Introduction of low-temperature swirl technology of burning as a way of increase in ecological of low power boilers

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Abstract. Work is devoted to the solution of problems of energy efficiency increase in low power boilers at combustion of solid fuel. The technological method of nitrogen oxides decomposition on a surface of carbon particles with education environmentally friendly carbonic acid and molecular nitrogen is considered during the work of a low-temperature swirl fire chamber. Based on the analysis of physical and chemical processes of a fuel chemically connected energy transition into thermal, using the diffusive and kinetic theory of burning modern approaches the technique, mathematical model and the settlement program for assessment of plant ecological indicators when using a new method are developed. Alternative calculations of furnace process are carried out, quantitative assessment of nitrogen oxides emissions level of the reconstructed boiler is executed. The results of modeling and experimental data have approved that the organization of swirl burning increases overall performance of a fire chamber and considerably reduces emissions of nitrogen oxides.

1. Introduction

The use of organic fuel for electrical energy production and heat inevitably involves an essential aggravation of environmental problems [1]. Torch way of burning widely now in use of solid fuel causes high profitability process of burning at the minimum excess of air and losses from chemical and mechanical incompleteness of combustion [2]. At the same time in coal-dust boiler it is observed strong aerodynamic and thermal heterogeneity near torches. The design of the burner device, placement of torches in the furnace camera, the nature of the gases movement has the most significant effect on ignition of coal dust. In some cases, at not smoothly running furnace process there can be a carrying out from a fire chamber of a significant amount of not ignited fuel. At the same time torch burning is followed by serious shortcomings, the following is basic of which: the worsened conditions of burning of rather large particles of fuel in comparison with small particles; existence of a high-temperature kernel of a torch in which ashes melt and arises danger of boiler heating surfaces slagging; potential of explosion of an installation running on the fuel, finely ground in dust; generation of a harmful substances in an significant amount at the zone of a torch kernel [3].

When burning fuel-air mix in fire chambers of boilers the nitrogen oxides and sulfurs which are one of the most dangerous gaseous pollutants of products of combustion [4] are formed. For decrease in emissions in the atmosphere of nitrogen oxides and sulfurs from boiler units it is recommended to use, first of all, technological and constructive methods [5]. They consist in impact on process of burning by change of a design and operating modes of furnace devices, torches, and creation of conditions under which formation of toxic components of combustion gases of boilers will be minimum [6]. At the same time many methods, such as, step burning, installation of double-light screens, etc., is inapplicable in relation to boilers of low power because of insufficiency of height and small volume of a fire chamber.

One of technological methods of harmful substances emissions decrease while burning fuel, is the low-temperature swirl (LTS) technology of burning [7–10] developed at the Leningrad polytechnic institute (The St. Petersburg polytechnic university of Peter the Great) under the leadership of professor V.V. Pomerantsev [11, 12], and recommended now [13, 14] as an alternative to coal-dust burning in a direct-flow torch.

The work purpose is a research of generation and transformation of nitrogen oxides and sulfur during low-temperature swirl burning of solid organic fuel for decrease in their emissions, improvement of the regime and efficiency factors influencing on furnace process, industrial check of results in relation to a boiler of low power.

2. Materials and Methods

Aerodynamics of LTS-furnace is created by a design of the furnace camera and includes three pronounced areas (figure 1): The I – stream of fuel-air mix coming to a fire chamber through torches, the II – stream of hot air coming to a fire chamber through the system of the lower blasting (SLB), the III – swirl zone of a fire chamber formed at interaction of streams of I and II.

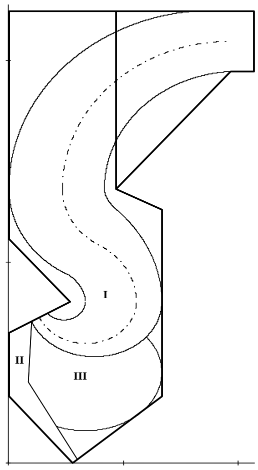

Figure 1. Organization of low-temperature swirl burning:
I – burner stream; II – stream of the lower blasting; III – swirl zone of LTS-furnace

In a LTS fire chamber fuel, mainly, burns out in a swirl zone where repeated compulsory circulation of fuel particles is organized that allows to level the temperature field in furnace volume and to reduce temperature level in a fire chamber (on average on 100...150 K) [15]. Combustion of fuel happens to high efficiency at a complete elimination of use of liquid fuel for torch illumination. At the same time temperature of gases in the furnace camera decreases and problems of heating surfaces slagging are almost completely solved, the probability of course of high-temperature corrosion of screens due to decrease in temperature level and reduction of concentration of oxygen in a fire chamber decreases. In the lower swirl zone, there is an intensive decomposition of the generated nitrogen oxides on a surface of the burning coke particles, and repeated circulation of fuel and ash particles leads to binding of oxides of sulfur a mineral part of fuel [16, 17]. LTS burning opens great opportunities for reduction of dimensions of boilers and reduction of expenses of metal owing to increase in intensity of processes of burning and heat exchange. Use of LTS technology allows to establish new boilers in the existing construction cells, and in certain cases – to increase the power of installation [18, 19]. Especially important it when replacing the worn-out equipment of combined heat and power plant (at their modernization).

The mathematical model of process of burning, generation and transformation of nitrogen oxides and oxides of sulfur, is presented in relation to the boiler of low power of BKZ-85-13 (figure 2).

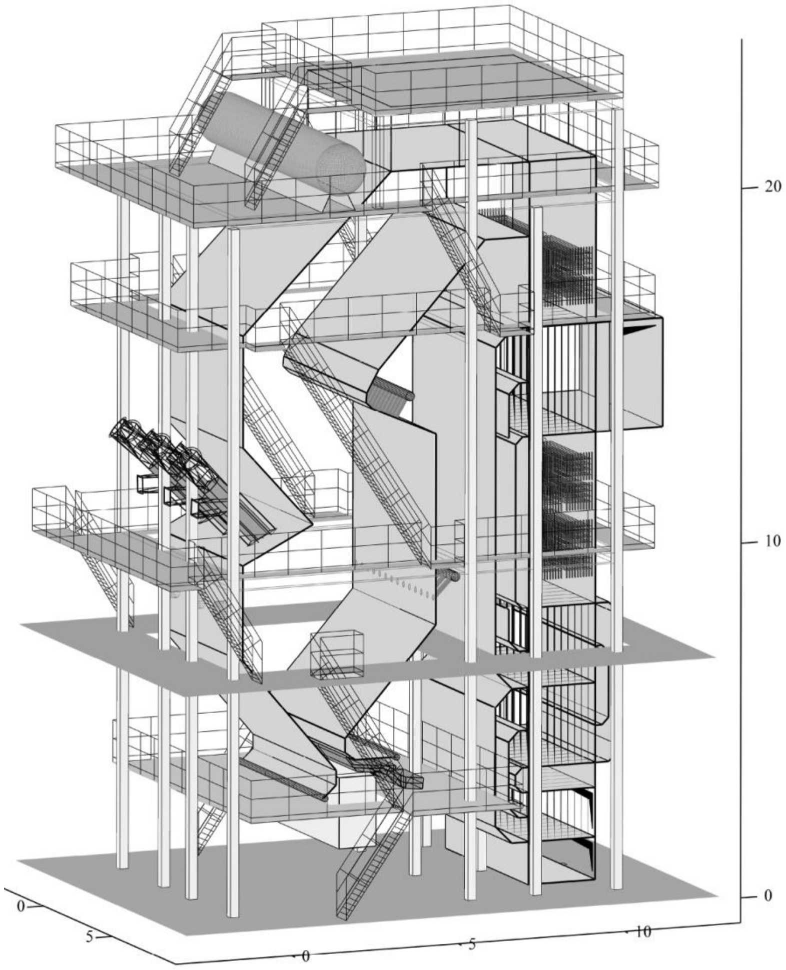

Figure 2. Mathematical model of a boiler BKZ-85-13 with low-temperature swirl technology of burning

Mathematical model of a BKZ-85-13 boiler (LTS) considers technical solutions at the organization of LTS burning and gives the chance of their change for optimization of constructive characteristics and regime parameters of work. After carrying out reconstruction increase in steam generating capacity of boiler installation up to 100 tons of steam per hour is supposed. Design characteristics of a boiler of BKZ-85-13 are provided in table 1.

The model of furnace process is based on the diffusive and kinetic theory of burning, considers generation and transformation of nitrogen oxides, has a possibility of change qualitative (a look and composition of solid fuel, its grinding and so forth) and quantitative characteristics of process (fuel consumption, speeds of burner air, air of the lower and tertiary blasting and so forth), and allows to carry out quantitative estimates of emissions of gaseous nitrogen oxides during the work of a boiler.

Calculations of trajectories of the movement 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 a particle of two main forces on a particle – gravity and forces of aerodynamic resistance:

Table 1. Characteristics of a boiler of BKZ-85-13

Parameter	Dimension	Coal
Steam generating capacity	t/h	100
Temperature of superheated steam	°C	280
Pressure of superheated steam	MPa	1.4
Feedwater temperature	°C	104
Settlement efficiency (gross)	%	89.65
Full fuel consumption	t/h	12.05
Heattension of furnace volume	MW/m^3	0.136
Fire chamber section heattension	MW/m^2	2.86
Temperature of gases at the exit from a fire chamber	°C	980
Temperature of the leaving gases	°C	115
Air temperature on an entrance in an air heater	°C	30
Temperature of hot air	°C	307
Coefficient of excess of air at the exit from a fire chamber	–	1.2
Mass concentration in combustion gases		
(under normal conditions and α=1.4): NO_x	mg/nm^3	470
SO_x	mg/nm^3	1200

$$\begin{cases} m\dfrac{dV_x}{d\tau} = \dfrac{cf\rho}{2}\left(W_x - V_x\right)\left[(W_x - V_x)^2 + (W_y - V_y)^2 + (W_z - V_z)^2\right]^{1/2} \\ m\dfrac{dV_y}{d\tau} = \dfrac{cf\rho}{2}\left(W_y - V_y\right)\left[(W_x - V_x)^2 + (W_y - V_y)^2 + (W_z - V_z)^2\right]^{1/2} \\ m\dfrac{dV_z}{d\tau} = \dfrac{cf\rho}{2}\left(W_z - V_z\right)\left[(W_x - V_x)^2 + (W_y - V_y)^2 + (W_z - V_z)^2\right]^{1/2} - mg \end{cases}, \quad (1)$$

where V and W – the speed of a particle and gas stream; m, f – respectively a weight and the area of a midelev of section of a particle; ρ_{gas} – density of a gas stream; $c = f(\mathrm{Re})$ – coefficient of resistance of the burning particles.

The sizes of fuel particles, their number on 1 kg of settlement fuel, weight within each fraction and the area of an initial surface of reaction, were by processing of a sieving curve of initial fuel (the Kuznetskii coal of brand "of SSR", R_{90} = 25 %, R_{200} = 4 %).

In case of giving in a fire chamber of particles of irregular shape, diameter of a sphere equivalent on volume, it was calculated on dependence:

$$\delta_{eq} = (6abc/\pi)^{1/3}, \quad (2)$$

where a, b, c – the characteristic linear sizes of particles of irregular shape.

For the accounting of particle size distribution of initial fuel the analysis of ways of the accounting of polydispersion of structure of a disperse phase when calculating various physical and chemical processes is carried out. With some degree of convention all known ways can be divided into two groups: it is necessary to carry ways of calculation which cornerstone splitting all range of particles into separate fractions with the subsequent calculation of dynamics of each fraction separately is to the first group; it is possible to carry the ways based on determination of density of probability of distribution of particles by the sizes with calculation of evolution of all system of particles in general to the second group. At the numerical solution of the tasks connected with burning of solid fuel, as a rule, the ways relating to the first group are used.

In the developed technique, Lagrange's method as the most exact is used at the description of process of burning of large particles [22]. The consumption of the natural solid fuel with polyfractional structure given to the furnace camera was recalculated for an equivalent expense of spherical particles. At the same time, equivalent fuel consumption has to have the same sieving curve, as well as initial. For performance of this condition, the sieving curve broke into N fractions (in the considered case N = 10 was accepted), each of which is characterized by the average diameter.

Distribution of particles of initial dust by the sizes was described by a Rozin-Rammler-Bennet formula:

$$R_{0i}=exp(-b\delta^{n}_{0i}), \tag{3}$$

where b and n – the skilled coefficients characterizing respectively a subtlety of a grinding and uniformity of grain structure.

Consideration of process of burning from diffusion and kinetic positions (see figure 3) allowed to make following system of the nonlinear differential equations of diffusion and kinetics [20]:

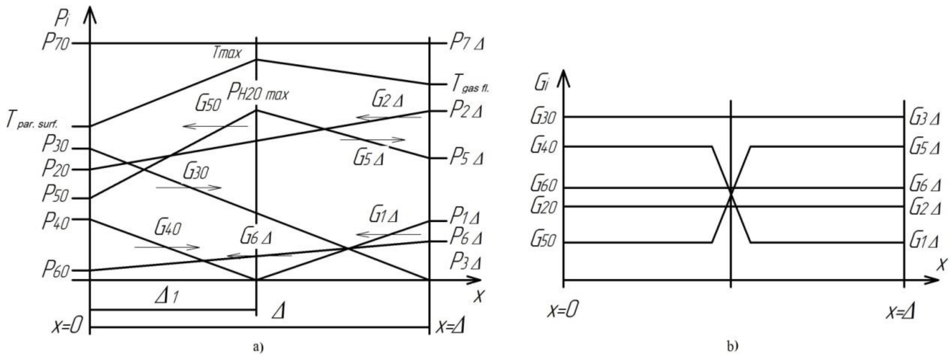

Figure 3. Distribution of partial pressures (a) and flows (b) of the components in the given film of coarse ash particle: 1 – O2; 2 – CO2; 3 – CO; 4 – H2; 5 – H2O; 6 – NO; 7 – N2; the "0" indexes – particle surface;

Taking into account the oxidizing and recovery reactions going on particle surfaces (considering decomposition of NO on carbon), and the homogeneous reactions proceeding within its interface (thermal effect in kJ/mol):

$$\begin{cases} dG_j = -(D/RT)\cdot(d^2 p_j/dx^2)dx \\ G_j = (\alpha_D/RT)\cdot(p_j - p_{j0}) \\ dG_i/d\tau = C_i \cdot k_i \end{cases}, \tag{4}$$

$$\left\{\begin{array}{ll} \multicolumn{2}{c}{\text{heterogeneous}} \\ \text{at "dry" gasification} & \text{at "wet" gasification} \\ 1.\ C + O_2 = CO_2 + 394.6 & 3'.\ C + H_2O = CO + H_2 - 130.4 \\ 2.\ 2C + O_2 = 2CO + 219.6 & 3''.\ C + 2H_2O = CO_2 + 2H_2 - 132 \\ 3.\ C + CO_2 = 2CO - 175.6 & 3'''.\ C + 2H_2 = CH_4 - 74.8 \\ \multicolumn{2}{c}{\text{homogeneous}} \\ 4.\ CO + O_2 = 2CO_2 + 570.2 & 4'.\ 2H_2 + O_2 = 2H_2O + 231.5 \\ & 4''.\ CH_4 + 2O_2 = CO_2 + 2H_2O + 891 \\ & 4'''.\ CO + H_2O = CO_2 + H_2 + 40.4 \end{array}\right. . \tag{5}$$

In addition, for the accounting of decomposition of nitrogen oxides on the surface of carbon, in system (5) reaction No. 5 is entered into consideration:

$$5.\quad 2\,NO + C = N_2 + CO_2 - 180.2, \tag{6}$$

and reaction No. 6 for the accounting of reaction of oxides of sulfur with CaO and MgO fuel ashes components:

$$6.\quad CaO + SO_2 + 0.5\,O_2 \rightarrow CaSO_4. \tag{7}$$

As a result of the solution of differential equations system, the expression for flow of the carbon disappearing from particle surface is received, (kmol/m^{2}s):

$$G_c = \frac{\alpha_D}{RT}\left[\frac{N_3}{1+N_3}p_{CO_2\Delta} + \frac{N_{3'}}{1+N_{3'}}\left(p_{O_2\Delta} + 0,5p_{H_20\Delta}\right) + \frac{N_5}{1+N_5}p_{NO\Delta}\right], \tag{8}$$

and at the same time to calculate decrease of particle weight and size on expressions:

$$dm/d\tau = dm_{W^r}/d\tau + dm_{volat}/d\tau + dm_c/d\tau,\ \text{kg/s} \tag{9}$$

$$dm_C/d\tau = -G_C \cdot M_C \cdot \pi \cdot \delta^2,\ \text{kg/(m}^2\cdot\text{s)} \tag{10}$$

$$d\delta/d\tau = -(2M_C/\rho_C)\cdot G_C,\ \text{m/s} \tag{11}$$

where M_C = 12 kg/kmol – the molar mass of carbon; $m = \pi/6\cdot\delta^3_{eq}\cdot\rho_C$ – mass of spherical particle; $f = \pi/6\cdot\delta^2_{eq}$ – the external surface area, m^2.

Distribution of concentrations of NO on the furnace section (concentrations field) in the known field of gas flow velocity, was defined by the numerical solution (scheme "against flow" [21]) of the differential equation of mass exchange in the presence of the source (NO generation zone):

$$\frac{\partial}{\partial\tau}(\rho\cdot C_{NO}) + \nabla\cdot(\rho\vec{w}C_{NO}) = \rho D_{NO}\nabla^2 C_{NO} + J_{NO}, \tag{12}$$

where C_{NO} – mass concentration of nitrogen oxides; $\vec{w}$ – gas flow velocity; D_{NO} – average effective coefficient of diffusion of NO in the mixture of furnace gases; J_{NO} – intensity of nitrogen oxides generation (NO source output).

Power of J_{NO} source is defined in the assumption of fuel nitrogen oxides generation (T_{max} < 1600 K) occurring at the volatile output stage and is solved from the solution of following equations system:

$$J_{NO} = \begin{cases} dN_{2i}/d\tau_i = k_{01}\exp\left[-E_1/(RT_i)\right]\left[N_i\right]^2 \\ dNO_{x_i}/d\tau_i = k_{02}\exp\left[-E_2/(RT_i)\right](1/T_i)\left[O_2\right]_i^{1.8}\left[N\right]_i \end{cases}, \tag{13}$$

where $[N]_i$ – concentration of atomic nitrogen.

Distribution of concentration of SO_2 on the fire chamber section (the field of concentration) at the known speeds of a gas stream, was defined by the numerical solution of the differential equation of a mass exchange:

$$\frac{\partial}{\partial\tau}(\rho\cdot C_{SO_2}) + \nabla\cdot(\rho\vec{w}C_{SO_2}) = \rho D_{SO_2}\nabla^2 C_{SO_2} + J_{SO_2}, \tag{14}$$

where C_{SO2} – mass concentration of oxides of sulfur; D_{SO2} – average effective coefficient of diffusion of SO_2 in mix of furnace gases) in the presence of the source member (a zone of generation of SO_2) which is written down in a look:

$$J_{SO_2} = dG_{SO_2} / d\tau = (G_C \cdot S^{daf}) / (V \cdot 100), \tag{15}$$

where J_{SO2} – power of a source of SO_2, kg/m^{3}s; G_C – speed of burning out of carbon of coke, kg/s; S^{daf} – the content of sulfur in the dry ashless mass of fuel, %; V – volume of a settlement cell, m^3.

By the provided technique, algorithm and the program of calculation is made, its debugging and testing is made. The program has block creation that gives the chance of carrying out calculations and the analysis of separate components of process by separate blocks removing or adding.

3. Results

Calculations of process of burning to a fire chamber are carried out to LTS in relation to the boiler of BKZ-85-13 of Southern Thermal Station Municipal Unitary Enterprise of Rubtsovsk planned for reconstruction for LTS technology of SSR brand Kuznetsk coal combustion. Characteristics of settlement fuel are provided in table 2.

Table 2. Average characteristics of the Kuznetsk stone coal of brand of SSR of Kiselevsky coal mine

Characteristics of working mass of fuel, %			
Humidity, W_t^r			14.5
Ash-content, A^r			9.8
Sulfur, S^r			0.26
Carbon, C^r			63.9
Hydrogen, H^r			3.2
Nitrogen, N^r			1.44
Oxygen, O^r			6.9
Heat of combustion of Q^r_i, MDzh/kg (kcal/kg)			23.91 (5710)
Exit flying, V^{daf}, %			24.5
Coefficient of a grindability, k_{lo}			1.5
Temperature characteristics of ashes, °C			
Temperature began t_A ashes deformations			1150…1200
Temperature began t_B ashes softenings			1300…1350
Temperature of the beginning of a fluid condition of t^C ashes			1350…1450
Chemical composition of ashes, %			
SiO_2	49.7	Na_2O	0.4
Al_2O_3	24.4	TiO_2	1.0
Fe_2O_3	16.1	P_2O_5	0.52
CaO	5.2	MnO_2	0.06
MgO	1.4	SO_3	3.1
K_2O	1.8		

Projections of speed vectors to coordinate axes decided in nodal points (figure 4 (a)), on the subsequent approximation for finding of a vector of speed in a required point according to the four-dot scheme (figure 4 (b)).

Calculation of a moving carbon particle burning (dependence 8) was carried out taking into account quantity of the reacting components (O_2, CO_2, H_2O) defined from fields of concentration of these components characteristic of LTS of fire chambers (figure 5). Concentration of nitrogen oxides and sulfur were in the settlement way.

The sizes of fuel particles, their number on 1 kg of settlement fuel, weight within each fraction and the area of an initial surface of reaction, were by processing sieving curve (figure 6) of initial fuel (the Kuznetsk coal of SSR, R_{90} = 25 %, R_{200} = 4 %) also are presented in the figure 7.

The analysis of temperature level in LTS showed to a fire chamber of a boiler of BKZ-85-13 received by zonal thermal calculation that settlement temperatures (figure 8 (a)) do not exceed the surfaces of heating, admissible on a condition of slagging, and do not promote emergence of thermal nitrogen oxides (T_{max} < 1800 K).

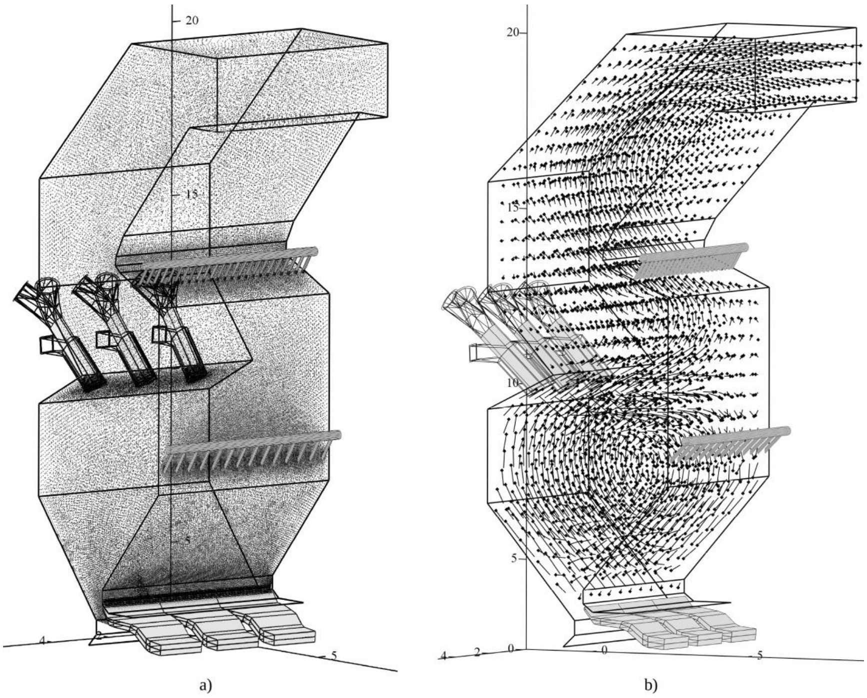

Figure 4. Nodal points (a) for calculation of an aerodynamic picture of currents and vectors of air-gas streams speed (b) in volume of LTS-furnace of a BKZ-85-13 boiler

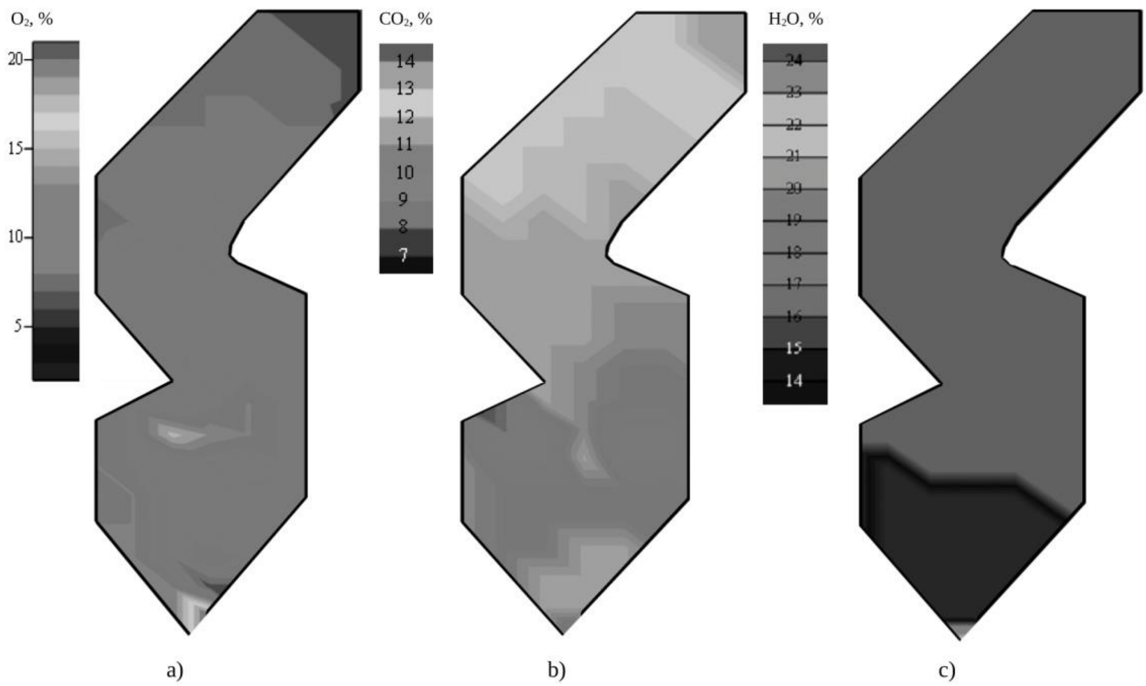

Figure 5. Concentration of the main reacting components in a LTS fire chamber of a BKZ-85 boiler: a) – oxygen, %; b) – carbon dioxide, %; c) – water vapor, %

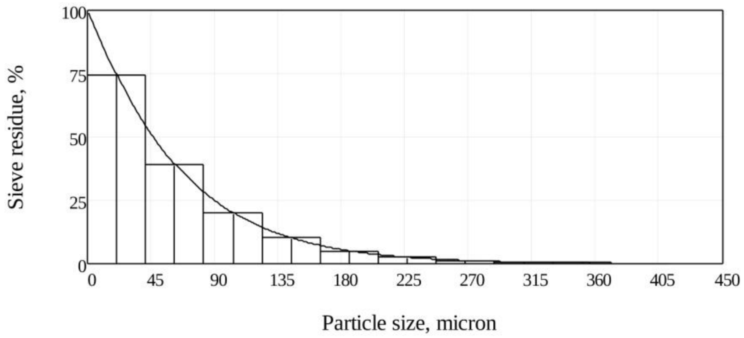

Figure 6. Processing of grain size distribution curve of the Kuznetskii coal of brand "SSR": (W^r = 14.5 %, A^r = 9.8 %, R_{90} = 25 %, R_{200} = 4 %) per 1 kg

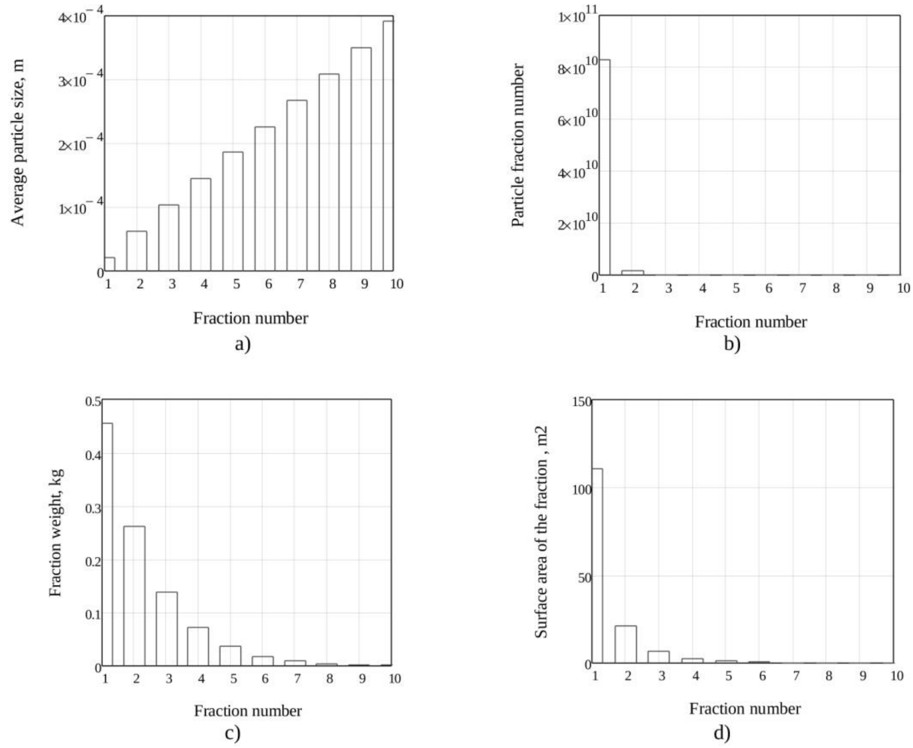

Figure 7. Results of a sieving curve processing (on 1 kg of initial fuel):
(a) – average sizes of fuel particles, m; (b) – quantity of particles in each fraction, piece; (c) – mass of particles of each fraction, kg; (d) – initial surface area of fraction, m^2

The analysis of initial fuel composition showed that in view of high content of nitrogen in working weight (N^r = 1.44 %), results of settlement definition of nitrogen oxides final concentration, while concentration in the leaving gases of sulfur oxides (are of interest at its content in fuel (S^r = 0,26 %), defined from balance of reaction of burning of sulfur ($S + O_2 = SO_2$), will not exceed the required standards [22].

Settlement fields of concentration of nitrogen oxides and oxides of sulfur were from the solution of the differential equations (12), (14) in the presence of the source member for each of elementary cells of an irregular curvilinear grid which maximum size does not exceed 0.2×0.2×0.2 m (figure 8 (b)). Generation of pollutants in elementary cells of a fire chamber (source members), was defined by summation of number of NO and SO_2 allocated in these cells during stay in them of the reacting particles.

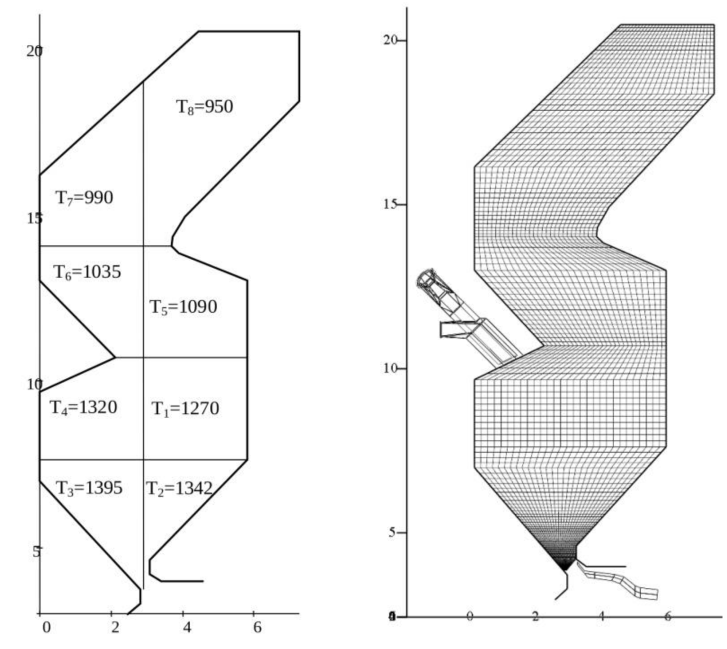

Figure 8. (a) – temperatures in zones of LTS-furnace of a boiler BKZ-85-13, °C;
(b) – elementary cells in a LTS fire chamber of a BKZ-85-13 boiler

The solution of the equation of the movement (system (1)) received trajectories of the reacting fuel particles in volume of a fire chamber (figure 9 (a)), time of their burning is defined, source members of generation of nitrogen oxides and sulfur for the equations (12), (14) are found. Results of the settlement analysis are presented in relation to the fire chamber section passing through an axis of the central torch (figure 9 (b)), at the same time initial coordinates of particles at the exit from the fuel channel of a torch were set in a random way.

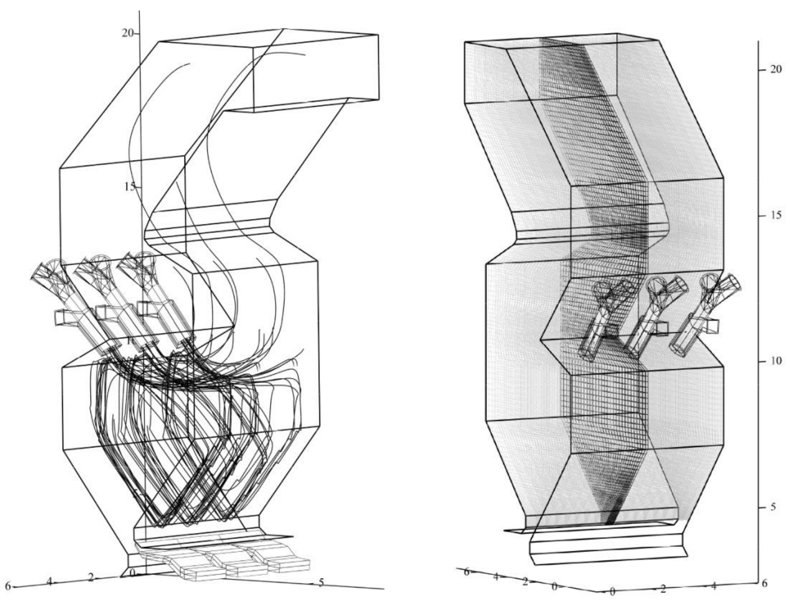

Figure 9. Trajectories of the movement of the reacting particles (a) – and control section
(b) – for the analysis of calculation results

In relation to sieving characteristics of the figure 6, time of full burning out of fuel particles depending on their initial size made from 0.35 to 6.2 about (figure 10).

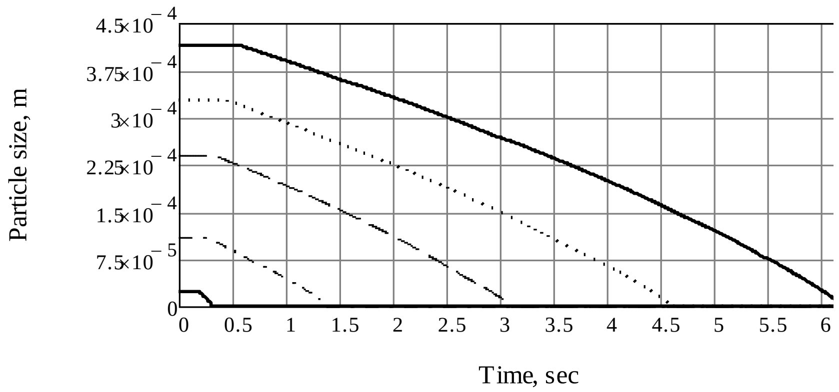

Figure 10. Burning out of particles of fuel in a LTS fire chamber of a boiler of BKZ-85-13

Combustion of bulk of fuel happens in the lower swirl zone of a fire chamber. Small particles (δ = 20...30 microns) during burning do in it less than one turn, and large (δ = 390... 412 microns) manage to make 4... 5 turns. Destruction of particles at their blow about screens of the furnace camera, in view of a high subtlety of a grinding of fuel, does not happen.

Generation of nitrogen oxides in the lower swirl zone (figure 11 (a)) increases their local concentration that improves conditions of further reaction with a carbon surface. For the considered conditions decomposition of nitrogen oxides on a surface of the burning coke particles reaches 30 % and depends on particle size distribution and time of stay of fuel in NVZ. Increase in an indicator of polydispersion (n = 0.8...1.6) leads to insignificant decrease in number of the decayed NO in view of what more uniform grinding should give preference. The formed oxides of sulfur (figure 11 (b)), react with CaO and MgO which are contained in fuel ashes.

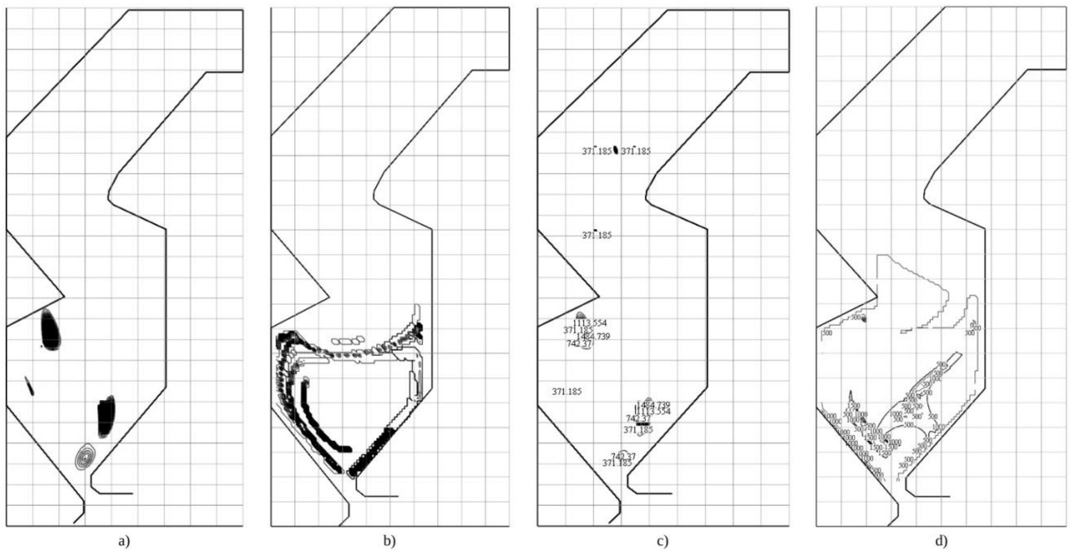

Figure 11. Zones of intensive generation (a, b) and average settlement field of concentration (c, d) nitrogen oxides and oxides of sulfur

The resulting concentration of nitrogen oxides at the exit from a fire chamber taking into account total impact on their generation and transformation in the course of burning: the lowered temperatures in the lower swirl zone, tightened a mixture formation and ignition of fuel, the lowered concentration of an oxidizer in NVZ and its step supply, and also decomposition of the formed nitrogen oxides on a surface of coke particles were made by 350... 400 mg/nm^3 (figure 11 (c)) that on 40... 50 % are lower, than when burning according to the scheme of a direct-flow coal-dust torch. Generation of oxides of sulfur is maximum in zones of intensive burning out of carbon (figure 11 (a)). To an exit from NVZ it is leveled and in a direct-flow part of a torch remains practically without change at the level of ~ 500 mg/nm^3 (figure 11 (d)).

Thus, results of the carried-out calculations confirmed a possibility of combustion of the Kuznetsk coal in a LTS fire chamber of a boiler of BKZ-85-13 with full implementation of the existing standard requirements for the level of emissions of harmful substances [22] that gave the grounds for realization of LTS technology on Southern Thermal Station Municipal Unitary Enterprise of Rubtsovsk.

4. Discussion

Tests of a boiler after modernization were carried out according to a technique [23] at combustion of the Kuznetsk coal of brand "of SSR" of Kiselevsky coal mine which average structure is brought in table 2. Technical characteristics of coal during tests changed in the following limits: humidity of W^r_t =11.2…15.0 %, ash-content A^r = 18.3…29.6 %; exit of flying V^{daf} = 24.3…27.5 %; specific heat of combustion of Q^r_i = 17.7…21.1 MDzh/kg (4230…5050 kcal/kg). The particle size distribution of dust varied by means of directing separator device within change of the full rest on a sieve of 90 microns from R_{90} = 9 … 10 % to R_{90} = 17 … 18 %.

Tests were carried out on one and two dust systems during the work of a boiler without torch illumination by fuel oil. The maximum profitability of a boiler is reached during the work on two dust systems. In the range of steam loadings of D = 80…126 t/h the efficiency (gross) of a boiler made η = 91.2…89.3 %. At the same time work of a boiler is most preferable at D = 80…105 t/h. The optimum coefficient of excess of air for the boiler superheater for this range of loadings makes 1.18…1.26, and efficiency (gross) – η = 90.5…91.2 %. In all studied range of work of a boiler temperature of superheated steam met requirements and made 250…280 °C. Visible influence grinding tannins on change of pyrometry of a fire chamber and mechanical underburning is not revealed. The fire chamber pyrometry at a rated load showed that the swirl zone of a fire chamber is enough isothermal. Temperature of a torch changes within 1250…1400 °C, at the exit from a fire chamber ~ 950…960 °C that practically coincides with calculated values (figure 8 (a)).

Thus, as a result of BKZ-85-13 boiler modernization with a transfer to LTS burning the following results are received:

1. The nominal steam generating capacity of a boiler is increased to 100 t/h (for 18 %) and its steady functioning on the Kuznetsk coal of brand of SSR in the range of loadings of $D = (0.5... 1.05)\cdot D_{nom}$ without torch illumination fuel oil.
2. Efficiency (gross) a boiler in the working range of loadings of $D = (0.8... 1.05) \cdot D_{nom}$ makes η = 90.5... 91.2 %.
3. Emissions of gas pollutants (nitrogen oxides and oxides of sulfur) do not exceed the established requirements at combustion of design fuel (the Kuznetsk coals of brand of SSR) in boilers of rated capacity (D < 420 t/h).

5. Conclusion

Advantages of introduction of a low-temperature swirl way of burning on boilers of low power are also experimentally shown to settlement. Are developed for carrying out optimizing calculations: model, an algorithm, the technique and the mathematical program of calculation of process of generation and transformation of nitrogen oxides and sulfur when burning solid fuel allowing to predict their emissions. Calculations for the offered technique confirmed advantages of the transfer of a boiler of BKZ-85-13 of Southern Thermal Station Municipal Unitary Enterprise of Rubtsovsk to LTS technology as a result of which modernization requirements of the modern nature protection legislation are provided, and the

LTS technology can be considered as a perspective technological method of increase in ecological indicators of boilers of low power.

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