Reduction of the intensity of heating of graphitized electrodes in electrode clamps of the electrode carrier by means of diminishing contact resistance between the pad and the electrode.
2. Decrease of water consumption in spraying mechanisms or substitution of water by air cooling.
3. Maintenance of low pressure in the working space of the furnace.
4. Intensification of vertical suction of the gases into the hood.
5. Production of plated electrode carriers out of oxygen-free copper.
6. High-quality welding of copper sheets and steel in order to reduce the gaps between the sheets.

### References

- [1] Dolgoplov V F, Derevyanchenko I V, Ermishin M V, Moshnyaga I A 2010 *Steel Transl. Reducing graphitized-electrode consumption by sealing the electrode gaps in the furnace roof* **40** 53-55
- [2] Simonov V K, Grishin A M 2014 *Russian Metallurgy. Kinetics and mechanism of the gas carbothermic reduction of  $\text{Cr}_2\text{O}_3$  in the absence of melts* **12** 995-999
- [3] Bogdandy L, Engel H-J 1967 *Die Reduktion der Eisenerze* (Berlin: Springer-Verlag) p 539
- [4] Cherednichenko V S, Bikeev R A, Cherednichenko A V, Ognev A M 2016 *Russian Metallurgy*.

*Acoustic characteristics of electric arc furnaces* **6** 509-516