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The nitrogen oxide formation studying at natural gas combustion in non-circular profile furnaces of fire-tube boilers

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Abstract

The chemical reactions and mathematical model accompanying the thermal, prompt and fuel nitrogen oxides emergence are presented in the paper. The furnace profile changing is a type of passive methods making it possible to decrease NOx concentration by means of gas flow velocity increasing, average temperature of gas mixture in the furnace decreasing and through the recirculation processes. The graphical study results in the form of variables characterizing ecological efficiency are represented.

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Keywords: combustion; nitrogen oxides; thermal; prompt; fuel; furnace; fire-tube boiler

1. Introduction

In the process of social production a man influences the environment and this is one of the main current problems. The fossil fuel combustion process is connected with air pollution therefore the boiler operation efficiency is now considerably determined by the environmental requirements [1, 2, 3]. Nitrogen oxides NO_x are the main toxic components generated in the fuel combustion process [1, 3]. Nitrogen oxides which are approximately 10 times more dangerous than carbon monoxides, constitute the greatest danger under the fossil fuel combustion [2, 3].

During the fossil fuel combustion process in gas-tube boilers furnaces, nitrogen contained in the air and fuel actively interacts with oxygen to form nitrogen oxide NO, dinitrogen oxide N_2O, and nitrogen dioxide NO_2. The most of NO_x produced in the exhaust products combustion process (95-99 %) in gas-tube boilers furnaces accounts for ntrogen monoxide NO. Other nitrogen oxides are formed in less amount.

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The profiled furnaces are studied insufficiently. The data of the theoretical studies at the furnace profile shape changing; rectangular, square, circle, horizontal and vertical ellipses showed that the fire-tube boiler having the furnace with the vertical ellipse profile shape has NO minimum concentration at the furnace outlet. In relation to the circle, NO outlet concentration is lower and able to amount to 23 % [4]. However, there is no data about the major semi axis - minor semi axis ratio influence on the nitrogen oxides formation process.

2. The study subject (Model, Process, Device, Synthesis, Experimental procedure, etc.)

The study subject of nitrogen oxides formation is a fire-tube boiler having the vertical ellipse cross section shape furnace at the different major semi axis a - minor semi axis b ratio (Fig.1). The furnace with the circle cross-section shape is the base model, upon that the comparisons will be made with its characteristics.

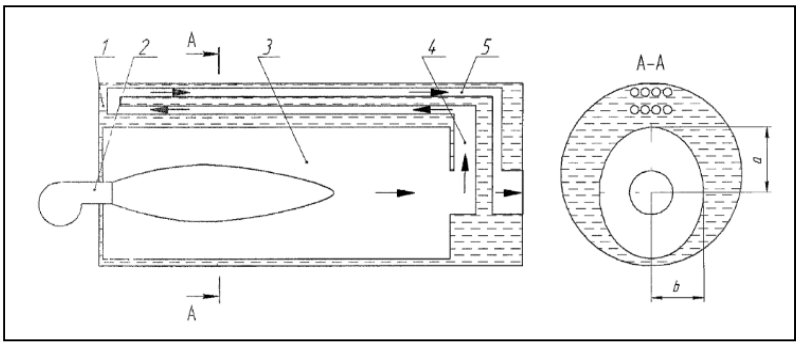

Fig.1. Then object scheme: 1 – water chamber; 2 – burner; 3 – furnace; 4 – reversing chamber; 5 – convection tube bank; a – major semi axis; b – minor semi axis.

Mass fraction $NO_{ellipse}$ / mass fraction NO_{circle} [1] ratio at the furnace outlet for the furnaces with vertical ellipse and circle shape cross section correspondingly was chosen as the values characterizing the furnace ecological efficiency.

3. Methods

The necessary stage of high-temperature processes modelling in power installation units is the chemical effect kinetic diagrams construction. In general, the kinetic diagram represents a set of elementary chemical reactions describing the working body components conversion process.

The gaseous fuel combustion is described by the following reaction: $CH_4 + 2O_2 = CO_2 + 2H_2O$.

In the given reactions one substance is combined with another one in strictly defined quantities. These quantities are regulated by the stoichiometric ratio for reversible and irreversible reactions being performed for one stage [4, 5],

$$\sum_{I=A,B,C,\dots}^{N_C} V'_{KI} I \Leftrightarrow \sum_{I=A,B,C,\dots}^{N_C} V''_{KI} I \qquad (1)$$

where N_C is the quality of reacting components;

V_{KI} are the stoichiometric coefficients for I-component in the elementary reaction K.

The velocity S_I of I-component forming is calculated as follows:

$$S_I = W_I \sum_{K=1}^{K} (V''_{KI} - V'_{KI}) R_K \qquad (2)$$

where W_I is the molar weight of I-component;