Research of the combustion of low-grade Kazakhstan coal in combustion chamber of the real energy facility

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Abstract— Thermal Physics problems arouse great interest to study with greater practical value, also covering such important branches of science, such as physics of combustion and explosion, power system and its economic and environmental aspects. Steady interest from the application, and theoretical perspectives cause questions associated with increased efficiency of energy use with simultaneous solving an ecological problems. In the atmosphere of Kazakhstan released substances such as carbon monoxide, nitrogen oxide, nitrogen dioxide, dust of lead, sulfur dioxide, etc., which cause significant harm to the human body. For example, the total CO_2 (carbon dioxide) emissions from fuel combustion per capita emissions with electricity and heat allocated to consuming sectors in 2009: for Kazakhstan 11930 $kgCO_2$/capita, compared to the neighboring countries Kyrgyzstan 1326 $kgCO_2$/capita, Uzbekistan 4047 $kgCO_2$/capita, Russian Federation 10800 $kgCO_2$/capita, China 5138 $kgCO_2$/capita [1]. In this regard, it is necessary not only economically profitable to produce electricity, but also closely monitor the concentration of these substances in the atmosphere.

The computational experiment was performed on a real energy facility. The selected object to study was the combustion chamber of the boiler PK-39 to the power 300 MW, steam capacity 475 t/h. The boiler installed on Yermakovskaya plant (Kazakhstan). As a result of 3-D modeling of the processes of burning natural fuels (Ekibastuz coal) in the areas of real geometry (boiler PC-39) we obtain a description of the process as the fields of temperature, concentration of combustion products, including harmful substances and turbulent characteristics around the combustion space for different operational conditions of the process. The calculation area for modeling and carrying out computational experiments was created with useful program complex PREPROZ.

***Keywords*—** Combustion, ecology, harmfulness, heat- and mass transfer, influence degree, modeling, numerical research, turbulence.

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I. Introduction

Numerical modeling of heat and mass exchange processes are now becoming to have increasingly important role due to the fact that modern science requires information on such processes, as the experimental study in which laboratory or natural conditions is very difficult and requires a lot of material costs, and in some cases even impossible. Recently, in the study of heat and mass transfer was the transition from solutions of individual specific problems to set of computational experiments involving a large class of phenomena in a wide range of determining parameters.

This creates whole complexes of programs that allow the numerical studies of the most complicated phenomena which include in particular the processes of convective heat transfer in high-temperature and chemically reacting flows in the presence of rapid physical and chemical transformations of substances. In recent years in designing and modernization of industrial furnaces and combustion chambers are widely used the high-speed computer technology, based on mathematical modeling of thermal-gas dynamics in a chamber space (combustion, heat and mass transfer). For this purpose, developed and used commercial packages of universal software that use the latest computer technology, mathematics, combustion, heat and mass exchange. At present the use of numerical methods in this area is becoming more acceptable and large problems become more appealing and crucial. In science and technology advantages of mathematical modeling are obvious: the optimization of the design, reduction of expenses for working off, reduction of operating costs, etc.

The main subject of researchers devoted to the utilization of the energy sources in more efficient and economical way. Heat transfer problems pertaining to the combustion in industrial furnaces are of great importance to the engineering designer of boilers and steam generators.

So using a computational program we create a geometric model, where each wall of the combustion chamber is described separately in the form of numerical codes. Input and output are defined primarily as a type of hole, and then set the coordinates of the spatial position of the burners on certain walls. Hole Burner (input) is described as concentric circles (for round burners), the output - in the form of the rectangle with the corresponding coordinates in space. In this paper

when creating a geometric model, circular holes were replaced with equal rectangular area, which also affected the accuracy of the calculations. In accordance with a given geometry we created the lattice for numerical simulation as shown in Fig. 1.

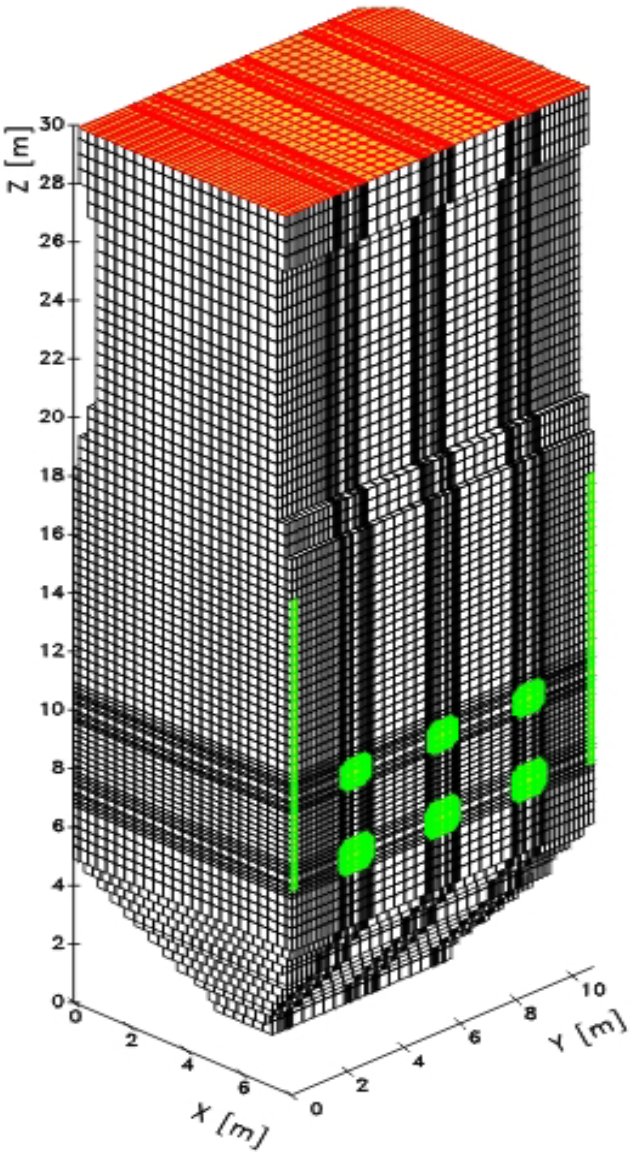

Fig. 1 general view of the combustion chamber of the boiler PK-39

II. Problem Formulation

Most devices that use the combustion process, is usually turbulent. Temperature, concentration of reactants and other parameters are changed as a result of chemical reactions, different physical processes: convection, diffusion, and radiant heat exchange, etc. Very often the physical factors have a determining influence on the completeness of combustion and conditions of ignition [2-3].

Influence of initial level of turbulence on the basic characteristics of burning process which shown has been investigated, that change of turbulence degree of dust gas a stream essentially affects distribution of the basic characteristics of burning process in top internal space. We according to investigating that, comparing the obtained data for concentration of CO (carbon monoxide), CO_2 (carbon dioxide), CH_4 (methane) for two degrees of turbulence Tu=10 and Tu=5. It is possible to draw a conclusion, that increase in degree of turbulence there is maximum hashing of mix and the minimum emission of harmful substances in environment. So for example, on exit concentration CO at degree of turbulence Tu=10 decrease on 52% in comparison with exit of the same substance at Tu=5 (Value CO on an exit for Tu=10–$9.33\cdot10^{-3}$ kg/kg, for Tu=5–$6.11\cdot10^{-3}$ kg/kg) [4].

In this paper, numerical study of the effect of turbulence degree on the complex physical and chemical processes occurring during combustion of pulverized fuel in the combustion chambers is carried out.

III. The Basic Equations of Mathematical Models

To derive the conservation relationships chosen stationary control element of volume or mass (Fig. 2). It is assumed that the center of gravity of the selected element moves with the velocity of flow. This corresponds to a stationary control volume sound approach for the Euler's flow. Change the value of the transport is described in a single fluid element. Value of transport size is defined in each point of considered area.

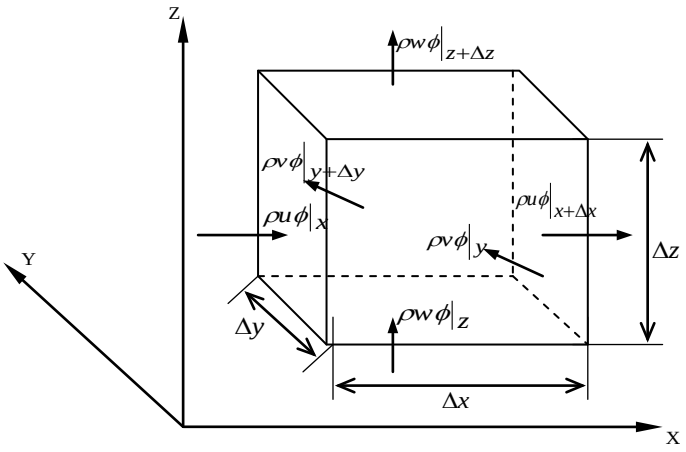

Fig. 2 control volume for the generalized transport equation

When converting from a finite limit to the infinitesimal volume element is obtained by controlling the differential equation describing the conservation of the transport variable ϕ:

$$\frac{\partial(\rho\phi)}{\partial t} = -\frac{\partial(\rho u_1\phi)}{\partial x_1} - \frac{\partial(\rho u_2\phi)}{\partial x_2} - \frac{\partial(\rho u_3\phi)}{\partial x_3} + \frac{\partial}{\partial x_1}\left[\Gamma_\phi \frac{\partial\phi}{\partial x_1}\right] + \frac{\partial}{\partial x_2}\left[\Gamma_\phi \frac{\partial\phi}{\partial x_2}\right] + \frac{\partial}{\partial x_3}\left[\Gamma_\phi \frac{\partial\phi}{\partial x_3}\right] + S_\phi \quad (1)$$

Replacing in equation (1) the convective and diffusive transport of flux density, cross-border control volume, we obtain:
Density of the convective flow:

$$\hat{O}_{(K),\,j} = \rho u_j \phi$$

Density of diffusion flux:

$$\hat{O}_{(D),\,j} = \Gamma_\phi \frac{\partial \phi}{\partial x_j}$$

Then, based on the data relationships (1) can be written as:

$$\frac{\partial(\rho\phi)}{\partial t} = -\frac{\partial \Phi(K),\,j}{\partial x_j} + \frac{\partial \Phi(D),\,j}{\partial x_j} + S_\phi. \quad (2)$$

We write equation (2) in vector form:

$$\frac{\partial(\rho\phi)}{\partial t} = div\left(\left(-\rho\vec{u}\phi\right) + \Gamma_\phi grad\phi\right) + S_\phi\,. \quad (3)$$

And in tensor form, equation (2) becomes:

$$\frac{\partial(\rho\phi)}{\partial t} = -\frac{\partial\left(\rho u_j \phi\right)}{\partial x_j} + \frac{\partial}{\partial x_j}\left[\Gamma_\phi \frac{\partial \phi}{\partial x_j}\right] + S_\phi\,. \quad (4)$$

Here, index *j* characterizes the spatial direction component of the velocity u_j in the chosen Cartesian coordinate system with coordinates x_j, where j = 1, 2, 3.
Then, we can use:

$$\begin{aligned} &x_1 \equiv x; \quad x_2 \equiv y; \quad x_3 \equiv z \\ &u_1 \equiv u; \quad u_2 \equiv v; \quad u_3 \equiv w \end{aligned} \quad (5)$$

Value of ϕ change by time: $\frac{\partial(\rho\phi)}{\partial t}$

ϕ change due to convective transport:

$$\frac{\partial\left(\rho u_j \phi\right)}{\partial x_j}$$

ϕ change due to molecular exchange phenomena (Diffusive exchange):

$$\frac{\partial}{\partial x_j}\left[\Gamma_\phi \frac{\partial \phi}{\partial x_j}\right]. \quad (6)$$

S_ϕ – is the source (sink) term for the quantity of ϕ.

Thus, to solve this problem will further we examine the equations describing the flow and which are derived from the generalized equations:

– ***The law of conservation of mass (continuity equation).*** The ratio of the mass balance for the control volume is the continuity equation. Mass flow through the surface of the control volume is:

$$\frac{\partial \rho}{\partial t} = -\frac{\partial\left(\rho u_j\right)}{\partial x_j} \quad (7)$$

– ***The law of conservation of momentum (Navier-Stokes).*** The ratio of the momentum balance is based on the second law of Newton. Change in momentum of the fluid in the control volume is the sum of all external applied forces. To control volume (as in Fig. 1) – it is a superficial force (pressure and frictional forces) and effective volume forces. Volume forces act as external forces, and are caused by gravity or applied electromagnetic fields. The frictional force, its normal and tangential component to the surface of the control volume depends on the condition of fluid motion and is written by the viscous stress tensor. Flux of momentum is also created by convection through the surface of the control volume, due to the pressure forces applied to the control volume and arising volume and surface forces. Thus, we obtain the momentum balance:

$$\frac{\partial(\rho u_i)}{\partial t} = -\frac{\partial\left(\rho u_i u_j\right)}{\partial x_j} + \frac{\partial \tau_{ij}}{\partial x_j} - \frac{\partial p}{\partial x_i} + \rho g_i \quad (8)$$

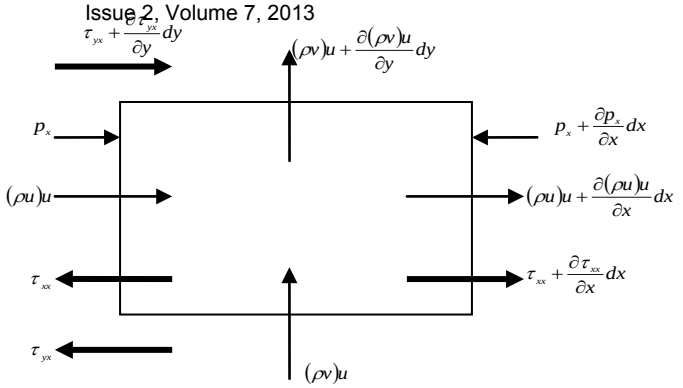

Fig. 3 momentum balance in two-dimensional volume element

– ***The law of conservation of energy (the first law of thermodynamics)***. We write the first law of thermodynamics to the control volume (Fig. 2) and thus obtain the following equation [5]:

$$\frac{\partial(\rho E)}{\partial t}=-\frac{\partial\left(\rho u_j E\right)}{\partial x_j}-\frac{\partial q_j^{res}}{\partial x_j}- \frac{\partial\left(p u_i\right)}{\partial x_i}+\frac{\partial\left(u_i \tau_{ij}\right)}{\partial x_j}+\rho u_i g_i+S_Q \quad (9)$$

Where, $E=e+\frac{\rho}{2}\cdot u^2$.

The total energy *E* is composed of the internal energy *e* and kinetic energy $\frac{\rho}{2}\cdot u^2$. The contribution of the potential energy is neglected.

$\frac{\partial(\rho E)}{\partial t}$ - Time variation of the total energy;

$\frac{\partial\left(\rho u_j E\right)}{\partial x_j}$ – Specific density of the total energy flow across the borders of control volume by convection;

$\frac{\partial q_j^{res}}{\partial x_j}$ – Specific density of the total energy flow across the borders of control volume due to molecular heat transfer;

$\frac{\partial\left(p u_i\right)}{\partial x_i}$ – Energy change due to the work of the pressure forces on the surface of control volume;

$\frac{\partial\left(u_i \tau_{ij}\right)}{\partial x_j}$ – Energy change due to the work of friction on the surface of control volume;

$\rho u_i g_i$ – Energy change due to the work volume forces in control volume;

S_Q – Absorption (release) of energy through chemical transformation, or by thermal radiation energy [6].

Thus we obtain the equation for the conservation of the internal energy:

$$\underbrace{\frac{\partial(\rho e)}{\partial t}}_{I}=\underbrace{-\frac{\partial\left(\rho u_j e\right)}{\partial x_j}}_{II}\underbrace{-\frac{\partial q_j^{res}}{\partial x_j}}_{III}\underbrace{-p\frac{\partial u_i}{\partial x_i}}_{IV}+\underbrace{\tau_{ij}\frac{\partial u_i}{\partial x_j}}_{V}+\underbrace{S_e}_{VI} \quad (10)$$

Where:
I - total change of the internal energy over time;
II - the flux density of the internal energy through the border of control volume by convection;
III - the flux density of the internal energy through the border of control volume due to molecular heat transfer;
IV - the reversible transformation of the work done by the pressure to the internal energy;
V - the irreversible transformation of the friction forces to the internal energy (dissipation); (28)
VI - the sources and sinks of internal energy.

– ***The law of conservation of components of a mixture.*** To determine the concentration of each component of the mixture (eg, CO, CO_2, O_2 , coke or C_xH_y) in the volume element will be written the balance relationships. This equation takes into account the physical and chemical processes that have an impact on change of the concentration of these substances. Along with convection and diffusion transfer must be considered contribution of chemical reactions and physical processes, such as the drying of fuel, etc. Total mass in the volume element is defined as the sum of the masses of all *n* components:

$$m=\sum_n m_n \quad (11)$$

To write the total equation of the balance relations for the components of the system as a variable, you can use a set of values. For example:
Mass concentration:

$$\sum_n \frac{m_n}{m}=1 \quad \left[\frac{\kappa g}{\kappa g}\right]; \quad c_n=\frac{m_n}{m} \quad (12)$$

Volume concentration:

$$\sum_n \frac{V_n}{V}=1 \quad \left[\frac{m^3}{m^3}\right]; \quad c_n=\frac{V_n}{V} \quad (13)$$

Concentration:

$$\sum_n \frac{m_n}{V}=\rho \quad \left[\frac{m^3}{\kappa g}\right]; \quad c_n=\frac{m_n}{V} \quad (14)$$

The use of volume concentration is not practical because of the need to set additional equations for volume over temperature.

Therefore, in our model, we use the mass concentration and in chemical reactions used molar concentrations mol/m^4. In total balance equations set corresponding coefficients for recalculation in the mass concentrations. In general, the equation for the concentration of components of the mixture can be written as [6]:

$$\frac{\partial}{\partial t}(\rho c_n)+\frac{\partial}{\partial x_i}(\rho u_i c_n)= \frac{\partial}{\partial x_i}\left[\frac{\mu_{eff}}{\sigma_{c_n,eff}}\frac{\partial c_n}{\partial x_i}\right]+S_{c_n} \quad (15)$$

In this equation, the summand S_{c_n} takes into account the contribution of chemical reactions in the change in concentration of the components. In multicomponent mixtures:

$$S_{c_n}=\sum \omega_{n,r} \quad (16)$$

Where $\omega_{n,r}$ is defined as the rate of reaction of a substance *n* in the reaction *r*.

IV. Simulation of Turbulence

The '*k*-*ε* model' is an eddy viscosity turbulence model based on the Boussinesq hypothesis of relating the Reynolds stresses to the mean velocity gradient, where the turbulent viscosity is expressed in terms of turbulent kinetic energy (*k*) and its dissipation rate (*ε*). For modeling of turbulent viscosity and the closure of the system we used the standard *k*-*ε* turbulence model [7].

$$\frac{\partial}{\partial t}(\rho k)=-\frac{\partial}{\partial x_i}\left(\rho u_i k\right)+\frac{\partial}{\partial x_i}\left[\frac{\mu_{eff}}{\sigma_k}\frac{\partial k}{\partial x_i}\right]+\Pi-\rho\varepsilon$$

$$\frac{\partial}{\partial t}(\rho \varepsilon)=-\frac{\partial}{\partial x_i}\left(\rho u_i \varepsilon\right)+\frac{\partial}{\partial x_i}\left[\frac{\mu_{eff}}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial x_i}\right]+ +c_{\varepsilon 1}\frac{\varepsilon}{k}\Pi-c_{\varepsilon 2}\rho\frac{\varepsilon^2}{k}. \quad (17)$$

Where,

$$\Pi=\left[\mu_t\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)-\frac{2}{3}\rho k\delta_{i,j}\right]\frac{\partial u_i}{\partial x_j}.$$

Convert the kinetic energy of pulsation motion into internal energy (dissipation). σ_k, σ_ε – corresponding to the Prandtl number. (42)

The system of equations is not closed, since the turbulent flow regime the effective transport coefficients μ_{eff}, a_{eff}, D_{eff}, are unknown functions. According to the Reynolds analogy, we can use the following relations:

$$\rho a_{eff}=\frac{\mu_{eff}}{Pr_{eff}};$$

$$\rho D_{eff}=\frac{\mu_{eff}}{Sc_{eff}} \quad (43)$$

Where, Pr_{eff} and Sc_{eff} – effective number of Prandtl and Schmidt, respectively, whose values are set to be constant.

The effective viscosity is determined by modeling the relationship of the Kolmogorov-Prandtl:

$$\mu_{eff}=\mu+C_\mu\rho\frac{k^2}{\varepsilon} \quad (18)$$

Where, μ – is physical viscosity, C_μ – experimental constant. (44)

V. Organizing of Burning Process

Theoretical study of turbulent heat transfer in reacting flows can be carried out using a mathematical model [8]. This model is a complex system of non-autonomous nonlinear multidimensional partial differential equations consisting of the equations of continuity, state and motion viscous medium, the equations of heat distribution and diffusion of the reaction mixture components and the reaction products with the radiant carry and multiphase of media and the equations of the selected model of turbulence. These equations need to add the equations of chemical kinetics, determining the intensity of nonlinear sources of energy and matter. This complete system of equations is difficult to solve, even for simple flows usually has no analytical solution and can only be solved numerically. Their exact calculation is a complicated problem of analysis, and if we consider the important from a practical point of view, three-dimensional combustion modes in systems with real geometry (furnaces, gas turbines and internal combustion engines), then it is extremely labor intensive and requires huge computational cost.

The development of mathematical modeling methods of heat and mass transfer investigations in flows with combustion has led to various application-oriented package, with which more or less successfully solved tasks as fundamental well as applied, which in daily practice faced different fuel and energy complex [9-10].

Numerical simulation of turbulent flows with chemical reactions, including thermo-dynamic, kinetic and three-dimensional computer modeling of combustion chambers, with the lowest cost will investigate in detail the turbulent combustion of pulverized coal in real combustion chambers, and give practical advice on the use of new technology of low-grade solid fuel burning.

The computational experiment was conducted on a real energy facility. As investigated object is chosen in the combustion chamber of the boiler PC-39 to the block 300 MW steam capacity of 475t/h The boiler is set to Yermakovskaya plant (Kazakhstan).

Ekibastuz coal has following characteristics: high-ash content about 40%, with a relatively high content of impurities. Total moisture in operation WP 6.5%, moisture absorbent Wg 4%, ash content of dry fuel Ad 36.9%, total sulfur of dry fuel Sd 0.7%, volatiles in dry ash-free state fuel Vdaf 25%, Net calorific value of the fuel in working condition Qr 17.38 MJ/kg of fuel milling factor Gr 1.29; sulfur pyrite in a dry ash-free state fuel Sdafp 0.3%; organic sulfur in a dry ash-free state fuel Sdafo 0.4% carbon in ash-free dry state fuel Cdaf 44.8%; Hydrogen in a dry ash-free state fuel Hdaf 3% nitrogen in the dry ash-free state fuel Ndaf 0.8%; Oxygen (by difference) in a dry ash-free state fuel Odafd 73% [11].

To intensify the fire and create favorable conditions for stable combustion burners have two sizes, which allows for different coefficients of excess air in them: the lower tier $\alpha_г$=1,4, the upper tier of $\alpha_г$=0,9.

A detailed description of the characteristics of the boiler is presented in Table 1.

To intensify the ignition air is supplied to the camera in such a way that it contained oxygen entered into the reaction gradually. For this purpose, the air supplied to combustion chamber is divided into primary, served in a mixture with coal dust, and the secondary, served separately from the primary through the same burner or, less frequently, in addition to them. Part of the primary air is used for drying the fuel in the system of pulverization. Hence, the primary air is used for three purposes: as a drying agent, to transport the dust in the furnace, and as a reactant of gas mixture.

Because of the difficulty of flaring of solid fuel (due to the complexity of fine grinding, ash wear and slagging of heating surface, put them ash) developed a method burning it in a suspended state, called a vortex. In the vortex furnace performed sustainable movement of rotating air flow, where coal dust is in suspended state. Characters of the vortex motion of fuel air flow creates good conditions for mixing fuel with air, and thus contributes to a more rapid and complete burning of fuel.

Method of burning of solid fuels in the form of dust in a torch has certain advantages over other methods. Grinding of fuel leads to the fact that supply of fuel in each dust particle is small for a large external surface. This provides a quick combustion of dust. Dust particles due to the smallness and sail move with the gas flow. The speed of their flow around is low. Even for large dust particles can be assumed that the relative speed of their movement is air speed. For these reasons, the Nusselt number for the dust close to the minimum value, and the coefficients of heat transfer and diffusion exchange large due to the small particle size. Heating of burning dust relatively low to gas media, because of good heattrasfer [12].

In coal-fired furnaces there is a strong aerodynamic and thermal heterogeneity near the burners. The design of the burner, placing burners in the furnace chamber, the motion of gases have the most significant effect on the ignition and combustion of pulverized coal. The actual process of ignition provided suction of hot gases from the flame kernel. This increases the temperature of incoming air- dust mixture. To some extent, affects the radiation torch. Warms of coal dust emit volatile, which mixed with the gas forms a combustible mixture.

A calculation shows that the rate of oxidation increases dramatically due to the increase in temperature, despite the decrease in the oxygen concentration. Increase the rate of reaction leads to inflammation. In zone of burners, where take place ignition, torch significantly heterogeneous. However, at the distance from burners there is an alignment of dust concentrations, oxygen and combustion products, as well as the temperature at cross section of the flame.

Table 1
Characteristics of combustion chamber of the boiler PK-39

Title of the character, dimension	Design ation	Value
1	2	3
Fuel consumption on the burner, kg/h	B_Γ	7291,1
Composition of Ekibastuz coal, %	W^p A^p S^p C^p H^p O^p N^p	7,0 40,9 0,8 41,1 2,8 6,6 0,8
Combustion heat, MJ/kg	Q_H^p	15,87
Volatile, %	V^F	30,0
Diameter of coal particles, m, 10^{-6}	d_{par}	30,0
Excess air coefficient at the outlet of the furnace	α_m	1,25
Excess air coefficient in the burners	$\alpha_г$	1,15
Air suction into the furnace	$\Delta\alpha$	0,1
Temperature of air mixture, K	T_a	423
Temperature of the secondary air, K	T_2	600
Tertiary air temperature, K	T_3	600
The wall temperature, K	T_W	873
Number of burners, pcs	n_B	12
Number of tiers, pcs	N	2
The height of combustion chamber, m	Z	29,985
The width of combustion chamber, m	Y	10,76
The depth of combustion chamber, m	X	7,762

The rate of the primary air of the burners of the lower tier (air mixture), m/s	W_1	15,0
The rate of the secondary air of the burners of the lower tier, m/s	W_2	28,0
The rate of the tertiary air of the burners of the lower tier, m/s	W_3	26,0
The rate of central air burners lower tier, m/s	W_0	10,0
The rate of the primary air of the burners of the upper tier, m/s	W'_1	15,0
The rate of the secondary air of the burners of the upper tier, m/s	W'_2	23,0
The rate of the tertiary air of the burners of the upper tier, m/s	W'_3	23,0
The rate of the central air of the burners of the upper tier, m/s	W'_0	10,0

VI. Results of Numerical Researches

The calculation area for modeling and carrying out computational experimental results was created with useful program complex PREPROZ [13]. Using this program we created basic files containing background information, which are then used in the program package. This computer software package allows carrying out complex, numerical experiments to simulate reacting multiphase flows in the areas of real geometry [14].

The mathematical model describing reacting flow in the combustion chamber includes the nonlinear differential equations: the equation of continuity, motion of a viscous medium, heat distribution and diffusion components of the reaction mixture and the reaction products, the equation of state and the equation of chemical kinetics. The solution of these equations was carried out on the basis of a program complex for three-dimensional modeling of FLOREAN.

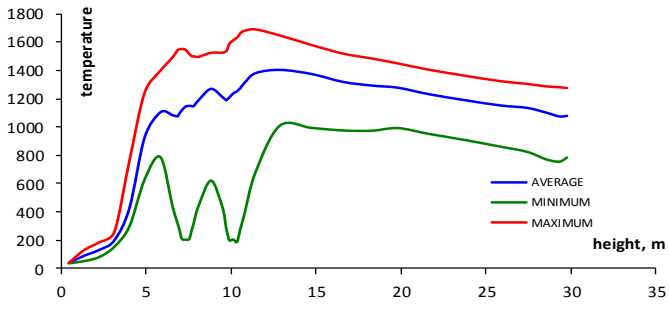

Fig. 3 temperature distribution by height of the combustion chamber at Tu=0.05
* - experiment [3]

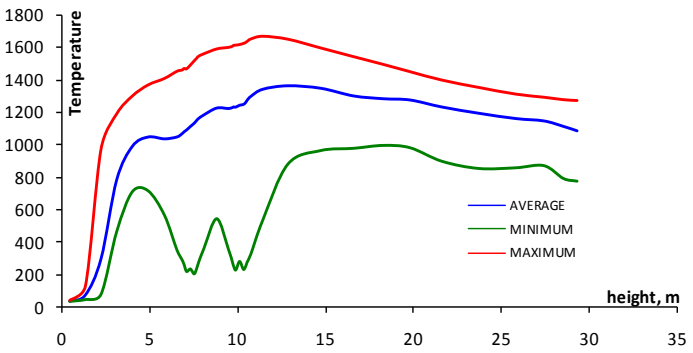

Fig. 4 temperature distribution by height of the combustion chamber at Tu=0.1

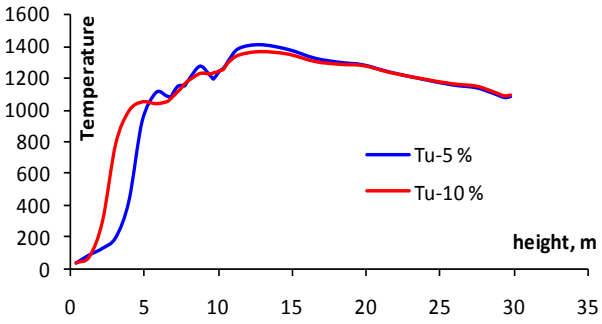

Fig. 5 comparison of temperature distributions along the combustion chamber for two turbulence degrees Tu=0.05 and Tu=0.1

Analysis for the graphs in Fig. 3-5, which shows the temperature distribution shows that the output of the combustion chamber have a lower gas temperature.

This is explained by the ignition conditions of high-Ekibastuz coal and impaired heat transfer in the furnace of polluted screens layer of fly ash. Ash settling on the heating surface affects the heat transfer and increases the resistance of flue pipes and causes great damage to the equipment. At the same time, it can be noted that the conditions of ignition at Tu=10% better, and at the output we have very small differences in temperatures.

It is known that at higher turbulence is a more complete combustion and fewer emissions of harmful gases, which has a positive impact on the environment. We can show it in the following figures.

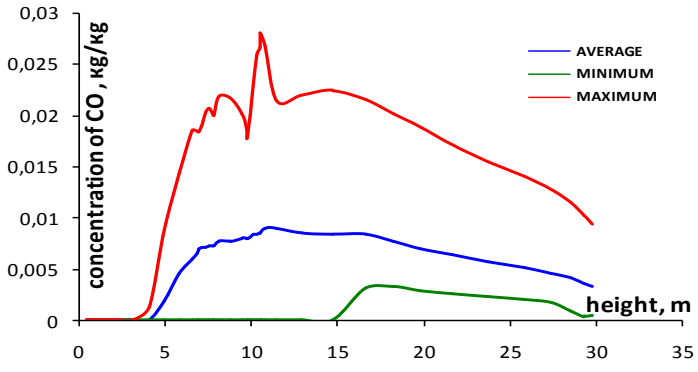

Fig. 6 concentration profile of CO by height of the combustion chamber at Tu=0.05

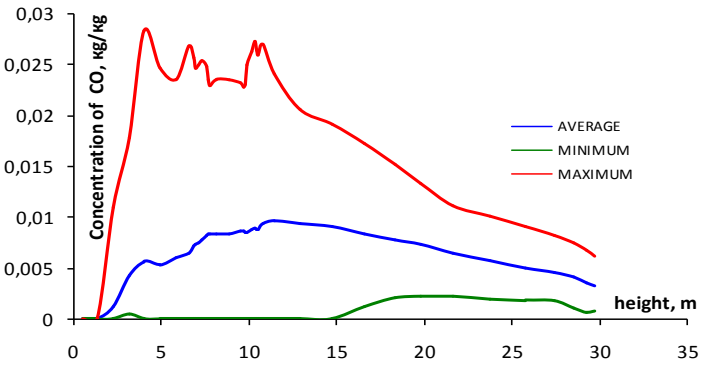

Fig. 7 concentration profile of CO by height of the combustion chamber at Tu=0.1

Distribution maximum, minimum and average on section of values of concentration of CO (carbon monoxide), and comparison of their mean values for the two turbulence degrees in the combustion chamber height are shown in figures 6-8.

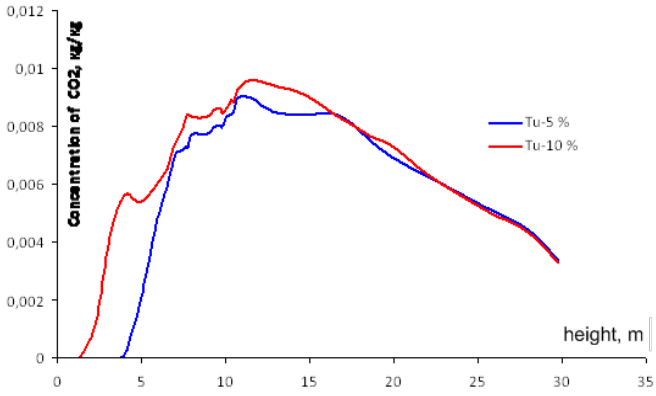

Fig. 8 comparison of concentration profile of CO by height of combustion chamber for two turbulence degrees Tu=0.05 and Tu=0.1

And the figures 9-11, 12-14 are the same distribution for the carbon dioxide CO2 and methane CH4.

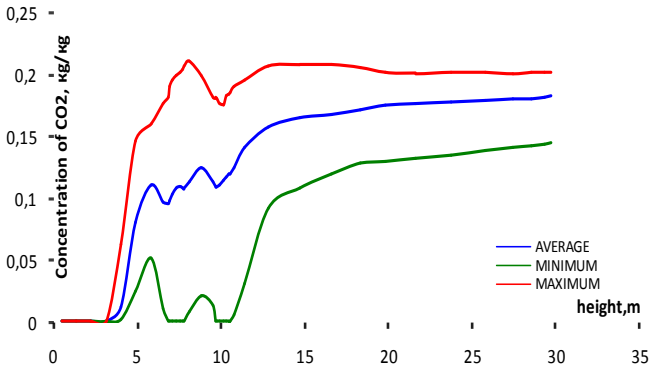

Fig. 9 concentration profile of CO2 by height of the combustion chamber at Tu=0.05

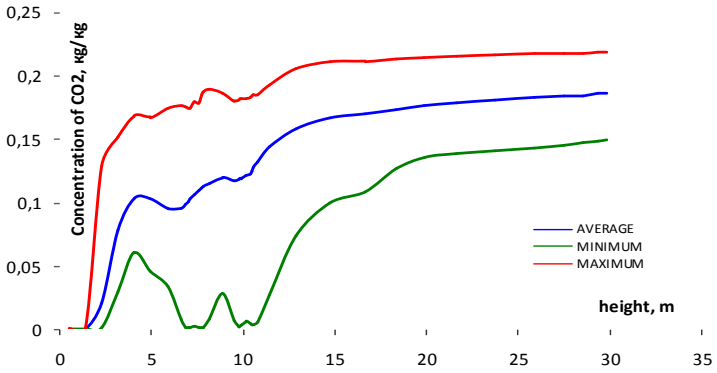

Fig. 10 concentration profile of CO_2 by height of the combustion chamber at Tu=0.1

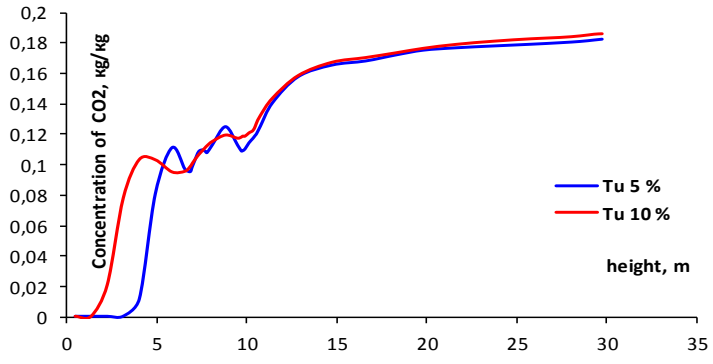

Fig. 11 comparison of the average concentration profile of CO_2 along the combustion chamber for the two turbulence degrees Tu=0.05 and Tu=0.1

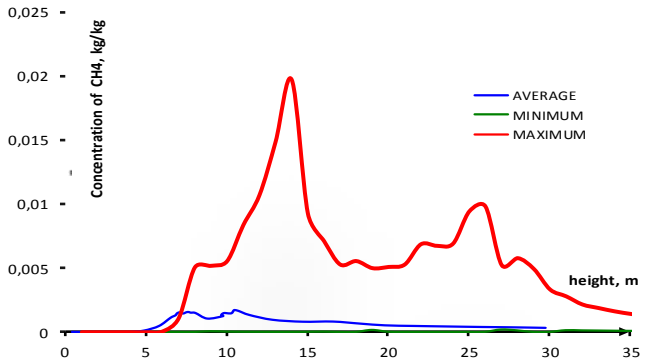

Fig. 12 concentration profile of CH_4 by height of the combustion chamber at Tu=0.05

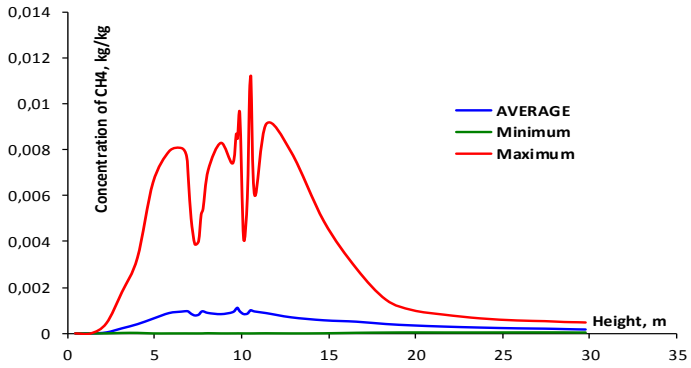

Fig. 13 concentration profile of CH_4 by height of the combustion chamber at Tu=0.1

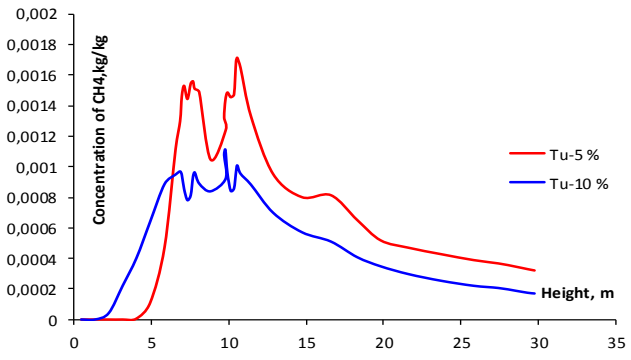

Fig. 14 comparison of the average concentration profile of CH_4 along the combustion chamber for the two turbulence degrees Tu=0.05 and Tu=0.1

From the graphs of Figures 6-14 shown that the concentration profile of the height of the combustion chamber, depending on the gas (CO, CO_2 , CH_4) for different values of turbulence (Tu=0.05 and Tu=0.1) are not qualitatively different. At the same time, there are quantitative changes, which can be explained by the fact that the more turbulent flow, the better the mixing of gases within the chamber. This in turn leads to more complete combustion and reduce emissions from coal-fired.

VII. Conclusion

The use of new computer and information technologies and software in the study of a wide range of modern problems of science and technology, namely, the numerical simulation of real processes is of particular importance and is of great practical application. The main tool of the theoretical investigations of the combustion of solid fuels in the combustion chamber of energy facilities into account the diverse of physical and chemical phenomena, such as radiative heat transfer, combustion, and so is the mathematical modeling and computer experiment. The mathematical modeling includes not only the development of numerical methods and numerical calculations, but also a deep scientific analysis of this model and its adequacy to the real process and the formulation of specific recommendations on the use of advanced computer technology to describe the actual process.

In this paper with the methods of numerical simulations carried out a comprehensive study of heat and mass transfer in high temperature and chemically reacting systems. Numerical simulation of the combustion of pulverized coal was based on three-dimensional transport equations of the chemical reactions. It is a system of nonlinear differential equations in partial derivatives consists of the equations of continuity and motion viscous media, the equations of heat diffusion and diffusion of components of reaction mixture and the reaction products with the multiphase fluids, the equations of k-ε-model of turbulence.

Were created physical, chemical and mathematical models to describe with sufficient accuracy of these processes in a real power object, what are the combustion chambers of various thermal power plants and internal combustion engines. The importance and convenience of numerical simulation of complex phenomena that occur in the combustion chamber are quite obvious. As a result of computer simulation for the boiler PK-39 Ekibastuz power plant in the present study was obtained by an extensive bank characteristics of the fuel process, the temperature field, concentration of combustion products, the energy released by chemical reactions for the two turbulence degrees Tu=0.05 and Tu=0.1. It is shown that the chosen mathematical model allows calculating the parameters of a satisfactory flow and thermal characteristics of devices.

We obtain detailed characteristics of temperature, concentration of coal combustion products (including harmful CO, CH_4, CO_2) around the combustion chamber for different values of the turbulence degree: Tu=0.05 (5%) and Tu=0.1 (10%).

The comparison showed that the nature of the temperature and concentration curves reasonably well modeled, and coincides with the experimental data. This shows the correctness of the applied in this paper a mathematical model of a turbulent jet and its coal-dust distribution in the

combustion chamber operating power plant. The greatest differences in the calculated and experimental values can only be seen in the area of inflammation and decay.

It is shown that modeling the formation of harmful substances (CO, CO_2, CH_4) through use in the model and software package is quite possible. The simulation results allow to optimize the combustion process of high-pulverized coal to reduce emissions and allow power plants to create a "pure" and the spectacular use of coal.

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