CHOICE OF FINENESS OF PULVERIZED COAL

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Translated from *Élektricheskie Stantsii*, No. 12, December 2002, pp. 17 – 20.

Various methods for choosing the fineness of power plant coal dust are reviewed and analytical expressions for determining the fineness are presented. It is shown that the use of the yield of combustibles as a parameter is not always suitable for evaluating the fineness of pulverized coal. The suggested expression for computing the fineness bears composite parameters that allow for the heat value of the volatiles and for the internal surface of the fuel particles.

Keywords: fineness of coal dust, milling, yield of volatiles, porosity, heat of combustion of volatiles, fuel density, degree of carbonization, dust surface, separator.

In order to provide efficient burning of pulverized coal the solid fuel is dried and milled after preparatory operations of unfreezing (in the wintertime), preliminary crushing, and separation of metals, pyrite, chips, and other long-length foreign admixtures.

The quality of the ready dust, which provides its efficient combustion, is primarily determined by its fineness, i.e., the surface, and is commonly evaluated in terms of the granulometric composition by means of screening analysis of dust samples.

The reliability of the ignition of the dust directly depends on the value of the total dust residue on the screen with a cell size of 90 μm (R_{90}), and the completeness of the burning is connected with the presence of coarse fractions in the dust, which is characterized by the value of the full residue on the screen with a cell size of 200 μm (R_{200}); the latter determines the heat losses to carbon underburning. Solving the Rozin – Rammler equation that relates R_{90} and R_{200}, we arrive at the dependence:

$$R_{200} = 100\left(\frac{R_{90}}{100}\right)^{2.2^n}. \tag{1}$$

The parameter of polydispersity n depends on the type of the mill, the fuel separator, and the kind of the milled fuel [1]. For ball-mill pulverizers of type ShBM the parameter n, which characterizes the uniformity of the granulometric composition of the dust, ranges within 0.7 – 1.3 for hammer mills (MM type), 1.1 – 1.3 for ball-race mills (SM type), and is about 0.9 for fan mills (M-B type).

The expedient fuel dust fineness characterized by various physicochemical and thermal engineering properties is chosen on the basis of the solution of an optimization problem that provides, on one hand, efficient burning of the fuel due to timely ignition of the dust and its full combustion and, on the other hand, a minimum cost of dust preparation including the electric power spent for pulverization, pneumatic transportation, and running (service and repair) of the coal-preparation plant (Fig. 1) [1].

This method is not used widely due to the great difficulties connected with collection of a great number of operational data for a full description of the operation of the coal-preparation plant. These difficulties are aggravated by the fact that despite the seeming structural identity and identity of the properties of the fuel prepared for combustion, virtually any coal-preparation unit has individual points of optimum performance [1].

The individual value of expedient fineness is typical for each kind of fuel, and even for each grade of fuel, and depends on the properties of the fuel that play a determining role in the oxidation of the organic part of the fuel by the air

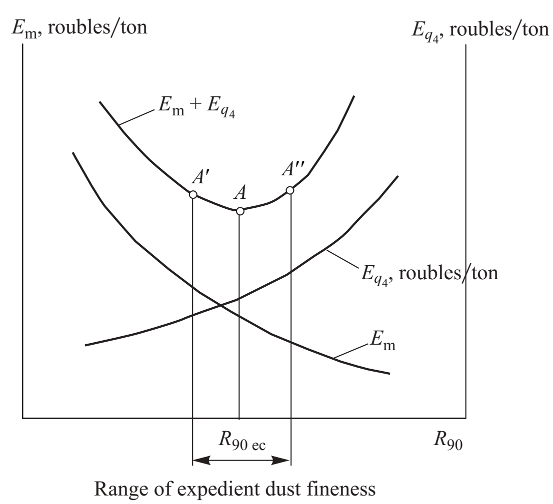

Fig. 1. Expedient fineness of coal dust.

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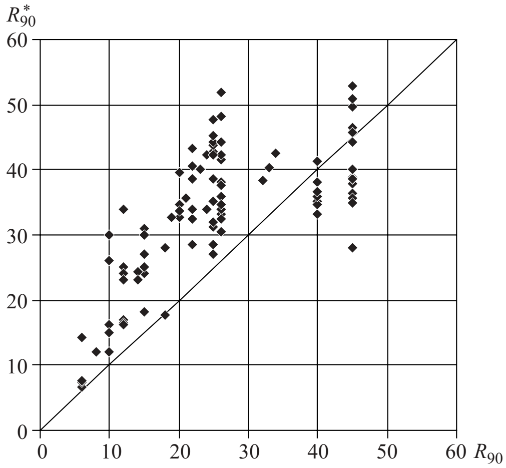

Fig. 2. Comparison of calculated (R^*_{90}) and tabulated (R_{90}) values of dust fineness.

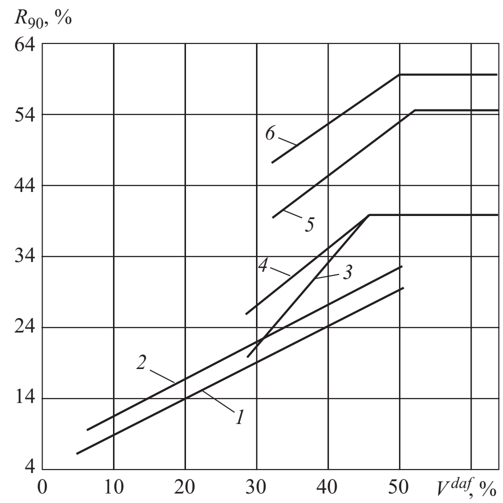

Fig. 3. Choice of dust fineness (R_{90}) as a function of the volatile yield: *1*, anthracite fines, semi-anthracites, lean and conventional coals milled in ShBM; *2*, lean and conventional coals milled in SM; *3*, coals milled in MM; *4*, brown coals milled in ShBM; *5*, brown coals milled in SM; *6*, brown coals milled in MM and M-B.

oxygen under specific conditions of organization of the combustion process.

It is known that the rate of burning of any kind of pulverized solid fuel is almost directly proportional to the diameter of the dust particles and substantially depends on the degree of metamorphosis of the fuel, and its aging (which determines the form of the fuel in question, i.e., anthracite, coal or brown coal, shale, or peat). The process of ignition and burning of pulverized coal depends considerably, other conditions being equal (for example, the same fineness), on the amount of volatiles contained in it. Numerous data obtained by foreign and domestic specialists allowed them to suggest relationships between the amount of the volatiles (V^r) contained in a fuel and the fineness of the dust (R_{90}) required for stable ignition and burning of the dust [2], i.e.,

$$R_{90} = \alpha + \beta V^r, \tag{2}$$

where $\alpha = 8$, 6 and $\beta = 0.9$, 0.7 are coefficients experimentally determined from the data of American and German specialists respectively.

With allowance for the uniformity of the granulometric composition of the dust n the dependence of the dust fineness on the content of volatiles in the dry ash-free mass of the fuel (Vdaf) can be written in the form

$$R^*_{90} = 4 + 0.8V^{daf} \tag{3}$$

Figure 2 shows the extremely unsatisfactory convergence of the values of R^*_{90} to the values of R_{90} recommended in [4]. The values of the parameter n were determined with allowance for the type of the pulverizing (milling) device in correspondence with the recommendations of [4].

The analysis of the values of R_{90} made in [4] shows that in some cases the recommended dust fineness does not satisfy its dependence on the content of volatiles in the fuel. For example, for the 3B brown coal of the Bogoslovskoe deposit having $V^{daf} = 48.0\%$ and $A^d = 47$, 9% the recommended value of R_{90} is 45%. The same value of R_{90} is recommended for the 1B brown coal of the Aleksandriiskoe deposit characterized by $V^{daf} = 59.0\%$ and $A^d = 22.5\%$. Unfortunately, the absence of correspondence with the dependence of the recommended values of R_{90} on the yield of volatiles for solid fuel dust is not a rare case. This is vividly illustrated by Fig. 3, where different dust fineness values are recommended for fuel characterized by the same content of volatiles, which contradicts the mentioned concept.

The fineness of the dust of every specific kind of fuel should provide its reliable ignition and burning, which is primarily determined by the properties that characterize the chemical activity of the fuel as a combustible substance. It often happens that guidelines recommend different values of R_{90} for the same kind and grade of fuel. This is connected with the fact that the recommendations allow not only for the chemical activity of the organic part of the fuel, which is determined by the volatile yield, but also for the type of the milling device used for pulverization. Specifically, the recommended values of R_{90} for the 2B brown coal of the Raichikhinskoe deposit with $V^{daf} = 49.0\%$, $W^r_t = 37.5\%$, $A^d = 10.5\%$, and $K_v = 1.3$ are 38.0, 55.0, and 49.0%; for the brown coal of grade D of the Cheremkhovskoe deposit with $V^{daf} = 47.0\%$, $W^r_t = 12.5\%$, $A^d = 26.0\%$, and $K_v = 1.3$ the recommended full residues on the screen with 90-μm cells are 28.0, 40.0, and 32.0%. (The values of R_{90} recommended in [4] for the mentioned kinds of fuel are given for the ShBM, MM or M-B, and SM mills.)

The necessary dust fineness for reliable ignition and burning depends on the milling device. The mill is chosen with allowance not only for the requisite dust fineness but also for such fuel characteristics as moisture content, abrasiveness, resistance to crushing, etc. It is economically expedient to obtain dust with a value of R_{90} below 7% in ShBM-type mills. It is impossible to obtain quality dust by milling coal with moisture content $W_t^r > 22.0\%$ in a ball-race mill. The high abrasiveness and resistance to crushing do not make it possible to mill such fuel in high-speed devices, because this substantially increases the operational costs. It is expedient to pulverize such coal in low-speed mils.

The recommendations on choosing R_{90} presented in [4] have been obtained by analyzing numerous operational data on preparation and combustion of solid fuels possessing various physicochemical and thermal engineering properties. However, today many grades of coal are not used due to the depletion of the deposits, and coals of new deposits have not been studied exhaustively. New requirements are imposed on the quality of ready coal dust due to the wide application of methods for suppressing nitrogen oxides.

The main disadvantage of the analyzed method consists in the fact that the recommended values of R_{90} integrally take into account not only the properties of the fuel that provide ignition of the dust and its full burning, in particular, the volatile yield, but also the physical possibilities of the milling devices, which sometimes become the main argument in choosing the fineness of the dust. Such an approach excludes substantiated differentiation of the effects of all the factors influencing the quality of ready dust, which is required for its reliable ignition and combustion.

All these aspects made us revise the approach to choosing the fineness of coal dust. In addition to the effect of the volatile yield V^d on reliable ignition of the fuel the new method allows for the heat of combustion of the volatiles Q_v in the form of the product of V^dQ_v and for the internal surface of the coal particles.

Brown coal dust prepared for burning has higher coarseness than coal dust. This is explainable by the fact that the particles of lignite, which is biologically younger than coal, possess a well-developed internal surface in the form of pores, cracks, and numerous channels with various configurations. Therefore, the reaction surface of coal dust bearing air oxygen is determined not only by the external surface of the particles, which is proportional to their diameter or to the quantity $\ln(100/R_{90})$, but also by the internal surface, which directly depends on the degree of carbonization.

The internal surface of the particles is quite difficult to determine. However, we do not need its exact value and it is sufficient to determine the porosity factor *Por*, which makes it possible to evaluate the relative internal surface of a particle. The porosity of the substance can be determined in terms of the apparent (ρ_{ap}) and true (ρ_{tr}) density of the fuel. The true density of the fuel is represented by the ratio of the fuel mass to its total volume without allowance for the volume of the pores; the apparent density is the same ratio with allowance for the total volume of pores inside the particles, i.e.,

$$Por = 1 - \rho_{tr}/\rho_{ap}. \tag{4}$$

The true density is either calculated from the composition of the fuel [5] or determined with the help of a density meter. The apparent density is determined either with the help of a volumeter or with the help of a special device.

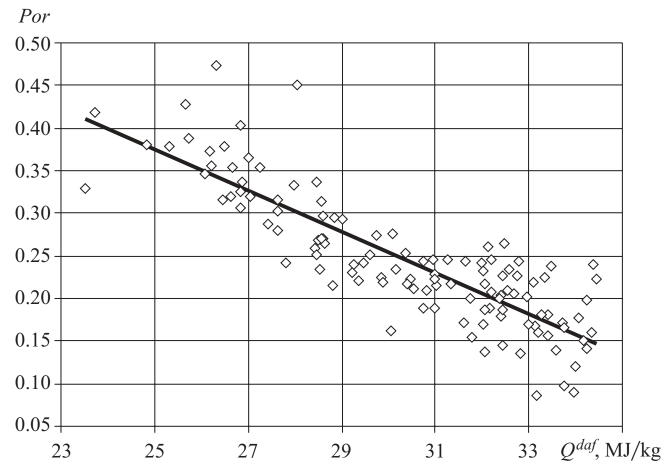

Fig. 4. Porosity of the fuel as a function of the heating value as fired.

The porosity is connected with the biological age of the fuel, which influences the degree of carbonization and, consequently, the combustion heat. This makes it possible to obtain a virtually linear dependence of the fuel porosity *Por* on the combustion heat recalculated to the combustible mass Q^{daf} (Fig. 4). The porosity of the fuel can be calculated from the expression

$$Por = -0.024Q^{daf} + 0.98. \tag{5}$$

We processed the data using the Rosenbrock method. The loss function determining the error of the numerical method was calculated by the least squares method. Expression (5) can also be used for determining the porosity of new kinds of fuel.

The final expression for the determination of the quantity proportional to the surface of the dust with allowance for its internal surface has the form

$$\ln\left(\frac{100}{R_{90}}\right) = \frac{4.8}{Q_v V^d Por + 1.2} - 0.25. \tag{6}$$

The fineness of the ready dust is represented in the formulas for calculating the milling efficiency of the mill by a term $[\ln(100/R_{90})]^m$ proportional to the surface of the dust. The exponent m depends on the type of the mill and of the separator. For MM with centrifugal and inertial separators $m = -0.6$; for a gravitational separator $m = -1$; for ShBM mills with centrifugal separator and mechanical discharge of the milled product and for SM and M-B mills $m = -0.5$.

Figure 5 presents a comparison of the recommended values of $\ln(100/R_{90})$ [4] and the values calculated by expression (6) that interpolate these data. The scattering of the tabulated values relative to the curve is explainable by the fact that the fineness values have been chosen for many kinds of fuel with allowance for the content of volatiles in it and for

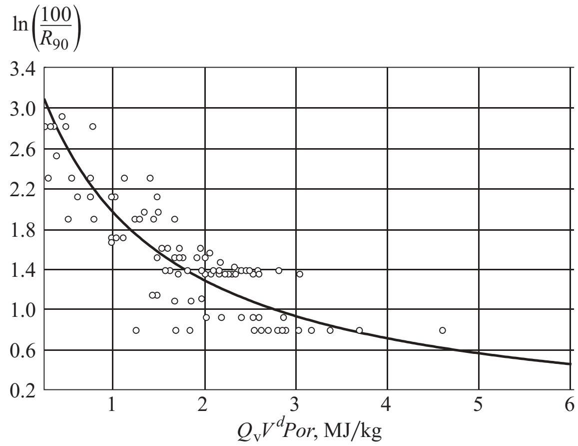

Fig. 5. Position of tabulated values of coal dust fineness with respect to the plotted dependence.

the actual possibilities of the milling device. We have already mentioned that this approach does not make it possible to take into account the effect of the combustion heat and the internal surface of the coal particles.

The combustion heat of the volatiles that enter the product $V^d Q_v$ are calculated using the data on the elemental composition of the fuel with the help of the known expression [6]

$$Q_v = \frac{Q_0^{daf} - 329 C_0^{coke}}{V_0^{daf}}. \quad (7)$$

The quantities present in this formula are determined by recalculating the elemental composition, the low heating value, and coke from the combustible mass of the fuel to its oxygen mass using the following expressions:

$$C_0 = 100\frac{C^{daf}}{\Sigma};\ H_0 = 100\frac{H^{daf}}{\Sigma};$$

$$O_0 = 100\frac{O^{daf}}{\Sigma};\ V_0 = 100\frac{V^{daf}}{\Sigma};$$

$$Q_0 = 100\frac{Q^{daf}}{\Sigma};$$

the content of carbon in the ash coke $C_0^{coke} = G_0 + H_0 + O_0 - V_0^{daf}$.

CONCLUSION

We have suggested an analytical expression that verifies the parameter directly proportional to the surface of natural solid coal dust. The parameter is suitable for evaluating the milling efficiency of coal mills. In addition to the external surface of the dust and the volatile yield, the suggested dependence allows for the heat of combustion of the volatiles and the internal surface of the fuel particles and the degree of its metamorphism.

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