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Using 3D Modeling Technology for Investigation of Conventional Combustion Mode of BKZ-420-140-7C Combustion Chamber

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Abstract: In this study, the results obtained by the numerical method modeling of Ekibastuz coal burning in BKZ-420 combustion chamber of Kazakhstan Power Plant. There are devoted to the numerical simulation of the furnace boiler BKZ-420, its steam generating capacity equal 420 T h^{-1}. Boiler has 6 vortical pulverized coal burners arranged in 2 levels with three burners on the front wall of the boiler. Burned in the furnace high ash, low-grade coal from Ekibastuz, its ash content 40%, volatile 24%, humidity 5%, highest calorific value 16750 kJ kg^{-1}. Milling dispersity of coal was equal to R90 = 15%.

Key words: Numerical modeling, combustion chamber, thermal performance, aerodynamic characteristics, reacting mixture, pulverized coal, combustion,

INTRODUCTION

Welfare of the country is determined by the amount of energy consumed. In the context of depletion of natural energy resources and pollution issues increase the efficiency of energy production and environmental concerns are important tasks of any specialist in the field of power engineering and ecology. Kazakhstan has huge reserves of energy resources, sufficient to cover not only their needs but also for export to other regions as in-kind or in the form of electricity.

The existing state of the mineral base is one of the most important factors determining the potential and prospects of development of the fuel and energy complex of Kazakhstan. Despite the availability of various kinds of fuels in the balance of energy resources of the Republic is dominated by stone and to a lesser extent, brown coals.

Currently in Kazakhstan, about 85% of electricity is produced by Thermal Power Plants (TPP), the main fuel is coal. More than 80% of coal combusted in these TPP, a low ash content which is about 50%.

The processes of heat and mass transfer during combustion of pulverized coal for example BKZ-420 the Ekibastuz Thermal Power Plant (TPP), using 3D modeling technology based on the solutions of differential equations of turbulent reactive flow. The distributions in full speed vector components in different studys of the combustion chamber shows the vector full speed dependence on the combustion chamber height. Obtained temperature profiles and its distribution in height of the combustion chamber. Set minimum and maximum values of the reduced quantities, shows the change in the volume of these characteristics investigated the combustion chamber.

Solution of many technical tasks impossible passed away without use of CFD software packages that allow to modeling difficult particular process in practice. In this study, explain numerical study of physical characteristics and aerodynamic properties of pulverized flue combustion in thermal power plants with calculate by Yevgeniya *et al.* (2009) and Askarova *et al.* (2009).

Investigation of problems of convective heat and turbulent flows in the presence of chemical reactions is an actual problem of thermophysics and hydroaerodynamics because such flows are widely distributed in nature and play an important role in many technical devices. Knowledge of the laws of such flows is important when constructing a combustion physics theory, at creation new physico-chemical technologies and also at the decision of problems of power system and ecology (Askarova *et al.*, 2012). In researches difficult combustion process should be analyzed according to the influence of numerous physical and chemical parameters of the combustion reaction.

There are devoted to the numerical simulation of BKZ-420 combustion chamber, Its steam capacity equal 420 T h^{-1}. Boiler is equipped with 6 vortex dust burner, arranged in 2 levels with 3 burners on the front wall of the boiler, as shown in the Fig. 1. In the boiler has burnt dust low-grade high-ash coal from Ekibastuz ash content 40%, volatile 24% moisture content is 5% and the highest calorific value 16700 kJ kg^{-1}. The fineness of coal milling is equal to R90 = 15%. All numerical calculations were performed on the earlier methodology (Table 1).

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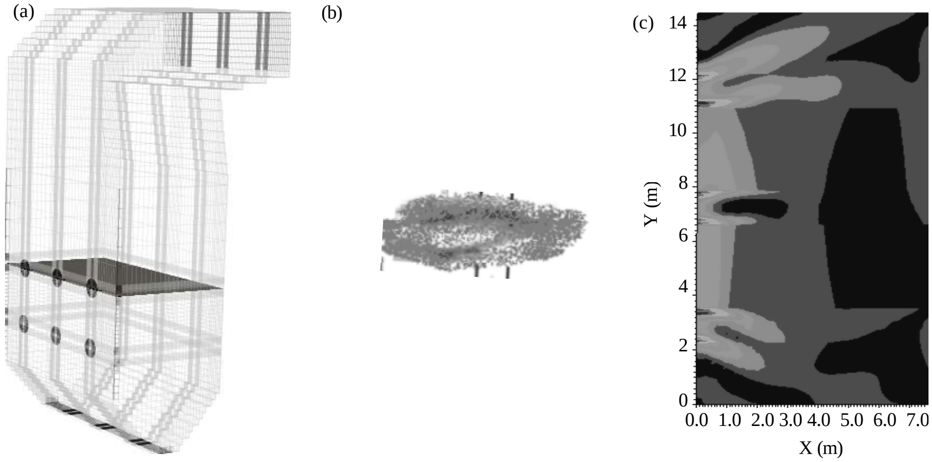

Fig. 1: General view of the industrial boiler BKZ-420 of the Almaty TPP-2. a) 3D view of BKZ-420 boiler and its breakdown into control volumes; b) Top view of burners establish form; c) Velocity profile on the cross study (h = 10.75 m)

Table 1: Source data for numerical calculation

Characterization	Quantity
Coal type	Ekibastuz
Density of particle	1300 kg m^{-3}
C_{daf} (%)	82.0
H_{daf} (%)	5.0
N_{daf} (%)	1.5
O_{daf} (%)	11.5
Ash (%)	40.0
Humidity (%)	5.0
Volatile content (%)	24-28
Coal consumption in the boiler	72,000.00 kg h^{-1}
Consumption of coal to the burner through two channels	12,000.00 kg h^{-1}
Primary air flow to the boiler	107,035 kg h^{-1}
Secondary air flow rate to the boiler	402,656 kg h^{-1}
The temperature the secondary air	280°C
Temperature of aeromixture	88.85°C
The average particle size of coal	64$_{MKM}$
The lower heating value of coal	16,750 kJ kg^{-1}
The lower estimated calorific value of coke	
The amount of computation (control volumes)	533,520

On the front wall of the combustion chamber has 6 double-flow vortex of dust and gas burners in 2 stages (3 per stage) are established. The last burner turned to the center of burner by 8 degrees. The capacity of one burner 12 T h^{-1} of the Ekibastuz coal.

MAIN BODY

Complex physical and chemical processes taking place during the combustion of gas, solid or liquid fuel are described by the equations of conservation. These include the conservation equations of mass, conservation of angular momentum and energy for the gas and solid phases. The gas flow is considered in the Euler system, the dynamics of a solid phase is considered in the Lagrangian system (Muller, 1992).

The turbulent structure of the flow is described by a 2-parameter model of turbulence. The radiation heat transfer is transfer 6 stream model. The mathematical description of the physical and chemical processes are based on the solution of the equation balance. In general, all of these equations contain four components:

- 1st changes in the value of time
- 2nd component describing convective transport
- 3rd component describing diffusive transport
- 4th component describing the source or flow

Florean solves a number of transport equations depending on the user's specific problem setup. In this study an overview is given of the (general) continuity, momentum, energy, species and turbulence equations. (Askarova *et al*., 2009; Muller, 1992; Yevgeniya *et al*., 2008) (Fig. 2).

Continuity equation: The general continuity equation is written as:

$$\frac{\partial \rho}{\partial t} + \vec{\nabla}.(\rho\vec{\vartheta}) = S_m \tag{1}$$

Where, S_m is a mass source from the discrete phase due to evaporation of droplets. It can also be a user-defined mass source.

Momentum equations: The momentum equation that is solved in this study is:

$$\frac{\partial \rho}{\partial t}(\rho\vec{\vartheta}) + \vec{\nabla}.(\rho\dot{\vartheta}\vec{\vartheta}) = -\vec{\nabla}\rho + \vec{\nabla},\bar{\tau} + \vec{F} \tag{2}$$

Where:

p = The static pressure

$\vec{\tau}$ = The stress tensor
$\vec{F}$ = A body force due to interaction of the discrete phase with the continuous phase and/or a user-defined momentum source

The gravity term in the momentum equation is neglected because of the minimal contribution compared to the high momentum injection event.

Energy equation: The energy equation in Fluent is written as follows:

$$\frac{\partial \rho}{\partial t}(\rho E) + \vec{\nabla}.\left[\vec{\vartheta}(\rho E + \rho)\right] = \vec{\nabla}.\left[(k + k_\tau)\vec{\nabla}T - \sum_j h_j \vec{J}_j + (\vec{\tau}.\vec{\vartheta})\right] + Se \quad (3)$$

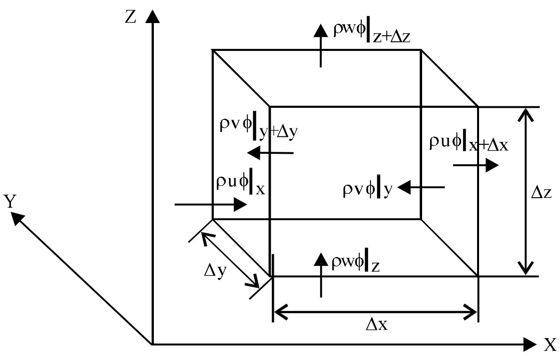

Fig. 2: Control volume for the generalized equation of transfer

Where, the term between the brackets on the right hand side consists of energy transfer due to conduction, species diffusion and viscous dissipation, respectively. S_e is a user-defined energy source (Askarova *et al*., 2009).

RESULTS

Figure 3-5, illustrate the picture of the velocity distribution in the combustion chamber by means of which one can characterize the behavior of pulverized coal flow within the combustion chamber. One can clearly see the area of the fuel mixture through the burner.

Also Fig. 3-5, illustrate a picture of distribution of speeds in furnace space with the help which can characterize behavior of a coal-dust stream in the combustion chamber. Areas of giving of a fuel mix through torches are clearly visible.

Aerodynamic conditions created in the combustion chamber during the motion of coal-fired flows, lead to the fact that in the plane of the fuel mixture and in the plane of symmetry of the furnace chamber there is a maximum convective transfer.

Due to variations in temperature in this area combustion reaction are the most intensively here. Near to the zone of reactions in the flame of the detected peaks in the distribution of the temperature and the temperature gradient. As researchers move to exit the combustion chamber temperature falls evenly (Fig. 6-7).

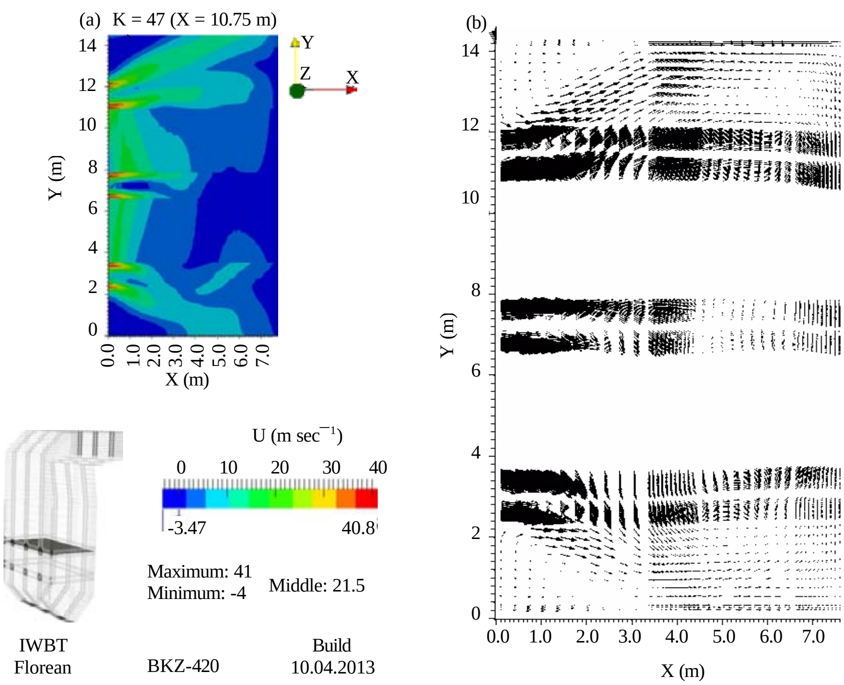

Fig. 3: The distribution of the velocity component U in cross-section of the burner of the combustion chamber height

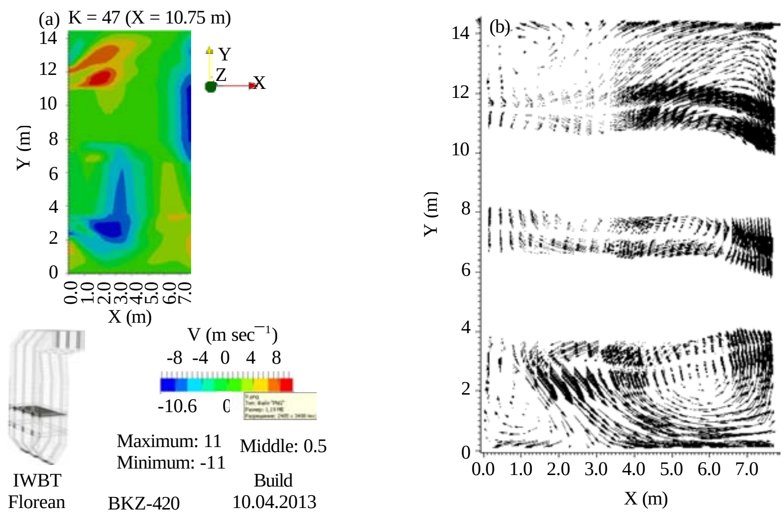

Fig. 4: The distribution of the velocity component V in cross-section of the burner of the combustion chamber height

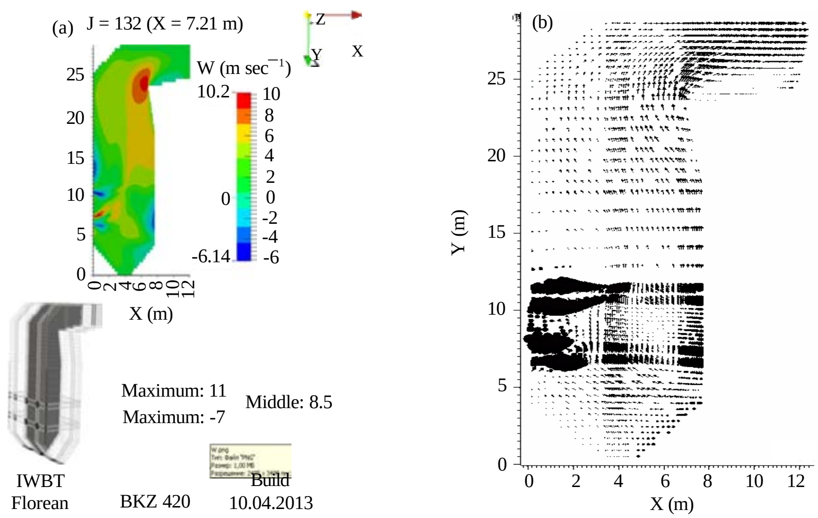

Fig. 5: The distribution of the velocity component W in cross-section of the burner of the combustion chamber height

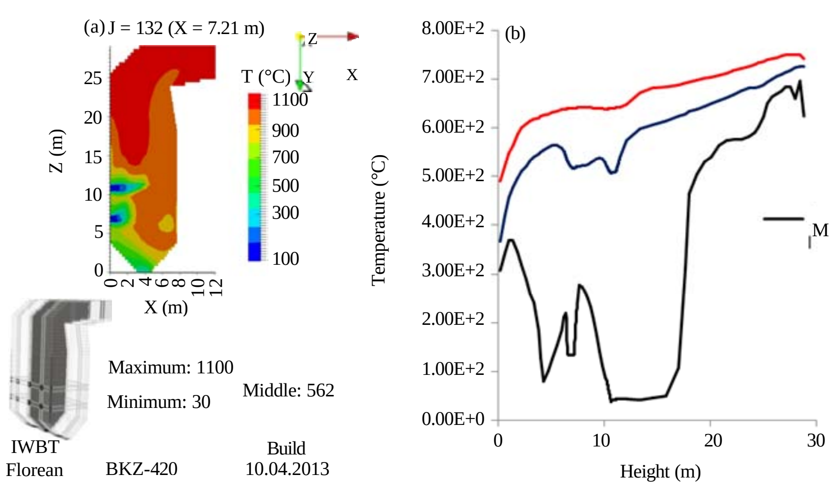

Fig. 6: The distribution of temperature by the height of combustion chamber

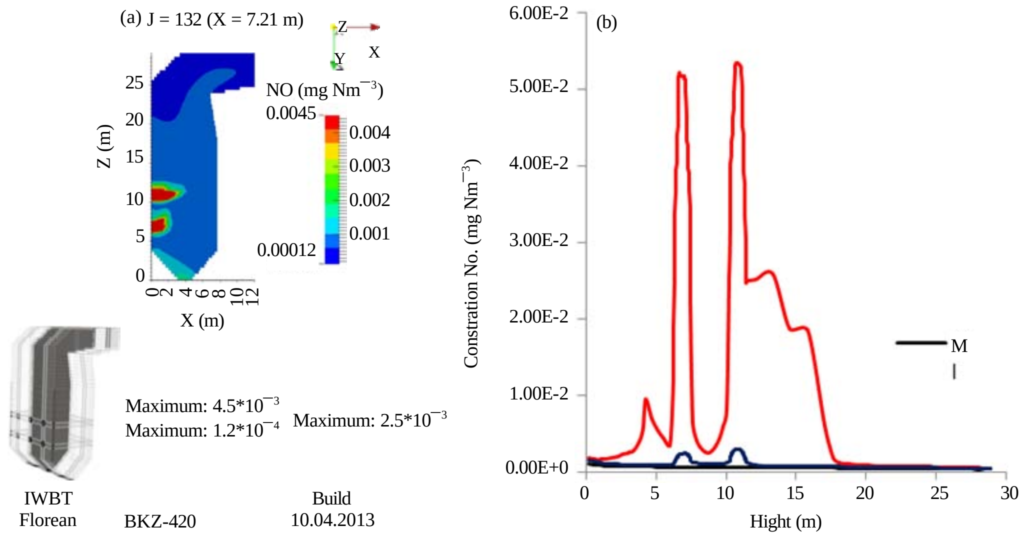

Fig. 7: The distribution of NO concentration by the height of combustion chamber

CONCLUSION

On the basis of mathematical models and 3D computer modeling had conducted the study of complex of heat exchange processes taking place during combustion of low-grade coal fuel (Karaganda coal) on real energetic facility of the Republic of Kazakhstan (the combustion chamber of the boiler BKZ-420 of TPP) (Yevgeniya *et al*., 2008).

Built geometrical model of the investigated object corresponding to the real chamber of combustion of the power generating unit, built its finite-difference mesh which made up of 1363250 points and 671113 cells in the control volume.

Obtained the distribution of temperature and velocity which are visible to the filing of pulverized-coal mixture, corresponding to the maxima of the examined characteristics.

It is shown that the most intense burning is observed in the central part of the chamber where the flow temperature reaches about 980°C. Due to the fact that coal particles in this area have a more intense radiation and have higher concentration and the total surface, it is seen that the temperature reaches a peak in the cross studys of the location of the burners. This is an area combustion reaction occurs more intensively. As you approach the exit from the combustion chamber temperature profile is stabilized and the differences between the minimum and maximum values decreases.

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