ESTIMATION OF MILLING FINENESS BASED ON CALCULATIONS OF COAL DUST COMBUSTION

by

Vladan Ivanović, and Ljubiša Brkić

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Primarily, Standard engineering method intended for planning the removal of a slag out of the furnace in a solid state, is applied for testing the constructive characteristics of the furnace of the boiler type OP–650b in TP "Kosovo" – A, Obilić.
A computer program was made, enabling a great number of the furnace thermal calculations for different input parameters.
In the paper determination of the optimal relevant granulometrical characteristic of pulverized coal, for existing geometric characteristics is presented, satisfying proposed nominal combustion condition.

Introduction

Primary task in designing a removal of the slag out of the furnace in solid state, mostly applied for the coal with relatively high reactivity (as the Kosovo lignite), is to prevent slagging of heat transfer surfaces that limit working time of the boiler.

Engineering calculation method [4] is preferably intended for planning the removal of a slag out of the furnace in solid state, and this method is supplement to the Normative standard method [3]. It is based on adopting temperature at the end of the furnace, in front of tube bars or semi iradiated superheater, in accordance with instructions, in order to avoid slagging, and it calculates particle residense time and volume of the furnace which are needed for combustion of coal dust, with assigned losses due to the unburned char particles, at proposed excess air in burners and fineness of coal dust. Further it is determined radiation of the furnace surface and necessary volume of the furnace for cooling of gases to prescribed values. The highest point of the furnace was taken as a basis determined according to the combustion conditions and cooling of gases.

Calculation method of coal dust combustion time and necessary height of the furnace is based on analytical determination of combustion time of the largest coal dust fraction with empiricaly determined constant of combustion rate. This constant is determined by industrial investigation of boilers with different furnace designs and fuels, and on the basis of laboratory experiments.

It is proposed that the particles of coal dust are uniformly distributed in the gas flow and the ignition time of coal dust is negligable in comparation with total combustion-time. Total combustion time is determined as combustion time of the coal char, and particle temperature is conditionally assumed the same as gas flow temperature.

Deviations of these values from the ones assumed in calculation scheme are taken into consideration by coefficient K_{gk}, which is experimentally determined for each sort of coal, separately.

Particle size distribution based on RRS (Rozin-Ramler-Sperling) equation, expressed by using rests on the sieves of 90 and 200 μm, is input data for calculations.

According to the rests of coal dust on sieves, value of polydispersion coefficient n and dimension of the biggest particles δ_{01} are determined by the equations:

$$n = \frac{\log \ln \frac{100}{R_{90}} - \log \ln \frac{100}{R_{200}}}{\log \frac{90}{200}} \tag{1}$$

$$\delta_{01} = 200 \cdot 10^{\frac{\log \ln \frac{100}{0.1} - \log \ln \frac{100}{200}}{n}} \tag{2}$$

Size of the biggest particle and polydispersion coefficient participate in determining particle free fall velocity (5). On the basis of condition that the particle residence time in the furnace should be equal to the combustion time, necessary residence time of the gases in the furnace is determined, and the correction to be due to the fact that particle velocity is less than gas velocity (4).

Height of burning down zone is determined according to the equation as following

$$h_{zd} = (w_g - w_{01})\tau \tag{3}$$

where

w_g [m/s] – average gas velocity

$$w_g = \frac{B \cdot V_g \cdot T_{sr}(100 - q_4)(1 + r)}{100 \cdot F_l \cdot 273 \cdot 3600} \tag{4}$$

B [kg/s] – fuel consumption,

V_g [m^3/kg] – volume of combustion products in the furnace, per kg of coal

T_{sr} [K] – average gas temperature in the furnace,

q_4 [–] – losses due to the unburned char particles,

r [–] – recirculation ratio of the flue gases,

F_l [m^2] – cross section of the furnace,

w_{01} [m/s] – particle free fall velocity, for particles $\delta_{01} > 530$ μm it is determined according to the equation (5)

$$w_{01} = \frac{7 \cdot 10^{-8}}{\mathrm{e}^{-6.9\left(\frac{500}{\delta_{01}}\right)^{n}} - 0.001} \sum_{500}^{\delta_{01}=30} \left\{ \mathrm{e}^{-6.9\left(\frac{\delta_{0i}}{\delta_{01}}\right)^{n}} - \mathrm{e}^{-6.9\left(\frac{\delta_{0i}+30}{\delta_{01}}\right)^{n}} \right\}. \cdot \sqrt{(\delta_{01}+15)^{3} \gamma_{k} T_{sr}} \tag{5}$$

where:

γ_k [kg/m^3] – apparent density of the char rezidue, for brown coals is approved ~1000 kg/m^3,

n [–] – coefficient of polydispersion in the equation RRS determined according to the rests on two sieves,

t [s] – combustion time of polydispersive dust

$$\tau = \frac{3600 \cdot I_2 \cdot \beta \cdot \delta_{01}^{2}}{\mathrm{Nu}_D \cdot D} \quad \text{at} \quad 0 < \frac{\mathrm{Nu}_D \cdot D}{K_{priv} \cdot \delta_{01}} \tag{6}$$

where:

δ_{01} [μm] – initial dimension of the biggest particle,

Nu_D [–] – Nusselt number for gas diffusion

$$\mathrm{Nu}_D = \frac{\alpha_D \delta_{01}}{D} \tag{7}$$

where:

D [m^2/h] – gas diffusion coefficient,

α_D [m/h] – mass transfer coefficient.

For brown coals with $V_g \geq 40\%$ and $\delta_{01} > 500$ μm parameter representing connection between combustion time and degree of particle burn-out is given by expression:

$$I_2 = I_{2r}^{dif} = I_2^{dif} + b^{dif}(n-1) \tag{8}$$

I_2^{dif} and b^{dif} has to be determined according to figures given in [4] and by using corresponding nomograms to find out combustion time of polydispersive coal dust for assumed losses, due to the unburned char particles, or by using appropriate computer subprograms, as it is explaned in [1].

Described methodology enables selection of optimal working regime of the steam boiler, milling fineness, excess air, and air temperature at all loads of the boiler.

The height of the furnace of the boiler type OP – 650b in TP "Kosovo" – A [2] calculated under the conditions of "total" combustion of the biggest fractions of coal dust, was considerably larger than real height of the furnace (42.62 m compared to 27.30 m).

Therefore, presented engineering method can be used for determination of the optimal granulometric characteristics of the fuel, providing that existing height of the furnace satisfies the required combustion efficiency.

Using described engineering calculation method it was also established that cross section of the furnace corresponds to the existing one, and that appropriate furnace height has to be determined.

For different milling finenesss, represented by rests on sieves of 90 and 200 μm, calculation results are presented on Table 1.

Table 1. Estimate of granulometric characteristics of the fuel

No.	Rests on the sieves		Characteristic of particle size distribution			Height of the furnace
	R_{90} [%]	R_{200} [%]	n [–]	δ_{01} [μm]	b [–]	H_l [m]
1	55	30	0.877	1.467	0.012	36.04
2		25	1.053	919	0.005	35.02
3		20	1.240	647	0.002	29.67
4		15	1.446	489	0.001	26.23
5	60	30	1.074	1.02	0.0041	38.58
6		25	1.250	723	0.0018	33.27
7		20	1.437	551	0.0008	28.85
8		15	1.643	439	0.0003	25.59
9	65	30	1.29	777	0.0013	36.77
10		25	1.464	599	0.0006	31.59
11		20	1.651	483	0.0003	28.88
12		15	1.857	401	0.0001	25.25

On basis of the obtained furnace heights optimal values for polydispersion coefficient n, constant of milling fineness b, and size of the biggest particle were determined by interpolation. Calculation results are presented at Figs. 1 – 3.

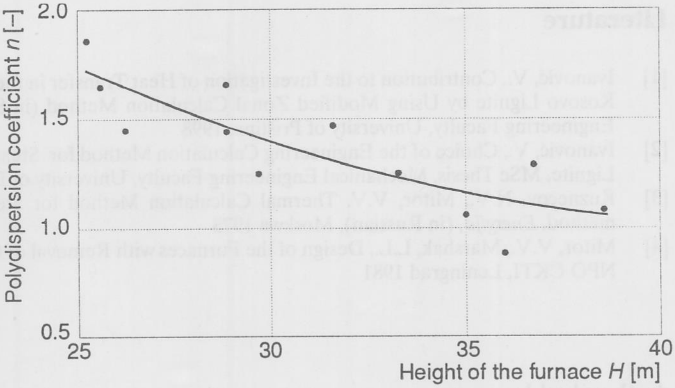

Figure 1. Relationship between polydispersion coefficient and the height of the furnace

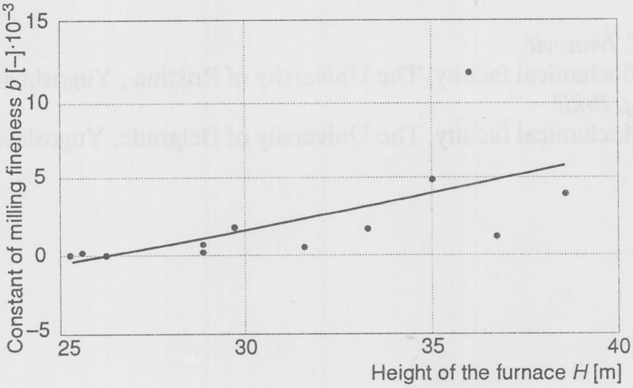

Figure 2. Relationship between milling fineness constant and the height of the furnace

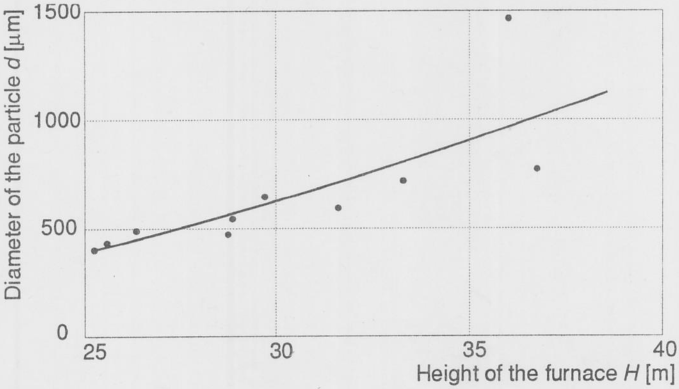

Figure 3. Relationship between diameter of the biggest particle and the height of the furnace

From the diagrams presented at Figs. 1–3 it is evident that existing furnace requires milling fineness with biggest particles smaller than 650 μm, polydispersion coefficient greater than 1.4, and with the fineness milling constant smaller than 0.0025. As far as the rests on the sieves are concerned it may be concluded on basis of the data presented in Table 1, that the rest on the sieve of 200 μm has to be in the range 20–25 %.

Literature

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Authors' addresses:

V. Ivanović
Mechanical faculty, The University of Priština , Yugoslavia
Lj. Brkić
Mechanical faculty, The University of Belgrade, Yugoslavia

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