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THE STUDY OF GAS-DYNAMIC PROCESSES IN THE CURRENT BOILER FLUIDIZED BED

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Abstract. The paper presents a numerical simulation of the furnace with a circulating fluidized bed. Numerical study carried out for the bottom of the combustion chamber with the varying heights of volume filling. The results of the concentration of particulate matter and fields of speeding, as well as a graphical representation of changes in the concentration of particles on the bed height. Simulation performed in Euler - Euler representation on a 2D model.

1. INTRODUCTION

Currently, much attention is paid to technology allows to achieve low emissions of harmful substances in the organization of low-quality solid fuels burning with high efficiency. Widespread in the energy sector gained boilers with circulating fluidized bed, in which the fuel is supplied from both the burners and of returning ash chutes. In the lower part of the furnace a fluidized bed of which there is a constant particle removal [1, 2].

Formation of the structure, particle distribution, the speed of solids and other physical and chemical processes are of scientific interest because insufficiently studied objects in the major energy [3, 4].

The object of investigation is selected CFB boiler height of 37 m and a depth of 4 m at the bottom of the furnace and 8 m in the main. The boiler is equipped with 4 burners and 2 rows of air nozzles 4 in a row (Fig. 1).

2. MATHEMATICAL MODEL

Mathematical modeling of combustion devices is one of the most important ways to obtain information about the aerodynamics, the local and the total heat transfer [5]. Information that can be obtained, it is necessary for the design and evaluation of new work has exploited thermal installations [6 – 9]. Simulation of the gas phase was carried out by Eulerian-Eulerian approach. In this case the mathematical model includes equations written for brevity, only one coordinate:

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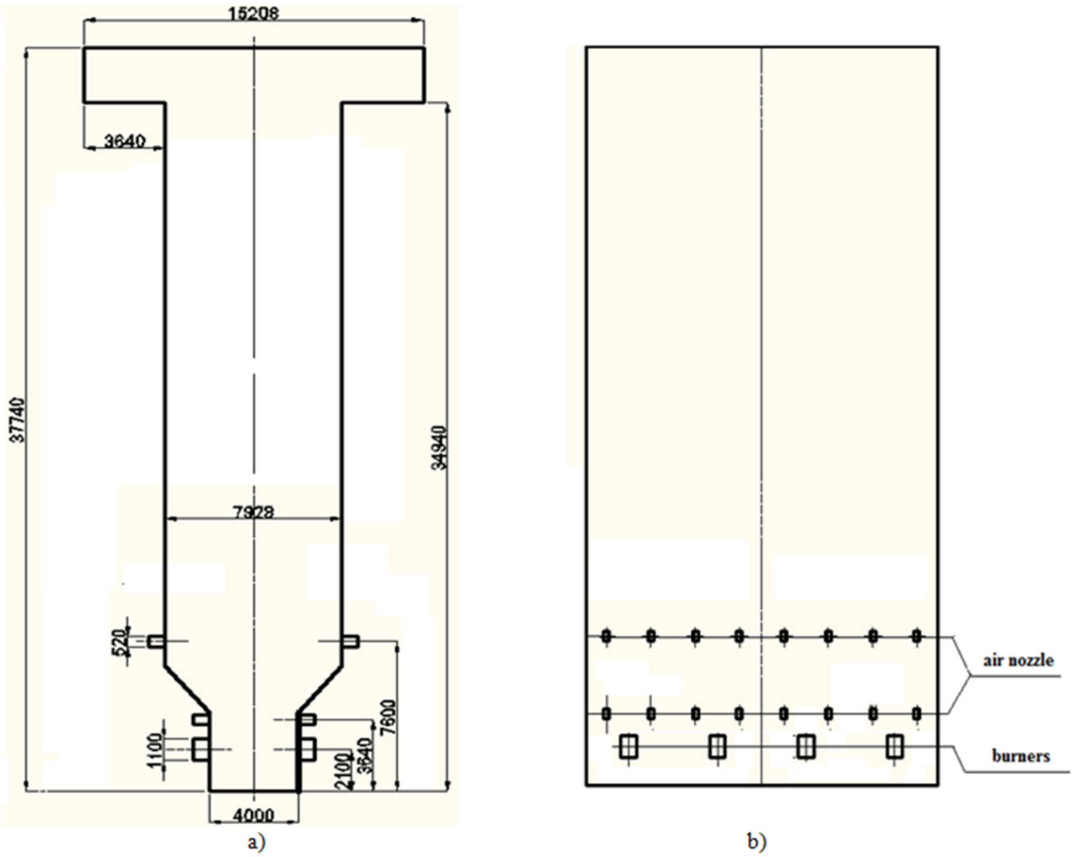

Figure 1. Sketch of the combustion chamber: a) a cross-section; b) side view.

- continuity

$$\frac{\partial(\rho U_i)}{\partial x_i} = 0;$$

- movement

$$\frac{\partial \rho U_i U_j}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\left[\mu\left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}\right) - \frac{2}{3}\mu\frac{\partial U_k}{\partial x_k}\delta_{ij}\right] + \rho g_i,$$

$$j = 1, 2, 3;$$

– energy

$$\frac{\partial U_i \rho c_p T}{\partial x_j} = -\frac{\partial q_i}{\partial x_i} + \frac{\partial \tau_{ij} U_i}{\partial x_j},$$

$$q_i = -\lambda\frac{\partial T}{\partial x_i};$$

– condition

$$\rho = \frac{p}{R_o T[\frac{C_{O_2}}{M_{O_2}} + \frac{C_{N_2}}{M_{N_2}} + \frac{C_{C_{19}H_{30}}}{M_{C_{19}H_{30}}} + \frac{C_{CO_2}}{M_{CO_2}} + \frac{C_{H_2O}}{M_{H_2O}}]}.$$

Here, the indices i - summation; U_i - the components of the velocity vector; ρ, p, T, c, μ- the density, pressure, temperature, specific heat capacity, dynamic viscosity of the mixture; C_j - concentration of components; M_j - molecular weight components of the mixture; J - stoichiometric ratio and the rate of combustion of gaseous fuels..

Boundary conditions for the mathematical modeling were: fuel type – anthracite. The diameter of its particles 2,5 mm. Fuel massflow through each burner B_g=1,89 kg/s; excess air ratio = 1,2; Air inlet temperature for burners 460 °C for air nozzles 300 °C; Air inlet velocity for burners 1,5 m/s for air nozzles 7,7 m/s.

The study was carried out using the program ANSYS Fluent 12.1.4 with the methods described in [5, 10, 11]. For simplicity and speed of calculation two-dimensional computational grid of combustion chamber lower part was used (Fig. 2).

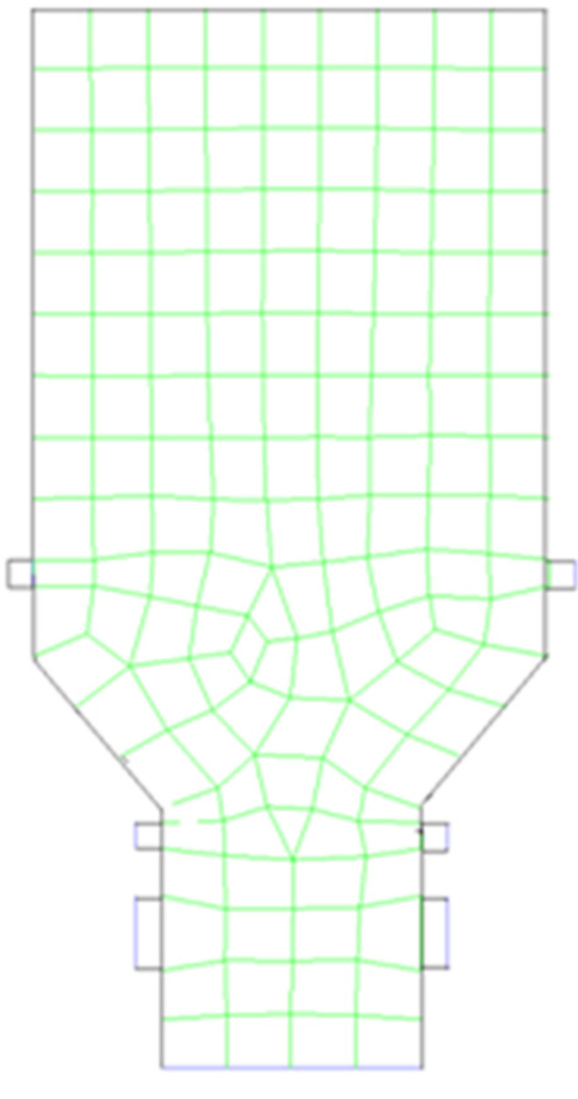

Figure 2. Computational grid of combustion chamber.

3. RESULTS OF THE STUDY

Figures 3 - 6 shows massfractions of fuel, the rate of fuel and the change of concentration with the height of the combustion chamber when loading fuel at 1,2 m, 2,4 m, 4 m.

Processing results obtained using the setup (Fig. 1) established dependencies (Fig. 3) of the ignition delay time of coal particles with various sizes from the temperature of the heating surface.

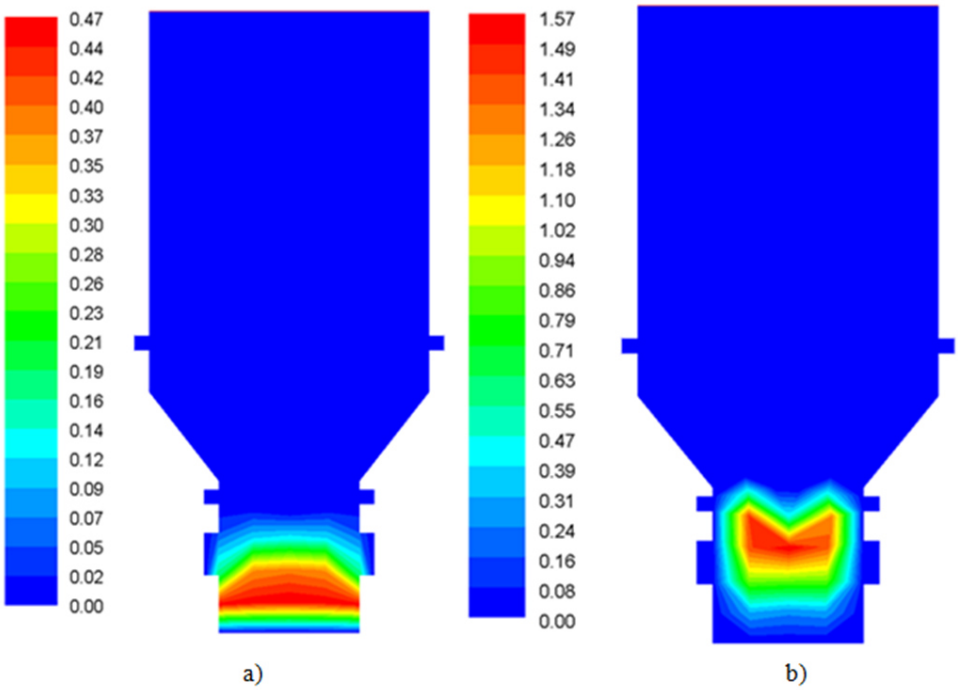

Figure 3. Gasdynamic structure with fuel loading at 1,2 m: a) mass fractions of fuel in a fluidized bed; b) fuel particle velocity (m/s)..

Figure 3 shows that when loading the fuel to a height of 1,2 m, velocity of solid particle reaches the average value of 0,8 m/s. Mass fraction of fuel particles reaches a maximum value of 0,47.

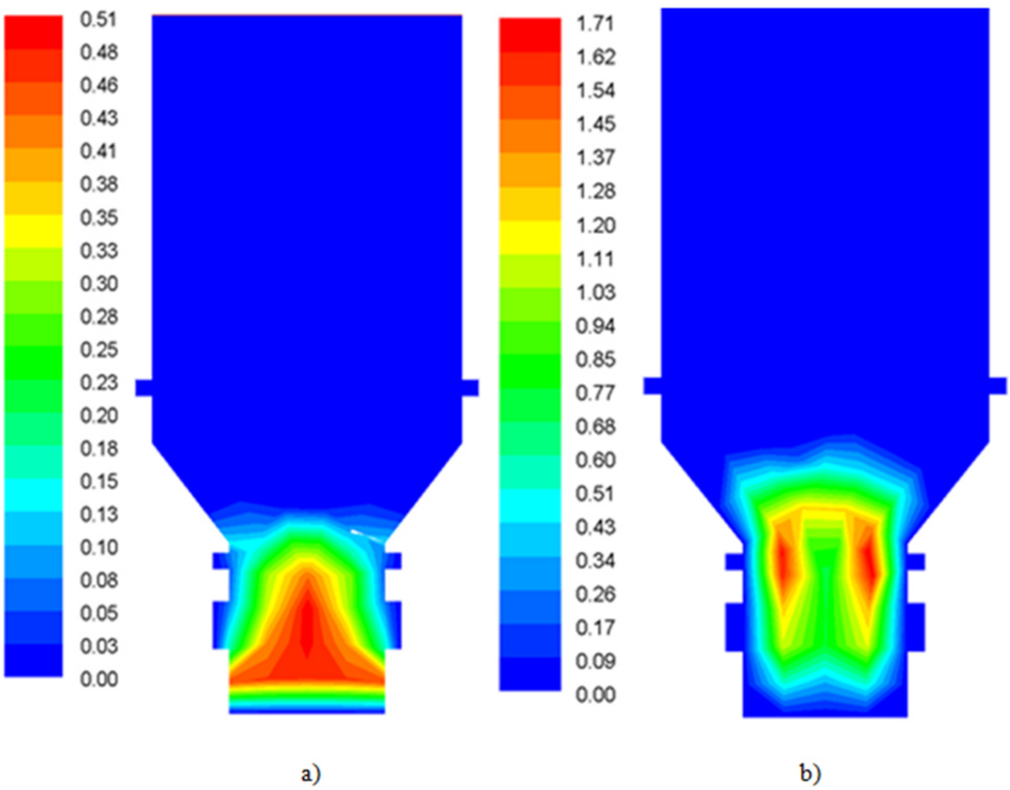

Figure 4. Gasdynamic structure with fuel loading at 2,4 m: a) mass fractions of fuel in a fluidized bed; b) fuel particle velocity (m/s)..

Figure 4 compared to Figure 3 shows the output of fuel fractions from a lower portion of the combustion chamber. The average solids velocity of 0,85 (m/s).

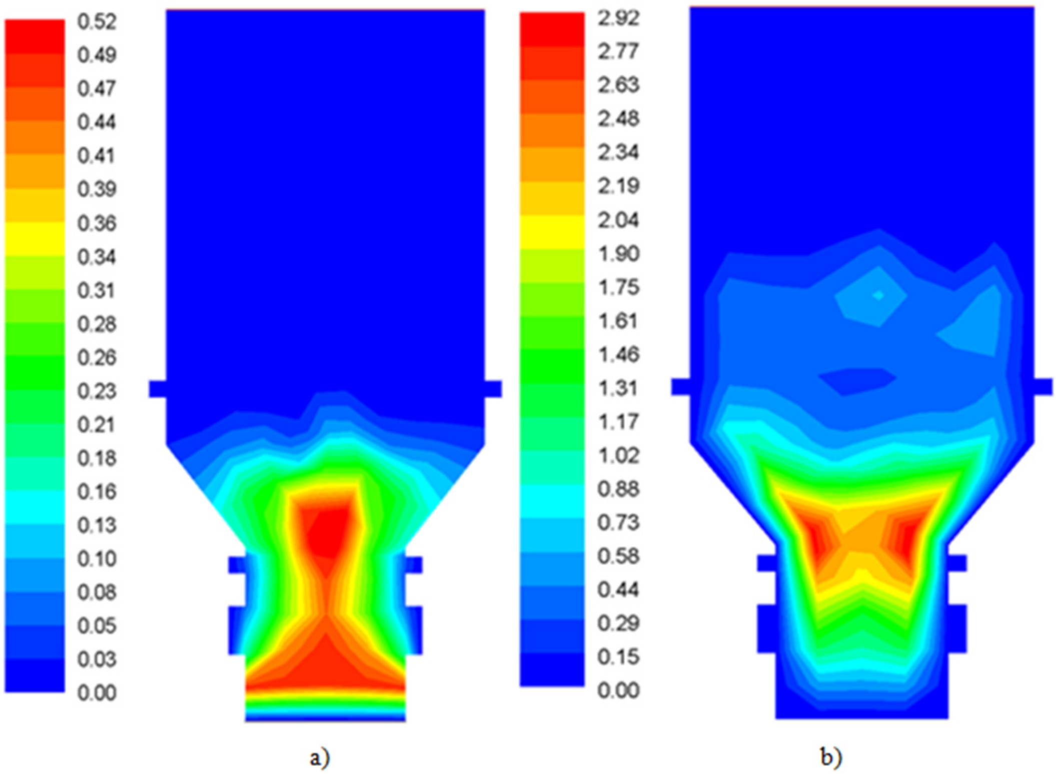

Figure 5. Gasdynamic structure with fuel loading at 2,4 m: a) mass fractions of fuel in a fluidized bed; b) fuel particle velocity (m/s)..

The most rational pattern can be observed in figure 5. The highest concentration is focused on the center of the combustion chamber and exposed to air, both below and on the sides of the air nozzles, climbs up the combustion chamber. The maximum speed of the solid phase is observed in the vicinity of the first row of air nozzles and reaches 2,92 m/s.

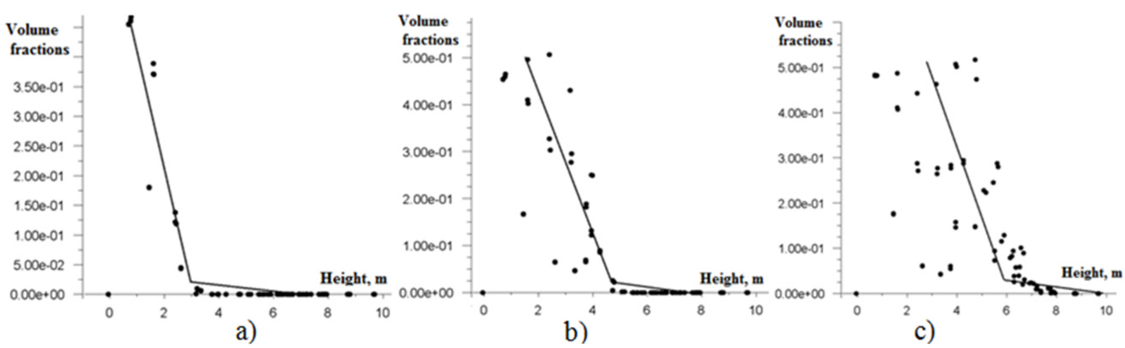

Figure 6. Changing of fuel mass fractions with the height of the combustion chamber when loading fuel at 1,2 m (a), 2,4 m (b), 4 m (c).

Analysis of figure 6 concludes that the more fuel loading, the higher fuel fractions are distributed with height. These visual results of a series of numerical modeling parameters investigated were prepared using Eulerian method.

4. Conclusion

The most rational pattern is observed when loading the fuel to a height in the range of 2.4 m - 4 m as when loading fuel at a lower height is difficult to draw any conclusions on the dynamic processes. This range allows the trace gas dynamic processes in the furnace of a fluidized bed boiler. There demolition fuel fractions closer to the center of the bottom of the combustion chamber and its subsequent distribution adjustment. Speed also remain within the range limits.

This approach is the study of gas-dynamic processes can rationally exploit the boiler units with circulating fluidized bed..

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