

Technology of Electrocontact Gaskets for Graphitizing Electrode Blanks in Direct Heating Furnaces

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Abstract

The article substantiates the choice of material for the manufacture of electrical gaskets designed for their placement at the ends of the electrode blanks before their graphitization in direct heating furnaces (Castner furnaces). It is proposed to use thermally expanded graphite (TEG) as a gasket material, with the gaskets being attached to the ends of the electrode blanks using dextrin or aluminosilicate glue with the addition of graphite powder. Two methods of forming contact gaskets are considered, the first of which consists in cutting them from a prefabricated sheet of TEG of a desired density, and the second – in waste-free pressing of gaskets from bulk TEG with low density to a given value of gasket material density. The sketch project of the form for pressing of electrocontact linings is developed and the numerical analysis of a stress-strain state of its design which confirmed possibility of use of the form in industrial conditions is executed.

Keywords: Castner direct heating furnace; Electrode blanks; Graphitization; Electrocontact gasket; Press form.

1. Introduction

The technological operation of graphitization of carbon materials is the final stage of a long and multi-stage process of manufacturing all types of graphitized products, including electrodes, which are widely used in metallurgy and chemical industry.

The blanks that have passed the stages of pressing and firing are subjected to graphitization, as a result of which the blanks acquire significant and uneven porosity and anisometry. In the process of graphitization, the products acquire the required electrical conductivity, thermal conductivity, strength, as well as frictional and some chemical properties. The graphitization process is carried out in special graphitization furnaces, which primarily include modern direct heating furnaces (Castner furnaces) and obsolete indirect heating furnaces (Acheson furnaces) [1].

Castner furnace is an electric resistance furnace in which the electrode blanks are heated as a result of the passage of electric current through them [2]. For the graphitization process, the electrode blanks are placed in the furnace in a certain way, forming a so-called "core" (or "column") – located between the two currents of the furnace blanks of carbon-containing electrodes to be graphitized, between which for reliable electrical contact are electrical gaskets. The formation of the core is the most important preparatory operation of the graphitization technology, and the role of electrical gaskets in ensuring the energy efficiency of the furnace is extremely large [3].

Analysis of the current state of the problem of assembling columns of electrode blanks for their graphitization in direct heating furnaces and theoretical and experimental studies on the development of energy-efficient regulations for the introduction of electric power into the furnace gives grounds to draw the following conclusions [4]:

– the decisive structural and technological factor of the process of graphitization of electrode blanks in direct heating furnaces are electrocontact gaskets, which are a component of the

core and are located between the ends of adjacent blanks and on the free ends of the final blanks in the core;

- the process of graphitization of electrode blanks in direct heating furnaces depends on such parameters of electrocontact gaskets as gasket material, its structure, density and electrical resistivity, as well as the shape and dimensions of gaskets.

2. The purpose and goal of the research

The purpose of research is to substantiate the choice of material for the manufacture of electrical gaskets, as well as the development of technology for their manufacture with minimization of production waste.

3. The choice of material and form of electrocontact gaskets and technology of their production

One of the most common in the manufacture of electrodes designs of electrical gaskets is a gasket made of carbon material in the form of a solid disk (US Pat. No. US1029121A; Fig. 1). This gasket provides a reliable contact of the electrode blanks of the core with each other or the contact of the end electrode blanks of the core with the compensating inserts of the Castner furnace. However, during graphitization due to uneven heating of the electrode blanks in the radial direction, the ends of the blanks are curved (with the transformation of flat ends of the blanks into convex), which impairs the electrical contact between gaskets and blanks and can lead to mechanical destruction of blanks [1].

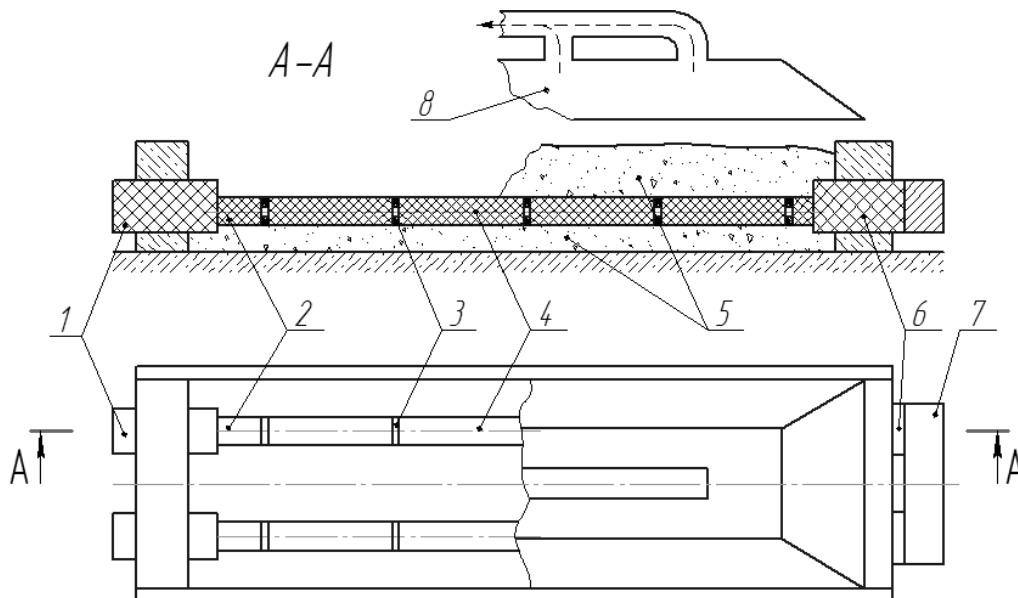


Fig. 1. Scheme of Castner graphitization furnace [1]: 1 – movable current supply; 2 – compensating inserts; 3 – electrocontact gaskets; 4 – electrode blanks; 5 – heat-insulating charge; 6 – stationary power supplies; 7 – electric jumper; 8 – shelter for gas removal

For an efficient electrode graphitization process, electrocontact gaskets must provide the following specific requirements [1, 4, 5]:

- have high heat resistance and electrical conductivity;
- withstand significant mechanical loads at temperatures of 3000°C and above, but also to compensate for the longitudinal temperature elongation of the workpieces in the core;
- to prevent the appearance of high electrical resistance at the points of contact with the blanks when changing the geometry of the ends of the workpieces;
- minimize radial and axial temperature differences in the electrode blanks of the core;
- to provide convenience of installation, etc.

These requirements for electrical gaskets in general determine the relevant requirements for both the material for their manufacture and their shape. Such a material can be thermally expanded graphite (TEG), which has high performance properties [6]. The expediency of the choice of this material is also confirmed by papers [1,4-5] and Rus. patents № RU2343112C1, RU2076085C1.

It has been experimentally established that electrical gaskets should have a thickness of 20–25 mm at a density of 1000–1500 kg/m³. To reduce the mechanical stresses in the core elements caused by deformation of the ends of the electrode blanks, the gaskets are proposed to be made in the form of an annular disk, and their fixation at the ends of the electrode blanks to provide dextrin [7] or aluminosilicate [8] glue with graphite powder. In this case, to simplify the assembly of the core of the electrode blanks, each gasket can be glued to one of the end surfaces of the corresponding blank [1] (Fig. 2).

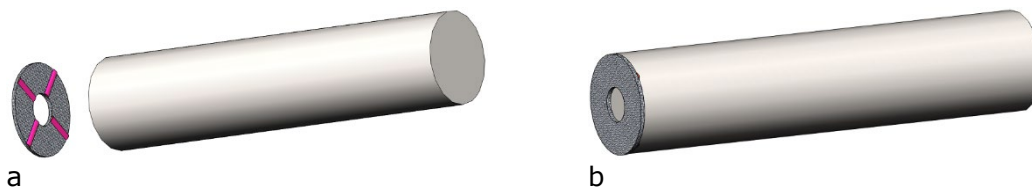


Fig. 2. Stages of fixing the electrocontact gasket $\varnothing 220/\varnothing 630$ mm 20 mm thick on the end surface of the electrode blank $\varnothing 630 \times 2815$ mm: a – application of four strips of glue on the electrocontact gasket; b – centering and gluing of an electrocontact lining to an end face of electrode preparation

Next, the electrode blanks with glued to them electro-contact gaskets are placed horizontally in the furnace on a layer of bulk insulating material butt-to-butt with the formation of the core of the electrode blanks (see Fig. 1).

The formation of electrocontact gaskets can be carried out in two ways, the first of which is to cut gaskets from a prefabricated sheet TEG of the desired density, and the second – in pressing gaskets of the desired density from the original granular TEG with low bulk density.

The first method has a high productivity and does not require special molds that need to be made for each size of electrode blanks. The disadvantage of this method is the need for prefabrication of sheet blanks TEG and a significant amount of waste generated.

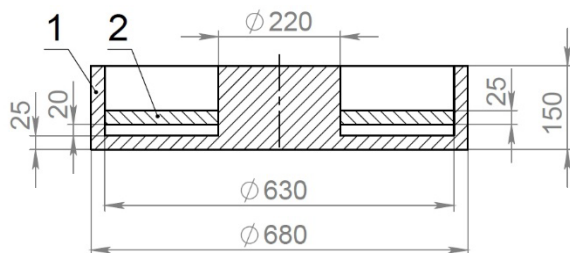


Fig. 3. Sketch of a mold for pressing of electrocontact gaskets $\varnothing 220/\varnothing 630$ mm 20 mm thick for graphitization of electrode blanks $\varnothing 630 \times 2815$ mm: 1 – matrix; 2 – punch

to form a source layer of TEG thickness of 80 and 120 mm, respectively. The pressing pressure is determined from Fig. 4 and is about 6 MPa and 11 MPa, respectively.

As previous tests of the obtained electrical contact gaskets have shown, they fully meet the above requirements. Also, to develop new designs of electrical gaskets, you can use the approaches laid down in the technical solutions for sealing gaskets of flange joints [9].

The second method involves the manufacture of a mold, but is characterized by waste-free production. For the production of gaskets for graphitizing electrode blanks $\varnothing 630 \times 2815$ mm (diameter \times length), a suitable mold made of C45 steel was developed and manufactured (Fig. 3).

The source material is bulk TEG with a bulk density of 250 kg/m³, so to make a gasket 20 mm thick with a density of 1000 kg/m³ and 1500 kg/m³ in the mold you need

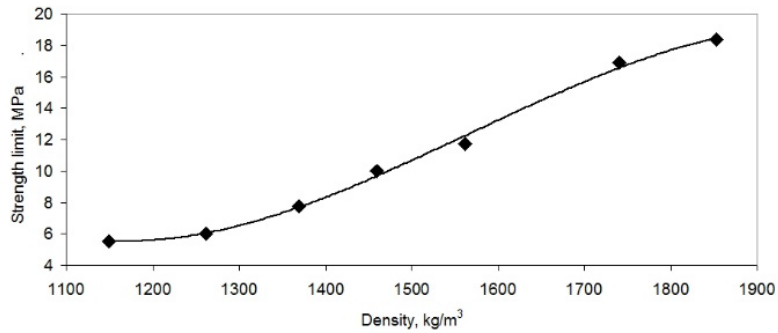


Fig. 4. The tensile strength of the contact gasket compressed from crushed graphite foil waste depending on the density of the gasket material (Russia Pat. No. RU2343112C1)

4. Results and discussion

Using the mathematical formulation of the problem of stress-strain state (SSS) and software [10], developed in the environment Mathcad [11] and built on the finite element method (FEM), the operational suitability of the developed mold was tested. Gmsh software was used to construct and discretize the geometric model of the mold on tetrahedral finite elements [12], and ParaView was used to visualize the results of calculations [13]. The results of SSS calculations of the developed mold for cases of pressing of electrocontact gaskets with TEG with a density of 1000 kg/m³ and 1500 kg/m³ are shown in Fig. 5 and Fig. 6, respectively.

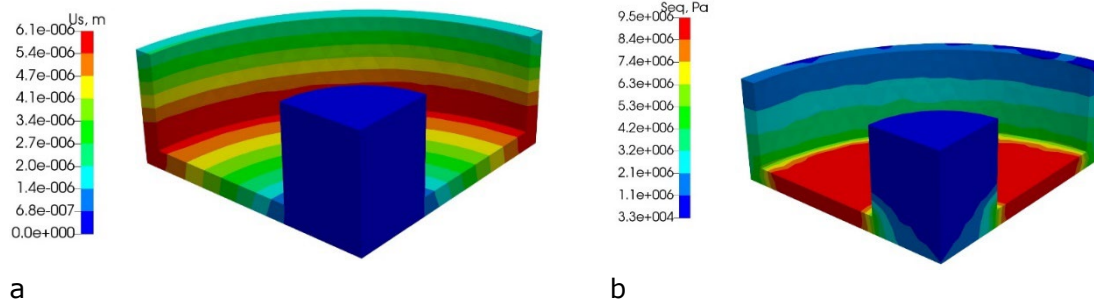


Fig. 5. The results of calculations of the SSS of the mold matrix during the pressing of electrical gaskets with a density of 1000 kg/m³: a – the field of the resulting movements; b – field of equivalent stress according to Mises; safety margin over 15

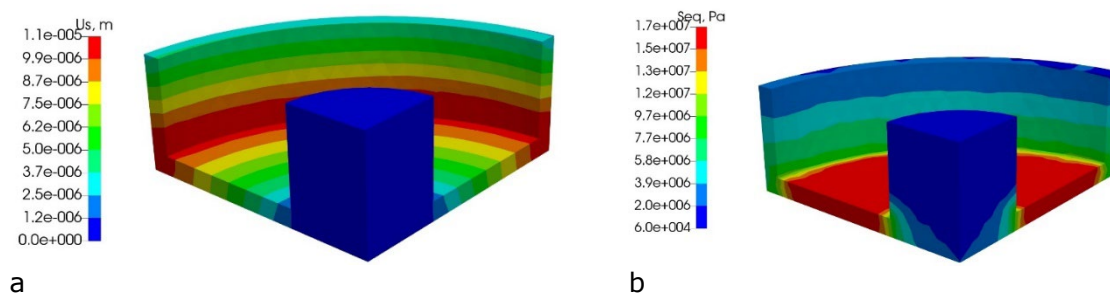


Fig. 6. The results of calculations of the SSS of the mold matrix during the pressing of electrical gaskets with a density of 1500 kg/m³: a – the field of the resulting movements; b – field of equivalent stress according to Mises; safety margin over 13.6

The analysis of the results of the numerical analysis of the SSS of the mold for pressing electrocontact gaskets shows that the margin of safety of the developed structure is 13.6–

15.0. This indicates that even taking into account the cyclicity of loads, which leads to a decrease in the strength limit of the metal [14], the developed design of the mold (see Fig. 3) should ensure reliable and long-term operation.

5. Conclusion

The requirements for electrical contact connections between the electrode blanks in the cores of the Castner furnace, which are mainly based on the physical and mechanical properties of the material for their manufacture.

On the basis of the formulated requirements the choice of material for production of electrocontact linings is made, their form and thickness are defined and selection of glue for their fixing on end faces of electrode preparations is executed. Thermo expanded graphite is proposed as a gasket material, and dextrin or aluminosilicate glue with the addition of graphite powder is proposed as an adhesive.

Two methods of forming electrocontact gaskets are proposed: the first – is to cut gaskets from a prefabricated sheet of TEG of the desired density; the second – in the waste-free pressing of gaskets from the original TEG with low density to the desired value of density.

The sketch project of a mold for formation of electrocontact linings is developed and the numerical analysis of the SSS of its design that confirms its operational suitability is executed.

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