CALCULATION OF FLOW AND HEAT TRANSFER OVER THE RADIATION SECTION OF A FLUIDIZED BED FURNACE-EQUIPPED BOILER

M. N. Abramzon and Yu. A. Popov

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Calculations of flow and heat transfer in the furnace volume and in the radiation part of the E-160 boiler (under the Russian trademark) for Tash-Kumyrsk coal burning at atmospheric and elevated pressures are made.

Under the conditions of an increasing shortage of high-quality fuel types and improvement of the ecological requirements, it becomes more urgent to develop coal burning technology in fluidized bed (FB) furnaces, which as it allows the noxious substance discharge into the atmosphere to be reduced several times [1].

Heat transfer and flow are calculated both in the furnace volume and in the radiation part of the boiler unit using the E-160-type boiler equipped with an FB furnace for burning Tash-Kumyrsk coal as an example.

The coal composition is as follows (%):

W^p	A^p	S^p_k	C^p	H^p	N^p	O^p
14.5	21.4	1.2	47.8	3.1	0.8	11.2

We consider that in the FB furnace there occurs incomplete combustion of the coal which is then burnt in the boiler radiation part. In this case, the length of the forming flame can be regulated due to varying aerodynamic burnout conditions. The function of the flame burnout is taken according to [2] as

$$\frac{d\Phi}{dz} = 2mz\exp(-mz^2), \tag{1}$$

where $m = 1/l^2$, l_{flame} is the flame length. The mean gas temperature at the radiation part inlet is $t = 280°\text{C}$, the cross-sectional area of the boiler radiation part is $S = 30\ \text{m}^2$, the fluidization velocity is 2.6 m/sec, the outlet gas flow rate is $G = 73\ \text{m}^3/\text{sec}$.

To calculate heat transfer and flow we used the energy equation

$$C_p\rho\mathbf{u}\nabla T = \nabla((\lambda + \lambda_{\text{T}})\nabla)T - \operatorname{div}\mathbf{q}_R + Q_{\text{chem}}, \tag{2}$$

where $Q_{\text{chem}} = Q_0 d\Phi/dz$, and the quantity Q_0 is determined in terms of the power of chemical heat release in a flame:

$$W_{\text{flame}} = Q_0 S. \tag{3}$$

The field of the turbulent thermal conductivity λ_{T} and the velocity fields were determined from the equations of the turbulence $k-\epsilon$ model [3]:

$$\rho\mathbf{u}\nabla k = \nabla\left(\left(\mu + \frac{\mu_{\text{T}}}{\sigma_k}\right)\nabla\right)k + \mu W - \rho\varepsilon, \tag{4}$$

$$\rho\mathbf{u}\nabla\varepsilon = \nabla\left(\left(\mu + \frac{\mu_{\text{T}}}{\sigma_\varepsilon}\right)\nabla\right)\varepsilon + \frac{\varepsilon}{k}(C_1(\mu + \mu_{\text{T}})W - C_2\rho\varepsilon), \tag{5}$$

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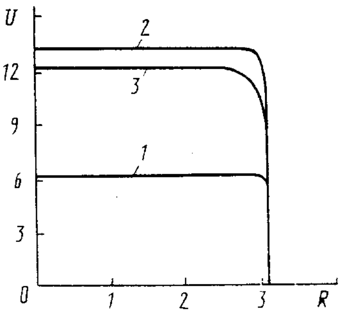

Fig. 1. Longitudinal velocity profiles in the boiler radiation part and in the above-layer space of the fluidized bed, P = 9.8 × 10^4 Pa: 1) z = 0.75 m; 2) 4.25; 3) 14.0. U, m/sec; R, m.

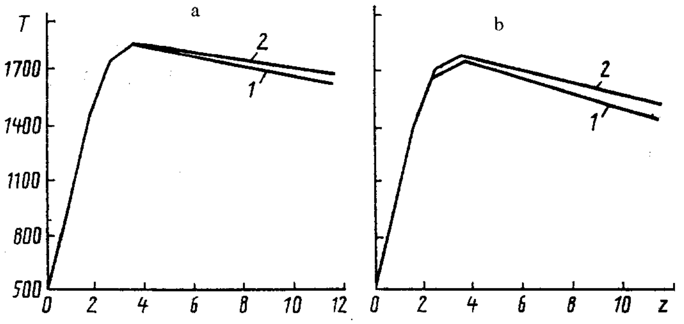

Fig. 2. Boiler unit height variation of the gas temperature, P = 9.8 × 10^4 Pa (a) and 9.8 × 10^5 Pa (b): 1) mean; 2) maximum. z, m.

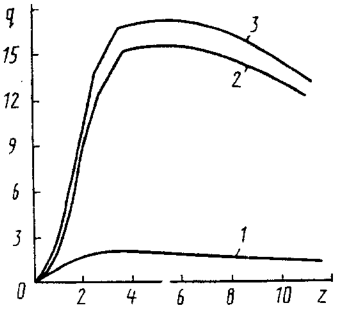

Fig. 3. Boiler unit height variation of wall heat fluxes, P = 9.8 × 10^4 Pa: 1) convective; 2) radiant; 3) total. q, 10^4 W/m^2.

where $\mu_T = C_\mu \rho k^2/\epsilon$, $\lambda T = C_p \mu_T/\mathrm{Pr}_T$, $\mathrm{Pr}_T = 0.9$ is the turbulent Prandtl number. The model coefficients C_1, C_2, σ_{boiler}, σ_ϵ, C_μ are standard. The cross section of the boiler radiation part was replaced by an equivalent circle. As a result, the problem was reduced to a two-dimensional one:

$$W = 2\sum_{i=1}^{2}\left(\frac{\partial u_i}{\partial x_i}\right)^2 + \left(\frac{\partial u_1}{\partial x_2} + \frac{\partial u_2}{\partial x_1}\right)^2. \tag{6}$$

The radiant flux divergence magnitude div q_R for a finite cylinder with a temperature-dependent diffusion coefficient was calculated by the iteration method. The temperature of the cylinder side walls was considered to be equal to $T' = 573$ K. Calculations were made both at atmospheric and elevated pressures when the absorbing and emitting gases CO_2 and H_2O [4] available in the furnace volume were taken into account [4].

Some calculation results are plotted in Figs. 1-3. A tenfold increase of the pressure results in a noticeable (up to 200 K) temperature reduction at the furnace outlet. This is mainly attributed to an increase of the gas volume emissivity, thus causing the growth of radiation heat transfer to the walls.

NOTATION

z, boiler height coordinate; $d\Phi/dz$, burnout function; t, temperature, °C; T, absolute temperature, K; C_p, gas heat capacity; ρ, gas density; λ, λ_T, molecular and turbulent thermal conductivity; μ, μ_T, molecular and turbulent viscosity; q_R, radiant energy flux; Q_{chem}, power of chemical heat release; u, velocity.

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