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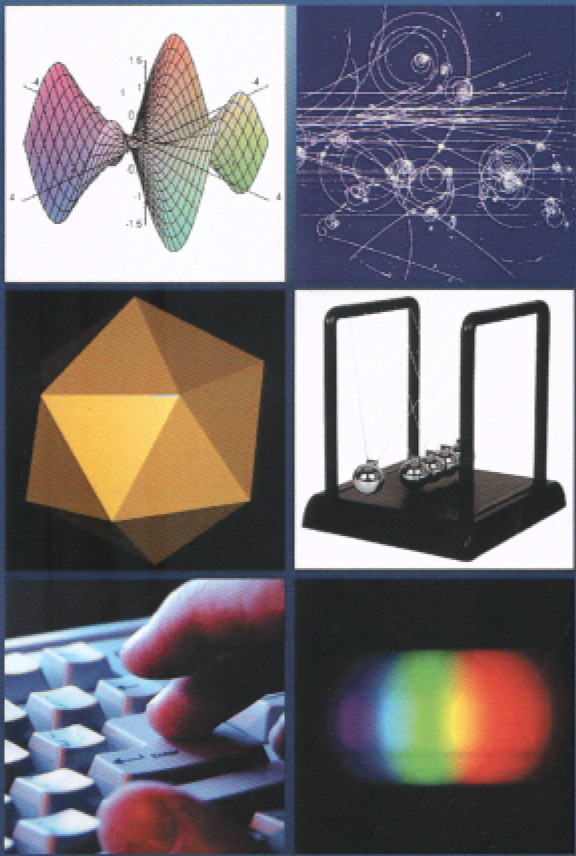

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Application of electron-beam technology to reduce anthropogenic load of thermal power plants

Abstract. This article evaluated the level of air pollution during the combustion of Karaganda coal in thermal power plants. The technical analysis of coal is lead and parameters of quality of coal are defined. With the use of the "Era-Air" software complex designed for solving a wide range of tasks in the area of atmospheric air protection, the complex indicators of average annual pollution in the atmosphere of the city Shakhtinsk were calculated, maximally different emissions of ash, sulfur oxides, carbon, nitrogen, resulting from the burning of Karaganda coal at thermal power plants. It is established that a complex index of pollution of atmospheric air of the city Shahtinsk more than two times higher than index of pollution, calculated for five types of pollutants. Currently available methods of reducing greenhouse gases into the atmosphere from coal combustion based on electron beam technology. Electron-beam technologies are aimed at changing the physicochemical properties of the combusted fuel with objective of increase of efficiency and completeness of coal combustion. Preliminary electron beam processing of coal leads to decrease in emissions into the atmosphere, reduces the amount of ash and slag, and reduces the maximum single-time emissions.

Key words: thermal power plants, high ash coal, maximum one-time emissions, surface concentrations, electron-beam processing.

Introduction

Air pollution – a serious environmental problem of Kazakhstan, especially in the industrial areas become by the centers of accommodation of the industrial enterprises and located in industrial areas. The basic volume of emissions of a dust, sulfur dioxide and nitrous oxide are accounted for by three main sectors of Kazakhstan: electric power industry with use of the mineral fuel, processing and mining branches and transport [1].

The greatest emissions of dust, sulphur dioxide and nitrogen oxide generates electric power industry, as well as heating plants, i.e. combustion sources natural fuel [2]. They make the most significant contribution to total emissions of pollutants into the atmosphere – 40% of total emissions, including 50% of particulate emissions, 47% of sulfur dioxide emissions and 60% of nitrogen oxide emissions [3]. A significant part of emissions is due to the use of poor quality coal and absence of the effective equipment for the control of pollution in power plants and district heating plants.

In recent years, Kazakhstan has seen a significant increase in air pollution. The substances polluting air increase the frequency of diseases and thereof lead to drawing of direct and indirect damage to national economy in the form of expenses for services of healthcare and decline of productivity of work. The republic's emission standards are much higher than European [4]. Therefore, to improve air quality in Kazakhstan should consider establishing more stringent standards on emissions of dust, sulphur dioxide and nitrogen oxide.

Currently, various methods of utilization of greenhouse gases contained in the emissions of enterprises are widely applied. However, it may be appropriate decrease in emissions due to improvement of quality of combusted fuel, increasing the efficiency of its combustion process.

Thus, the purpose of this article is to quantify maximum one-time emissions and surface concentrations of pollutants from a thermal power plant when burning irradiated and non-irradiated Karaganda coal.

Materials and Methods

As object of research was selected Karaganda coal, burned in the combustion chamber of the boiler BKZ-75, established at Shakhtinskaya CHP (Kazakhstan) [5].

To modify the quality of the Karaganda coal, experiments on the radiation treatment of coal were carried out, carried out on the electronic accelerator ILU-6. The accelerator generated electrons with energy of 1.3 MeV, the dose rate varied from 0.19 to 0.33 Mrad / s, the total absorbed dose varied from 10 to 200 Mrad. The temperature of the coal layer thickness 7 mm was controlled using thermocouples and supported between 60-70 and 250-260^{0}C. Gaseous products released during radiolysis were collected in a gasometer and analyzed on a chromatograph. The composition of coal after radiation exposure was studied by chemical elemental analysis and OS spectroscopy [6]. The general view of accelerator ILU-6 is shown in the Figure 1. The main characteristics of the burned Karaganda coal and coal that has passed the electron-beam processing are shown in Table 1.

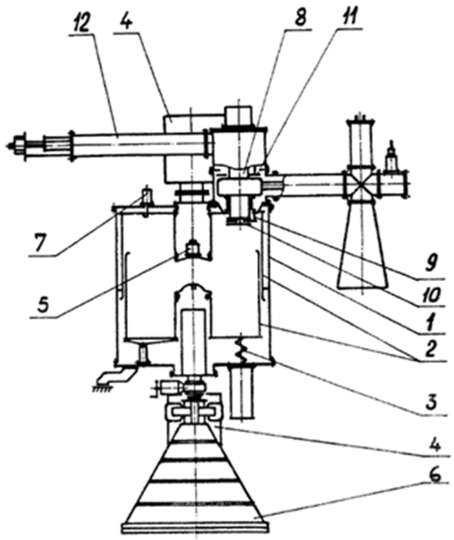

Figure 1 – The general view of the ILU-6 accelerator.
1 – vacuum volume, 2 – the resonator, 3 – choke of the lower half of the resonator, 4 – magnetic discharge pumps, 5 – electron injector, 6 – the venting device, 7 – measuring loop, 8 – lamp of the generator, 9 – pillar of a loop of communication, 10 – vacuum loop coupling capacitor, 11 – moving plate of feedback capacitor, 12 – cathode loop

Table 1 – The main characteristics of the burned Karaganda coal and coal that has passed the electron-beam processing

Fuel	W %	V_{daf} %	S_d %	A_d %	C_{daf} %	H_{daf} %	N_{daf}%	O_{dafd} %	Q MJ/kg
non-irradiated	10.6	22	1.04	35.1	43.21	3.6	1.21	5.24	18.56
radiated	8.4	16	1.02	31	45	4.06	1.20	6.37	18.2

In this paper are carried out researches on influence of electron beam processing of coal on increasing the efficiency of its combustion and reducing emissions of harmful substances into the atmosphere. The calculation of the maximum values of surface concentrations of harmful substances in the atmospheric air was performed in the "Era-Air" software package [7]. The "Era-Air" software package is intended for the decision of a wide class of problems in the field of air protection connected with calculations of atmospheric contamination.

For the calculation the analytical method was used using the accepted data analysis technique [8]. For calculation of total emissions of solid particles, the values of the required values for each fuel are selected in accordance with international standards and reference data of the standard method for calculating boilers in accordance with the calorific value, capacity of boilers:

$$M_S = B\frac{A^r}{100-G_{entr}}\alpha_{entr}(1-\eta_3), (\mathrm{g/s}) \quad (1)$$

here B is the consumption of natural fuel, t/year (g/s);

A^r – ash content of fuel on the working mass, %;

α_{entr} – the proportion of ash carried away by gases from the boiler;

η_3 – fraction of solid particles trapped in ash collectors;

G_{entr} – the content of combustible in the entrainment,%.

Calculation of emissions of nitrogen oxides: when burning solid fuel combustion [9]:

$$M_{NO_x} = B_p Q_i^r K_{NO_x}^G \beta_r k_p, (\mathrm{g/s}) \quad (2)$$

where B_p – estimated fuel consumption, t/year;

Q_i^r – l–ower heat of combustion of fuel, MJ/kg;

$K_{NO_x}^G$ – specific emission of oxides depending on the type of fuel burned;

β_k – dimensionless coefficient, taking into account the principal design of the burners;

β_t – dimensionless coefficient, taking into account the temperature of the air supplied for combustion;

β_k – dimensionless coefficient that takes into account the effect of excess air on the formation of oxide substances;

β_r – is a dimensionless coefficient that takes into account the stepwise introduction of air into the combustion chamber;

k_p – conversion factor (when determining emissions in grams per second is 1, in determining emissions in tons per year is 10^{-3}).

Calculation of sulfur oxide emissions [10]:

$$M_{SO_2} = 0.02BS^r\left(1-\eta'_{SO_2}\right)\left(1-\eta''_{SO_2}\right), (\mathrm{g/s}) \quad (3)$$

where B is the natural fuel consumption, t/year (g/s);

S^r – sulfur content in fuel for the working mass,%;

η'_{SO_2} – the proportion of sulfur oxides bound by fly ash in the boiler;

η''_{SO_2} – the proportion of sulfur oxides trapped in a wet ash trap along with the trapping of solid particles.

Calculation of carbon monoxide emissions [11]:

$$M_{CO} = 10^{-3} B C_{CO}\left(1-\frac{q_4}{100}\right), (\mathrm{g/s}) \quad (4)$$

where C_{CO} is the yield of carbon monoxide during fuel combustion, g/kg;

q_4 – heat loss due to mechanical incompleteness of fuel combustion,%.

Specific emissions of pollutants are calculated on the basis of the known amount of emissions per unit time and the corresponding fuel consumption spikes[12-13]. The specific release of the $i-th$ substance can be determined by the unit of heat introduced into the furnace (g/MJ) or expressed as the concentration of this substance in 1 m^3 of flue gases, taken under normal conditions, and the excess air factor α= 1.4.

Results and Discussion

In the given work total emissions of harmful substances according to characteristics of a boiler have been calculated. Steam boiler factory brand BKZ-75 – performance 75 t/h (51.45 Gcal/h), the temperature of superheated steam 440 C and the pressure of superheated steam 39 kgf/cm.

The results of the calculation of gross emissions (t/year) and specific emission (g/s) of pollutants are given in the Table 2. When burning fossil fuels n an atmosphere are thrown out carbon oxides, nitrogen and sulfur dioxide. According to the hygienic requirements set maximum-permissible concentration (maximum concentration limit, mg/m^3) of harmful substances polluting the atmospheric air are established. Maximum permissible concentration are accepted according to [14] and resulted in Table 3.

It has been established that when burning Karaganda coal, a large amount of pollutants are emitted into the atmosphere, the concentration of which exceeds the maximum one-time and daily average concentrations of impurities.

Our calculations show that average daily concentrations of pollutants exceed maximum permissible concentrations (concentration not having adverse effects on human health). From this we can conclude that will worsen human health (environmental condition). Therefore, it is necessary to reduce the anthropogenic load on the ecosystem.

Table 2 – Calculation of gross emissions (tons/year), specific emissions (g/s) of pollutants and average daily surface concentrations (mg/m^3)

Fuel	Harmful substances		
	CO	NO_2	SO_2
	Gross emissions, t/year		
Karaganda coal (non-irradiated)	120.3	7.4	12.72
Karaganda coal (irradiated)	100.4	7.6	10.56
	Specific emissions, g/s		
Karaganda coal (non-irradiated)	3.8	0.23	0.40
Karaganda coal (irradiated)	3.18	0.24	0.33
	Average daily surface concentrations, mg/m^3		
Karaganda coal (non-irradiated)	9.1	0.1	0.24
Karaganda coal (irradiated)	8.3	0.7	0.20

Table 3 – Maximum permissible concentration (maximum concentration limit) of polluting substances in atmospheric air of localities

№ code	The name of substance	The formula	The value of maximum concentration limit (mg/m^3)		Hazard class
			maximum one-time	average daily	
1	Carbon oxide	CO	0.05	0.15	4
2	Nitrogen (II) oxide	NO_2	0.04	0.85	2
3	Sulfur (II) oxide	SO_2	0.03	0.005	3

Conclusion

The following conclusions can be made from the research:

– Preliminary electron beam processing of coal leads to decrease in emissions in an atmosphere, decrease in emissions in an atmosphere, and reduces maximum-one-time emissions (see Tables 1, 2) at least from 0.6% up to 9% for different greenhouse gases.

– Electron beam processing is an environmentally friendly non-reagent way to control the quality of the burned fuel. To obtain a significant technological effect, treatment with doses up to 50 Mrad is necessary. The given dozes can be recruited for 4-5 seconds. The environmental purity of electron-beam processing is due to the fact that the irradiated coal does not have induced radioactivity, because the energy of accelerated electrons are ten times less energy electrons provoking the occurrence of nuclear chemical transformation in the irradiated material. When exposed to electrons of this energy, there are processes associated with the excitation of valence electrons, and unusual valence states can occur, chemically active particles, ions, and other.

– Thus, the electron beam method allows you to change the processes of burning coal that have undergone preliminary electron beam processing. Given the high performance of modern electron accelerators, preliminary calculations show the economic integrity of using electron-beam processing of coal in practice.

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