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Research on Influence of the Furnace Chamber Aerodynamics on Ecological Indicators of Boiler Plants (Part 1: Model of a Low-temperature Swirl Furnace)

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Abstract

The paper presents the results of a study of the effect of organization of the aerodynamic structure of gas-fuel streams in the combustion chamber on the ecological parameters of the boiler plant. The technological method of decomposition of nitrogen oxides on the surface of carbon particles with the formation of environmentally safe carbon dioxide and molecular nitrogen in the case of low-temperature swirl combustion of solid fuel is considered. The model, algorithm, methodology and mathematical program for calculating the process of generation and conversion of nitrogen oxides in the combustion of solid fuel by low-temperature swirl technology have been developed and tested on the experimental data.

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1. Introduction

The main objective of "The ecological program" in the field of heat-and-power engineering is definition of ways and conditions under which reliable power supply of the existing and planned loads of consumers will not lead to increase in technogenic influence on environment. The accepted "Energy strategy of Russia" is oriented to increase efficiency of power production and carrying out policy of energy saving. Further increase in production of the electric power should be followed not only economic, but also ecological justification of expediency of use of

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different power sources, expansion of use of local fuel and energy resources, forming of the energy market for creation of the competitive environment in the field of production and consumption of energy resources.

Within many decades preference is given in large power to torch way of combustion of solid fuel [1, 2]. The researches conducted in VTI in the 30th years of the last century showed that combustion of dust fuel in chamber furnaces in comparison with its burning in layered furnaces causes high profitability process of burning at the minimum excess of air and losses from chemical and mechanical underburning [3].

However in process of growth of capacities of boiler installations and deterioration in fuel characteristics the shortcomings inherent in direct-flow coal-dust torch began to become clearer: the worsened conditions of burning of rather coarse particles of fuel in comparison with fine particles; availability of high-temperature kernel of torch in which ashes melt and owing to what there is danger of slagging of surfaces of heating of boiler installation, potential of explosion of installation owing to use of fuel [4], ground up in dust, generation in the intensive combustion zone of significant amount of nitrogen oxides [5, 6].

One of the perspective directions of use of solid fuel is the low-temperature swirl (LTS) technology developed in the early seventies at the Leningrad Polytechnic Institute (nowadays Peter the Great St. Petersburg Polytechnic University) under the leadership of professor V. V. Pomerantsev [7], and recommended now as alternative to coal-dust burning in direct-flow torch [8–11].

2. Principle and features of LTS technology

Aerodynamics of LTS-furnace is created by construction of the furnace camera where two zones of burning – swirl and direct-flow – are located on different height levels. The swirl zone occupies the volume of the lower part of the fire chamber from the mouth of the furnace funnel to the torches established in the aerodynamic overhang on the front wall. The movement in the swirl zone is created by interaction of the fuel-air mix flow coming to the fire chamber through torches and the flow of the hot air given to the fire chamber along its front slope through the lower blasting system. The direct-flow zone of burning is located over the swirl zone in the upper part of the fire chamber.

In LTS-furnace, mainly, burns out in swirl zone where repeated forced circulation of particles of fuel is organized that allows to level temperature pattern in furnace volume and to reduce temperature level in furnace (on average on 100–150 K) [12, 13]. Fuel burning happens to high performance at complete elimination of use of liquid fuel for torch illumination. At the same time temperature of gases in the furnace camera and almost completely decreases, problems of slagging of surfaces of heating are solved, the probability of high-temperature corrosion of screens due to decrease in temperature level and reduction of concentration of oxygen in furnace decreases. In the lower swirl zone, there is intensive dissipation of the generated nitrogen oxides on surface of the burning ash particles, and repeated circulation of fuel and ash particles leads to binding of sulfur oxides with mineral part of fuel [14]. LTS burning opens great opportunities for reduction of dimensions of boilers and reduction of metal costs to increase in intensity of processes of burning and heat exchange. Use of LTS technology allows to install new boilers in the existing construction cells, and sometimes to increase plant capacity. Which is especially important when replacing the worn-out equipment of combined heat and power plant (at their modernization).

3. Model of the LTS furnace process, generation and transformation of pollutants

The mathematical model of the boiler BKZ-210-13,8 (LTS) (see Fig. 1) considers designs at the organization of LTS technology and gives an opportunity to change them for optimization of constructive characteristics and operating conditions.

The model of furnace process is based on the diffusion and kinetic theory of burning, considers generation and transformation of gaseous pollutants, has possibility of change qualitative (type and composition of solid fuel, its grinding etc.) and quantitative characteristics of process (fuel usage, speeds of burner air, air of the lower and tertiary blasting etc.), and allows to carry out quantitative estimates of emissions of gaseous pollutants during a boiler usage.

Calculations of trajectories of the reacting particles were made by the numerical solution of the equation of the movement which is written down in projections to axes of the Cartesian system of coordinates which considers action on particle of two main forces – gravity and forces of aerodynamic resistance:

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